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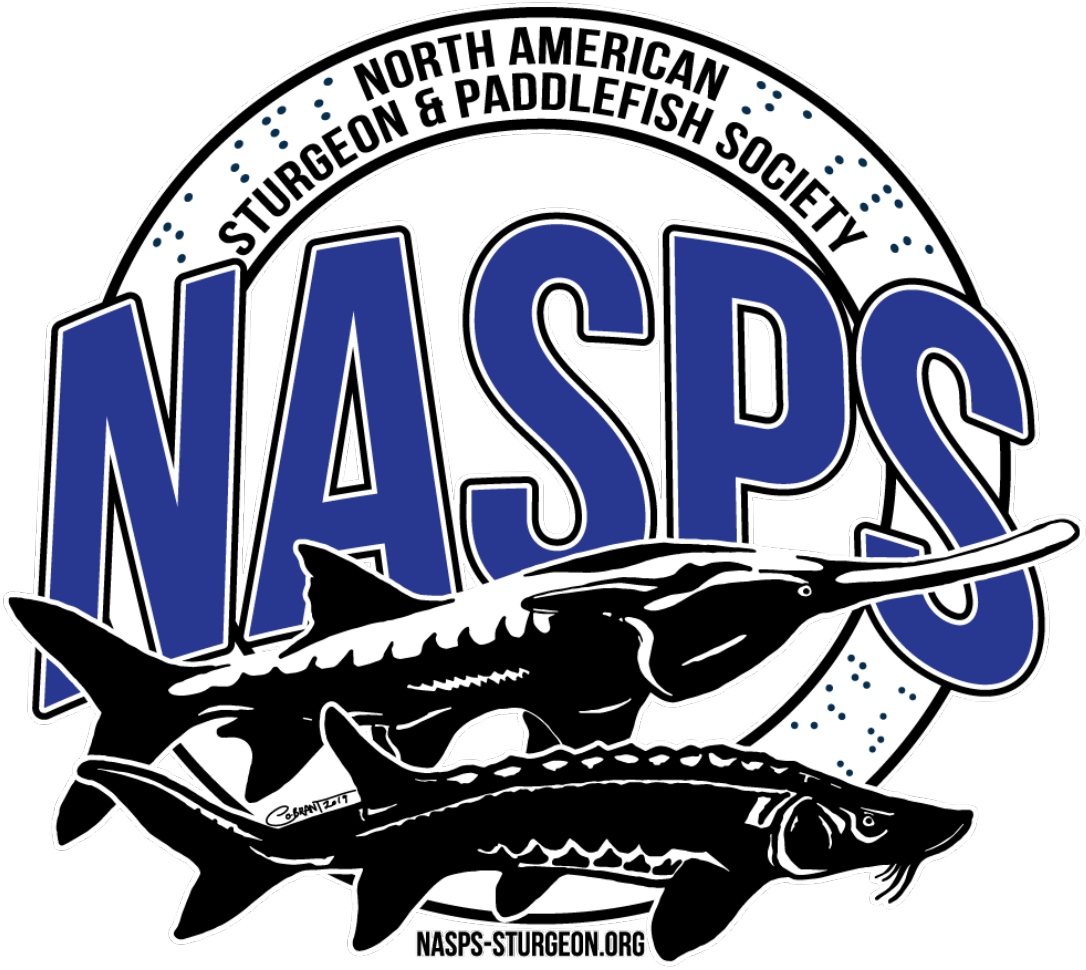

The Path Towards a Multinational Population Monitoring in the Danube River

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Within the Danube catchment, the range of the native sturgeon species covers twelve states, and further three along the coastlines of the Black Sea. While two species are considered locally extinct, the remainder of the family are critically endangered. While legal protection is in place and population support through supportive releases is increasing, ongoing IUU- fishing and habitat destruction remains a major threat. Comprehensive monitoring of the remnant populations is a prerequisite to evaluate impacts, bottlenecks and the effectiveness of conservation actions as the base for sound management decisions. Through the large range and complex life-cycle, monitoring must cover the different life-phases throughout the catchment to enable predictions on the development of populations. Therefore, a multinational approach using standardized and replicable methodology is required. A lack of coordination, resources, language barriers and cooperation hampered these efforts in the past. Combining multiple projects and initiatives we aim to provide a monitoring scheme that focuses on clear objectives, is cost effective and replicable among the catchment states over the long-term to help in sturgeon recovery.

Gulf Sturgeon (*Acipenser oxyrinchus desotoi*) Use of Mobile Bay, AL; A Large Estuary Outside of Designated Critical Habitat for the Species.

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Gulf Sturgeon (GS; *Acipenser oxyrinchus desotoi*) are a federally threatened, anadromous species that feed primarily in estuarine and marine systems from October–April. All estuarine and marine environments adjacent to extant natal river populations of GS were designated as critical habitat in 2003, excluding Mobile Bay as no literature supported that GS were within Alabama waters. Previous studies had identified habitats within the Mississippi Sound and in Florida's waters as habitat for GS populations both west and east of Mobile Bay; suggesting sturgeon must at least traverse Alabama waters. Therefore, our objective is to describe habitat use of Mobile Bay by GS from both western and eastern systems. Captured GS were measured and tagged in both eastern and western river systems from 2010–2021. We detected tagged individuals with an array of 44–55 receivers maintained by the Dauphin Island Sea Lab from 2015–2022. A total of 103 adult (n=73) and subadult (n=30) GS were detected from both western (n=77) and eastern (n=26) populations associated with Mobile Bay since 2015, with 67 individuals detected between 2–7 consecutive years. The highest number of detections occurred at receivers deployed along the Dauphin Island causeway (the connection between the Mississippi Sound and Mobile Bay) and within the mouth of Mobile Bay. Despite variable receiver effort between years, GS were detected in Mobile Bay near the mouths of the Alabama, Mobile, and Tensaw rivers. Previous sediment and benthic macroinvertebrate sampling within and around Mobile Bay showed relatively low percent sand content and high polychaete richness that is characteristic of foraging habitats previously identified in the Pascagoula River delta region. Sustained use of this system by eastern and western GS populations strongly suggests Alabama's waters are suitable habitat despite the natal population for this system being extirpated.

Competition Overwhelms Environment and Genetic Effects on Growth Rates of Endangered White Sturgeon from Conservation Aquaculture

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Improving the status of endangered species can be challenging because there is often considerable uncertainty about the efficacy of conservation actions. White sturgeon in the Transboundary Reach of the upper Columbia River spanning Canada and the US are undergoing recruitment failure, and aquaculture has been a primary conservation measure to prevent extirpation and restore the population. We used a long-term mark-recapture dataset (2002-2018) to predict variation in growth rates of hatchery-origin white sturgeon due to genetic, environmental, and competition effects to evaluate the efficacy of the aquaculture program. Estimates of hatchery-origin biomass were used as a covariate to quantify differences in competition for prey and habitat over time and across countries. We hypothesized that growth rates would decline with increasing biomass, and associated competition, caused by continued stocking combined with high survival rates. Overall, environmental conditions (by season and country) and competition had the greatest effects on growth. Notably, growth rates, length-at-age, weight-at-age, and condition factor were all much higher for fish residing in the reservoir environment in the US compared to those in more riverine habitat in Canada. There was an overall slow decline in growth rates over the 17-year study period in both countries, and growth in length for larger fish (>100 cm fork length, FL) was much higher in the US. On average, fish > 100 cm in Canada did not grow. Within year differences in growth rates among families were small, indicating that differences in genetics among parental groups for each family produced in the hatchery had negligible effects on growth following release in the wild. Our study indicates the carrying capacity of white sturgeon in the Canadian section of the Transboundary Reach of the upper Columbia River may have been exceeded. Changes in growth rates can influence individual condition, reproductive success, and even mortality, and our estimate of substantive negative density-dependent growth in Canada is an important result to consider in making decisions about white sturgeon aquaculture in the Columbia River, and perhaps other systems.

The Expanding Sturgeon Captive Culture Industry Threatens Decades of Global Conservation Efforts

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After centuries of overexploitation and habitat loss, many of the world's sturgeon populations are at the brink of extinction. Although significant resources are invested into the conservation and restoration of imperiled sturgeons, the burgeoning commercial captive culture industry poses an imminent threat to the persistence of many populations. In the last decade the number and distribution of captive sturgeon facilities has grown exponentially and now encompasses diverse interest groups ranging from hobby aquarists to industrial-scale commercial facilities. We highlight the global impact that commercial captive culture has had on wild sturgeon and comment on future adverse interactions that are likely to occur without more stringent regulation of captive populations. Therefore, we note modifications to regulatory frameworks that could improve the ability of captive culture to support wild sturgeon conservation. Ultimately, without increased oversight, continued expansion of the captive culture industry is poised to jeopardize decades of conservation and management efforts and could contribute to accelerated population declines.

Nechako White Sturgeon: Research Supporting Habitat Restoration

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Despite identifying substrate change as the primary causal mechanism of Nechako white sturgeon recruitment failure, implementing substrate restoration within the Nechako River presents multiple challenges. While the historical spawning location is uncertain, the absence of data supporting an alternate spawning location supports the current focus on restoring habitat at current spawning locations at the downstream end of a braided reach. Habitats at this spawning site do not fit a 'classical' understanding of preferred spawning habitat, and a recent habitat restoration plan identifies both biological and geomorphological research required to implement effective habitat restoration. The fact that spawning may occur at multiple locations within the spawning reach complicates the identification and spatial delineation of areas for restoration. Substrate placement tests in 2011 may have led to a recruitment pulse, although rapid infilling highlighted the challenge of sustaining specific habitat conditions within a geomorphically active river channel. Subsequent studies evaluated mechanical and diver-assisted substrate cleaning in 2016, 2020, and 2022. Continued seasonal changes in discharge and substrate conditions highlight the importance of a conceptual understanding of environmental conditions that led to recruitment pulses in 1994/95, 2007 and 2011. One step toward addressing this question is the initiation of long-term monitoring of surface and subsurface conditions within the river bed that will improve our understanding of any relationships between the regulated discharge and both infilling and winnowing (cleaning). The habitat restoration plan also identified the need for a more detailed description of restored substrate requirements, such as specifications for substrates used for restoration and the responses of early life stages to differences in conditions such as substrate depth and composition.

Captive Bolt Stunning to Improve Fish Welfare for Euthanasia and Slaughter in Sturgeon

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The American Veterinary Medical Association stipulates that appropriate slaughter processes must first render the animal insensible quickly and painlessly to be considered humane. Currently, many of the techniques used to stun sturgeon in aquaculture do not accomplish this goal. Due to their size and anatomy, sturgeon, particularly white sturgeon, are challenging to create insensibility or brain death. Their cartilaginous anatomy requires greater force to cause brain damage when compared to bony fish. Current techniques include both cranial concussion with a bat, fish priest or other blunt instrument, cervical dissociation, or non- penetrating captive bolt (NPCB). While NPCB provides superior reliability in both location and force, there are no studies to date describing the appropriate force required to ensure brain death in sturgeon. This study aims to provide the appropriate NPCB operating pressure (PSI) for both meat fish and caviar-fish. Adult caviar-ready, 6-9 yr old female white sturgeon, (mean mass = 27.1kg) and 2-3 yr old juvenile male white sturgeon (mean mass = 8.4kg) were stunned with a Jarvis HPS-1 pneumatic NPCB with a 2.5 cm striking surface. The caviar-ready sturgeon were slaughtered on a commercial farm using 175, 200, and 225 PSI delivered by compressed nitrogen gas. Control animals experienced multiple strikes at 145 PSI by a commercial air compressor which is the current farm practice. All fish were exsanguinated as a second step termination method. Juvenile sturgeon were stunned at 120, 145, and 170 PSI. Skull and brain were removed by a reciprocating saw, fixed in 37% formaldehyde, and histology of the brain was performed to quantify damage. This study validates that the use of NPCB is an effective tool as part of a humane slaughter protocol at the specified settings for sturgeon, and improves upon current available techniques and fish welfare for all cartilaginous fish.

Using Fin Ray Microchemistry to Age Lake Sturgeon *Acipenser fulvescens*

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Fin rays are the most common aging structure for Lake Sturgeon Acipenser fulvescens but tend to underestimate the true age in older slow-growing fish (> age 14). Current aging practices involve counting opaque and translucent bands (known as annuli) along the structure that are presumed to represent different seasonal zones. Oscillations of certain trace elements corresponding with annuli have been seen across a variety of fish species with patterns continuing to the marginal edge of the structure. This study explores fin ray microchemistry patterns in known age Lake Sturgeon (n = 54, age 5-8) to determine their potential use as an alternative or supplementary aging technique. Elements of interest were chosen for age determination analysis by examining the relationship between profile minima and maxima with visual growth zones. Fish were assigned ages using two chemical age estimation methods as well as the traditional visual method. Fin ray concentrations of Ba, Mn, Zn, and Mg showed the highest seasonality with consistent chronological patterns across years and age classes. Mean coefficient of variation between estimated age and known age was 2.4% and 4.5% for the two chemical estimation methods and 7.3% for the traditional method. Accuracy was higher for ages estimated from the novel methods than for ages estimated with the conventional method (80.2% and 64.8% vs 54.3%, respectfully). Our results suggest that chemical aging techniques may provide more reliable age estimates for Lake Sturgeon. Future work is required to determine if this technique can provide a way to estimate ages of older Lake Sturgeon when distinct growth bands are no longer visible.

Dietary Optimization of Macronutrients in On-growing White Sturgeon, *Acipenser transmontanus*

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White sturgeon, *Acipenser transmontanus*, is an economically valuable freshwater species farmed in Idaho and California. Sturgeon farmers rely on commercial diets that have been found successful even though no commercial feeds, other than a larval diet, are specifically designed for sturgeon grow-out. Despite the growing interest in white sturgeon aquaculture around the world, there is scarcity of information on sturgeon specific nutrient needs. A statistical mixture model design was determined to optimize the combination of macronutrients in grow-out feeds for dietary protein, lipid and digestible carbohydrate levels on growth, feed utilization, nutrient retention, and deposition of mesenteric fat. Fourteen diets containing fishmeal, fish oil, and wheat starch at various mixture levels were formulated and fed to 1.5 yr old white sturgeon (mean tank body mass of 9.6 kg) until fish reached 200 percent growth in the California reared fish. Fish were randomly allocated to 2m diameter tanks, hand-fed twice daily at 1.5 percent body weight, and weighed every 6 wks. At the end of the 120d feeding trial, a response surface will be fitted to the results and the range of mixtures producing at least 90 percent of the optimum response to each variable. The findings of this research will be used to develop cost-effective diet formulations for white sturgeon farmers and feed producers. This study is funded by the USDA Western Regional Aquaculture Center.

Navigating Sampling Challenges and Habitat Variability for Monitoring and Evaluating a White Sturgeon Hatchery Program

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Hatchery fish make up most of the individuals in the endangered Kootenay White Sturgeon population. Targets for this population were set relative to historic estimate of 8000 adults pre-hydroelectric dams. Present estimates suggest we are on track with our hatchery release numbers, however growth and low age-1 survival data from the river portion of the range suggest we are over habitat capacity. We address the lack of lake specific dynamics by using telemetry and mark recapture data to estimate abundance, biomass and movement rates. Monitoring of the hatchery population spans two states and one Canadian province, including 190 river kilometres downstream of Kootenai Falls into Kootenay Lake (400 km2); standardized index site gill net sampling was established in 2003 in Idaho and BC. Most of the hatchery releases (92% from 1990 to 2019) and monitoring activities have historically focussed most heavily on the river portion of the range. To address our sampling habitat bias, 2022 was the pilot season for a spatially balance generalized random tessellation stratified (GRTS) approach; we evaluate field logistics and capture trends for both gill nets and setlines to guide modified approaches in future years. The first lake only population estimate in 2020 suggests increased and stable emigration rates starting with the 2007 year class resulting in increasing abundance and biomass in Kootenay Lake. Telemetry data shows low mixing rates between lake and river and annual movement increases with age; from 13 km at age four years to 379 km at 25 years old. These low movement rates at the younger ages suggest the importance of release locations for growth and survival. Juveniles are already facing habitat and density limitations to growth and survival in most of the river habitat, suggesting the importance of Kootenay Lake for the recovery of this endangered White Sturgeon population.

Snake River White Sturgeon Repatriation Aquaculture: The Implementation and Evolution of a Fish Culture Program Built from the Ground Up

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Idaho Power Company

Per hydropower license requirements, Idaho Power Company has implemented and continued to update a White Sturgeon Aquaculture Plan to restore the species' populations in the middle Snake River. This plan was originally supported by adult collections and broodstock spawning but changed directions once the possibility of a repatriation method became realistic and feasible. With clear benefits to repatriation such as increased genetic diversity and the minimizing of spontaneous auto-polyploidy, it became the obvious choice for the program heading forward. This new program is the result of collaborative efforts between Idaho Power Company (IPC), The College of Southern Idaho (CSI) and the Idaho Department of Fish and Game (IDFG). From 2017-2020, the College of Southern Idaho facilitated the experimental rearing of naturally spawned White Sturgeon embryos collected from the Bliss Reach of the Snake River by Idaho Power biologists. With drastic increases in embryo collections and successful hatchery rearing leading to juvenile releases, Idaho Power constructed the new Niagara Springs Sturgeon Hatchery (NSSH) in 2020. Throughout the first two rearing cycles at NSSH, the IPC and IDFG staffs have experimented with feed types, tactics and husbandry practices which have led to significant increases in survival during critical rearing periods with this species. These increases in survival during the early years of operation at NSSH have been offset by the growing pains of the facility, but many of these new findings will significantly improve this program going forward.

Lake Michigan Lake Sturgeon Rehabilitation Using Streamside Rearing

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Once abundant throughout the Great Lakes, Lake Sturgeon (*Acipenser fulvescens*) populations are now a small fraction of their historical numbers. Lake Michigan, specifically, once had 41 spawning populations with an estimated adult population ranging between 177 thousand to 385 thousand. The current population is estimated to be around 3,000 adults from eight extant populations. Only three of these extant populations (i.e. Winnebago, Menominee, and Peshtigo River populations) are considered heathy and secure. In an effort to reestablish and supplement populations, Lake Sturgeon reintroduction is taking place. Since 2006, several partners, including federal, state, and tribal agencies, have coordinated in the use of streamside facilities to rear and release fingerling Lake Sturgeon. Nine streamside rearing facilities are operating throughout the Great Lakes. Six of these facilities are located on tributaries to Lake Michigan and have stocked over 45,000 fall fingerling age-0 sturgeon. The Cedar River, a 67-mile free flowing river located in Michigan's Upper Peninsula, historically supported a population of Lake Sturgeon. However, this population is now considered functionally extirpated. After a three-year hiatus, the Cedar River streamside rearing facility recommenced raising sturgeon this year. The stocking efforts are expected to continue for approximately 20 years with the goal of creating self-sustaining adult populations.

Adaptive Management of Nechako White Sturgeon Conservation Fish Culture Program

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When the Nechako White Sturgeon Conservation Centre (NWSCC) was built in 2014 it was designed to rear 12 maternal families with 1,000 progeny from each family. This design, which utilized many small tanks, was used to achieve a robust genetic mix of one-year old juveniles for stocking into the Nechako River. Over the last 8 years we have actively adapted our recovery strategy in an effort to maximize the recovery of the Nechako White Sturgeon population. The first few years of data showed that predation from otters was a significant concern for meeting recovery targets, and hatchery reared progeny from wild parents was a concern in other geographic areas containing different populations of white sturgeon. Statutory Decision Makers from the Province of BC decided to mitigate risk for adjacent populations, and excessive mortality due to predation, by increasing the size of released individuals and testing some alternative lake release sites. The target release size was moved from 150g to 70cm (2500g) which was intended to get individuals past the point of easy predation. The release number was also greatly reduced to 200-300 individuals per year to reduce possible impacts to adjacent populations. This target of fewer larger-sized juveniles for release is being achieved at the NWSCC by rearing juveniles in a state-of-the-art Recirculating Aquaculture System (RAS) for two years. Initial data supports the effectiveness of this strategy in keeping numbers of fish leaving the Nechako Watershed very low, and reducing mortality from predation.

A Mathematical Model to Assess the Genetic and Demographic Risks of a White Sturgeon Conservation Hatchery

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Hatchery production has the potential to be valuable tool for conservation and fisheries management, but it is accompanied by genetic and ecological risks which can produce long lasting negative consequences for natural populations. These consequences have been most extensively studied in salmonids with large scale long-term supplementation. In some cases, hatchery production might involve shorter-term conservation objectives. One example of such a program is on Nechako River where a hatchery has been used to temporarily support a declining population while restoration efforts address root causes. These differences in the objectives and program design, coupled with the unique-long live life histories of sturgeon may act to mitigate the risks associated with hatchery production. To evaluate this potential, we develop a mathematical model that describes the coupled genetic and demographic consequences of hatchery production in a White Sturgeon population. We find that even temporary use of hatchery production can have long lasting genetic and demographic impacts on natural populations. However, limiting the duration of hatchery production is an effective strategy for mitigating these risks because 1) it reduces the amount of time over which genetic effects can accumulate and 2) it can eliminate positive feedback loops which amplify the genetic and demographic consequences of the hatchery over the long run. Furthermore, we find that the time scale over which these dynamics play out depends on the generation time of the population. In long lived species such as White Sturgeon this implies that hatchery production can be used over longer periods of time for a given level of risk compared to shorter lives species, but it also implies that the population will recovery more slowly once supplementation ends.

Quantifying Spontaneous Autopolyploidy in Wild and Hatchery Reared Lake Sturgeon (*Acipenser fulvescens*)

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Polyploidy, the state of having more than two complete sets of chromosomes (>2N), is characteristic of extant Acipenseriformes – sturgeon and paddlefish. This group undergoes spontaneous autopolyploidy, an unintentional 1.5 times increase in genome size, more frequently than any other order of fish. For lake sturgeon (*Acipenser fulvescens*) which are evolutionary octoploids (8N), spontaneous autopolyploidy results in fertile dodecaploid (12N) progeny. When progenies later reproduce with octoploids, it is possible that decaploid (10N) offspring will have poor physiological performance and survivorship. In other octoploid sturgeon species incidence of spontaneous autopolyploidy in the wild is very low; however, incidence in fish hatcheries is evidently greater. We investigated this disparity in lake sturgeon, where we predicted to find more dodecaploid (12N) individuals in hatchery populations than in the wild. Ploidy was determined for a total of five populations of lake sturgeon from Manitoba, Canada – three hatchery and two wild - using blood samples from caudal sinus puncture (n ≈ 800). All individuals were weighed and measured, and a fin clip was taken from a subset for molecular sex identification (n ≈110). Red blood cell size was evaluated with a Z2 Coulter Counter, where triplicate measurements of the mode erythrocyte nuclei volume (fL) were averaged, and volume was used to assess ploidy. A subsample from each population was further examined using blood smear analysis (n=130) and flow cytometry (n=60). Ploidy determination for all methods was based on ranges published for octoploid white sturgeon (Acipenser transmontanus); however, this comprehensive data set could be used to establish species-specific ranges for lake sturgeon. Preliminary analysis suggests the presence of a 12N lake sturgeon from a hatchery population. This individual demonstrates the need for ploidy monitoring in conservation hatcheries, as releasing any 12N fish could produce hundreds of 10N offspring, likely having a detrimental effect on population fitness.

Sturgeon Diversity and Interspecies Hybridization in Eastern Black Sea, Georgia

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Inter-species hybridization in nature is considered as one of the threats for natural populations. Different studies show that it causes extinction of rare species by genetic swamping and loosing genetic variability. Eastern part of the Black Sea in Georgia exhibits unusually high sturgeon diversity despite habitat alterations and anthropogenic influence. Three sturgeon species still enter to the Rioni River for spawning: Stellate Sturgeon, Russian Sturgeon, Ship Sturgeon. Ship sturgeon was considered as extinct from the Black Sea basin. Inter-species hybridization facts where found between Russian and Stellate sturgeon in the Rioni River. We used Control Region gene fragment for species identification, species-specific diagnostic markers for detecting inter-species hybrids, and sex-specific markers for detecting sex ratio. From tested 110 Russian sturgeon and 35 Stellate sturgeon genetic samples five where identified as hybrids between these two species, 9 specimens were identified as Ship sturgeon. Ship sturgeon hybridization was not detected with Stellate or Russian sturgeon. Sex identification markers show almost 1:1 ratio for Russian Sturgeon, meaning that the Russian sturgeon in the region is stable. For Stellate and Ship sturgeon sex-specific marker did not show female-specific PCR amplification. Meaning that either all the specimens are males or the designed sex-specific marker does not work for those two species. The hybridization fact can be caused by overlapping populations and altered environmental conditions. The hybridization can be more problematic for Stellate Sturgeon populations since they are low in numbers and by hybridizing with Russian Sturgeon might lose the possibility to reproduce in the region. The hybridization fact is alarming for the Ship sturgeon which is recently found in the same region as remnant Black Sea ship sturgeon population.

Genetic Determination of Sex Ratios for Spawning Lake Sturgeon within Lake Superior's Tributaries

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Managers rely on sex ratios and population size to evaluate the success of lake sturgeon restoration efforts. However, it can be challenging to distinguish between the sexes in the field as lake sturgeon lack external features to differentiate the sexes. Several methods are used to determine the sex of a sturgeon in the field, but these methods are dependent on the age and reproductive state of the fish and may result in "unknown-sex" individuals. This study used a newly developed genetic protocol to perform sex assignment on Lake Superior spawning lake sturgeon, calculate the sex ratios for the Lake Superior spawning populations, compare the sex ratios of the Bad River spawning population over time, and compare the sex assignment results to those obtained using field techniques. The AllWSex2 marker was used to perform sex assignment on spawning lake sturgeon collected from the Bad River (n=194), White River (n=45), Black Sturgeon River (n=57), Pic River (n=34), and Goulais River (n=30) from 2000 to 2010. Genetic sex determination produced similar results to field sex determination and was able to assign the sex of individuals previously labeled "unknown sex" in the field. Results suggest some variance in ratios between spawning sites and across years in the Bad River population. This may be due to lake sturgeon spawning behavior or differences in agency survey efforts. This study provides insight into the breeding ecology of lake sturgeon and will allow managers to better evaluate the population status of Lake Superior lake sturgeon.

Gastric Evacuation Analysis of the Sterlet (*Acipenser ruthenus*) Utilizing Gastric Lavage and Metabarcoding Techniques

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The ancient order of sturgeons (Acipenseriformes) are presently threatened with extinction; these threats include migration barriers, overfishing, and habitat loss. Within the Upper Danube River Basin, the sterlet (*Acipenser ruthenus*) is the last native sturgeon species. This study aims to better understand what sterlets consume in a heavily modified river; however, to measure this, it is important to know how quickly organisms are digested within the stomach. Methods to gather stomach content from sterlets must reflect their vulnerability, and therefore must not harm the organism. Consequently, gastric lavage techniques were applied to gather stomach content. For this study, five sterlets raised in captivity were utilized. They were starved for 72 hours prior to the experiment, subsequently individually fed 20g of Mysis, pacific krill, and red chironomids for 30 minutes. After either 1 hour, 3 hours, 6 hours, or 12 hours of allotted digestion time, stomach content was extracted by anesthetizing the sterlet with clove oil and performing the gastric lavage; this allowed to analyze how quickly they may digest various types of organisms, as well as to test how effective the gastric lavage technique is following a specific amount of time after feeding. This was repeated three times for total of 12 runs. The stomach content that was gathered was analyzed with metabarcoding using cytochrome oxidase subunit 1 (COI) as a universal primer. The resulting sequences were matched to an organism within a database with a 97% to 99% threshold. Additionally, gastric lavage stomach sampling techniques and metabarcoding were applied and utilized to gather stomach contents from eight wild sterlets caught in the Danube, below the Hydropower Plant Freudenau from March to April 2022. These results allow for a better and more accurate understanding of stomach content gathered from wild caught sterlets and allows for a safe and non-invasive method.

Physiological Effects of Elevated Temperatures and Simulated Heatwaves on White Sturgeon (*Acipenser transmontanus*) Embryos and Larvae

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White sturgeon are threatened or endangered throughout their range in British Columbia. While rapid declines in larvae and juveniles in these populations is likely caused by many factors, without doubt irregular water discharge from dams, resultant sedimentation changes, and increasing temperatures are playing a role. Thus, it is crucial to understand how current and future river temperatures affect sturgeon thermal phenotypes and associated early life stage survival. To assess the effects of various river temperatures (14°C, 18°C, or 21°C) on larval phenotypes and survival we reared Nechako river white sturgeon embryos at three different temperatures from shortly following fertilization to expulsion of their yolk-plugs. Throughout embryogenesis and following hatch, fish were sampled throughout development to assess morphology, metabolism, thermal tolerance, and gene expression. Embryo metabolic rate, measured one day prior to hatch, increased between 14°C and 18°C but not 18°C and 21°C ($P<0.001$).Thermal tolerance, measured as CTMax at the time of yolk-sac plug ejection, increased with acclimation temperature ($P<0.001$). Gene expression across a panel of thermal stress, metabolic, and hypoxia related genes differed among acclimation temperature groups in control fish ($P<0.01$) and less so following exposure to CTMax. Lastly, survival was reduced at both 18°C and 21°C , suggesting reduced likelihood of sturgeon surviving these conditions in the river. In addition, we also exposed the 14°C fish to a simulated heatwave to assess the effects of rapid and sustained heat exposure on larval sturgeon. Temperature increased to 21°C over 3 days and fish were acclimated for 20 days to simulated heatwave temperatures. Thermal tolerance, hypoxia tolerance, and DNA methylation of the gills and heart were assessed. Sturgeon exposed to the heatwave decreased global DNA methylation, exhibited thermal cross-tolerance, and were able to maintain hypoxia tolerance following heat acclimation.

Elevated Temperatures Impact Molecular and Whole-organism Physiological Responses of Developing Lake Sturgeon

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Rising temperatures elevate threats to physiological function in endangered freshwater species such as the lake sturgeon, *Acipenser fulvescens*, especially throughout vulnerable periods of early development. If temperatures breach sub-lethal thresholds, molecular and whole-organism physiological responses to environmental stressors may be diminished, increasing the sturgeons vulnerability to compounding environmental stressors. We investigated the effects of elevated temperatures on the molecular and whole-organism physiology of developing lake sturgeon from Manitoba, Canada. A common garden strategy was employed, where lake sturgeon from northern and southern populations within Manitoba were reared at equivalent and environmentally-relevant temperatures (16, 20 and 24oC). Lake sturgeon demonstrated acclimation-specific effects on whole-organism physiological responses including morphology, metabolic rate, critical thermal maximum and mortality. Many of the above phenotypic responses were population-specific, with lower thermal maxima and sub-lethal thermal thresholds in the northern population of lake sturgeon. Next, we used mRNA sequencing of gill tissue and found increased mRNA responsiveness in the southern population relative to the less thermally tolerant northern counterparts. Further functional analysis of mRNA changes implicated mitochondrial function, oxidative damage, and immunity as key physiological mechanisms altered by increasing acclimation temperatures with population-specific impacts. Last, we specifically investigated the effects of elevated temperatures on innate immune capacity through mRNA level molecular responses. Acclimation temperature impaired the survival and activation of molecular pathways involved in the innate immune, stress, and fatty acid responses of pathogen-challenged lake sturgeon in early development. Collective results suggest that as environmental temperatures intensify, molecular and whole-organism physiological responses may be impaired, likely resulting in the increased susceptibility of developing lake sturgeon to the effects of compounding environmental stressors, especially in the northernmost parts of their range.

Transcriptional Responses to Interacting pCO2 and Temperature Treatments in Lake Sturgeon, *Acipenser fulvescens*

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Freshwater acidification may be more system-dependent than marine acidification, but may nevertheless have important ecological consequences for fishes worldwide. The lake sturgeon (*Acipenser fulvescens*) was used to study transcriptional responses to the interacting effects of pCO2 and temperature. An experiment with n=66 larval individuals total was conducted over four groups and three timepoints. The groups were control (15 °C, 1000 µatm pCO2), increased temperature (22 °C), increased pCO2 (2500 µatm pCO2), and increased temperature and pCO2 (22 °C, 2500 µatm pCO2). Each group was reared in its respective pCO2 level and temperature. Following an overwintering period, all fish were exposed to acute hypercapnia of 10,000 µatm pCO2 at 3 °C. The timepoints sampled were at 0, 6, and 168 h post hypercapnia exposure for each group, held at their rearing conditions. Gill tissue was used for mRNA sequencing, which was used to assess differential gene expression and perform gene set enrichment analyses. We identified gene sets related to a variety of ion regulatory mechanisms in the increased pCO2 group, and signals of mitochondrial stress, viral immune responses, and gene expression regulation in the increased temperature group. In the treatment with both increased temperature and pCO2, gene sets related to developmental processes were significant, in addition to one gene ontology term related to calcification, with a possible role in otolith development. The distinct molecular responses present between the combined temperature and pCO2 treatment provide evidence for a response to compound stressors that is not otherwise present in the respective treatments alone. Overall, these results demonstrate potential transcriptional responses to individual and cumulative stressors in lake sturgeon and other fishes faced with increasing pCO2 in fresh water.

Detecting Spawning Activity of Lake Sturgeon (*Acipenser fulvescens*) with Environmental DNA

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Environmental DNA (eDNA) is a non-invasive approach used for the indirect detection of organisms within an environment. With aquatic species, determining when life events occur, such as spawning, can be difficult to monitor and detect without visual surveys to provide confirmation. For species at risk, such as Lake Sturgeon (*Acipenser fulvescens*), the management and protection of spawning events proves critical from a fisheries management perspective. eDNA provides the opportunity for improved management possibilities. In this study, we used eDNA to detect a known Lake Sturgeon spawning event in the Winnipeg River located in Manitoba, Canada. Using a known spawning area will provide validation for the use of eDNA to detect spawning events. Water samples were taken prior to, during and post spawn below the Pointe du Bois generating station. Collected eDNA was assessed for the presence and quantity of Lake Sturgeon eDNA using a species-specific quantitative PCR (qPCR) assay that targets the cytochrome b (cyt b) gene. We predicted that eDNA signal strength will be positively correlated with spawning activity, with significant spikes during peak spawn. Preliminary research from data collected in 2021 displayed that there is a positive relationship between the concentration of DNA and the presence of a spawning event at the collection site. These findings aim to provide support for future studies focused on determining spawning grounds in unmonitored environments. eDNA practices can additionally be transitioned to other species to assist in conservation and protection efforts of these critical life history events.

Small Scale Habitat Use of the Sterlet (*Acipenser ruthenus*) during Spawning Season in the Danube Downstream of the Hydropower Plant Freudenau

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Hydropower plants as migration barriers are a main reason for habitat degradation in the Danube. In the Upper Danube, sturgeons clearly show the consequences of this critical development. Of the five native sturgeon species, only the potamodromous sterlet (*Acipenser ruthenus*) is still present in a few small, isolated populations. As knowledge is limited on the behavior, an acoustic 3D telemetry study on small-scale habitat use below the hydropower plant Freudenau near Vienna was carried out during spawning season from March to May 2021. Five wild sterlets were caught in the study area, tagged and observed by an array of five hydrophones deployed during this time covering an area of 38.200 m². Three female and one male sterlet occupied the study area for 43 days. Primary zones of movement ranged between 8,391 m² and 10,655 m². Habitat overlap of the individuals varied between 8,5 % and 37 %, number of encounters reached up to 331. On average, the sterlets preferred residence depth of 9,7 m ((± 1,8), with no significant difference between day (10,1 m (± 1,5)) and night (9,3 m (± 1,9)). The observed movement distance in the array ranged from 762 m/day to 2264 m/day, with two individuals being more active during day and two during night. No correlations between discharge and temperature with movement distance were visible. It is noticeable that the array performance deteriorated significantly with increasing discharge ($n = 34$, p-value = 0.006559). This study fills knowledge gaps in sterlet behavior and shows that 3D acoustic telemetry is a valuable tool for gathering data with extremely high temporal and spatial resolution. Nevertheless, it is essential to collect more data on the behavior during spawning season for targeted restoration actions.

Just How Many Shortnose Sturgeon Are Out There; A Non-traditional Approach to Estimating Sturgeon in a Large River System

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Shortnose sturgeon (*Acipenser brevirostrum*) were initially listed as an endangered species in 1967. Previous studies in the Hudson River indicated a substantial increase in the spawning population from the 1970's to the 1990's. However, the most recent estimate is now >25 years old, and new estimates are needed to support management and recovery actions. Newer technologies are available to provide enhanced population estimates, such as integrated approaches based on side-scan sonar and acoustic telemetry which have been successfully employed in population estimates for other sturgeons. In 2021-2022, 100 adult shortnose sturgeon were acoustically tagged, a river-wide array and overwintering area array were deployed and side scan surveys were conducted. Using the methodology developed by Kazyak et al. (2020), side-scan derived counts of shortnose sturgeon abundance will be related to the number of acoustic transmitters detected within the survey area, providing an estimate of the proportion of telemetered individuals. By combining the total number of individuals released into the river with transmitters and our estimate of the proportion of individuals fitted with transmitters (and the associated estimates of uncertainty), an estimate of the overall adult population will be generated. Long lived batteries (10 years) will also inform spawning periodicity, seasonal movement and use of the river.

Calculating Adult Sex Ratios from Observed Breeding Sex Ratios for Wide-ranging, Intermittently Breeding Species

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A sex ratio is one of the most basic demographic estimates produced because it is easy to collect and provides deeper insight into population dynamics for the species under consideration. For inconsistently or intermittently breeding species, the breeding sex ratio (BSR) and adult sex ratio (ASR), both reported as the proportion of males, can be quite different. The entire adult population of some wide-ranging species may never be present and capable of being sampled in the same time and place. We explore equations to indirectly estimate ASRs and annual abundance estimates from annual surveys of BSRs. We sampled Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) from 2013 through 2019 and implanted acoustic transmitters during those sampling periods. The BSRs calculated during capture from 2015 through 2019 were 0.65, 0.75, 0.69, 0.75, and 0.64 each year. Relying on telemetry detections from the lowest potential spawning region, the expected BSRs in the same years were 0.64, 0.74, 0.67, 0.69, and 0.60, suggesting telemetry is a reliable and passive way to estimate BSR. The BSRs were used to indirectly estimate ASR to be approximately 0.51 (95% confidence limits of 0.43–0.58). Estimates of annual abundance derived through sex ratios matched previously published mark–recapture estimates of the same breeding population, but provide additional detail on abundances of each sex. For populations where BSR is more accessible, ASR and abundance estimates can be estimated with capture data and acoustic telemetry.

Seasonal Migration Pattern of Wild and Stocked Sterlets in the Danube

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Sturgeons (Acipenseridae) are an ancient fish family which experienced a drastic decline due to migration barriers, habitat loss, overexploitation, pollution and hybridization. In the Danube River Basin six sturgeon species are native, with five being critically endangered (one being locally extinct and another one functionally extinct) and one being vulnerable. In the chain of impoundments in the Upper Danube, the sterlet (*Acipenser ruthenus*) is the only sturgeon species left, with one proven reproductive population below the hydropower plant (HPP) Jochenstein in Austria. The project "LIFE-Sterlet" has the aim to re-establish self-sustaining sterlet populations in the last free flowing sections of the Austrian Danube. Since knowledge on habitat use and migration behavior of the sterlet is still scarce, this study aims to gather information on migration patterns and habitat use of wild and stocked sterlets between the HPP Freudenau and HPP Gabčíkovo. In this study 38 sterlets (5 wild, 33 stocked) were observed over a period of 1.6 years via acoustic telemetry. The stocked sterlets were reared in a container hatchery under near natural conditions and the wild sterlets were caught via net fishing below the HPP Freudenau. Five different migration patterns could be distinguished. The wild sterlets had the smallest migration ranges and mostly stayed below the HPP Freudenau together with a few of the stocked sterlets. However, most of the sterlets from the hatchery showed a straight downstream movement after their release, with some individuals migrating upstream again. The observed migrations could not be related to changes in temperature or discharge. The variability of migration patterns was interpreted as the individual ability to adapt to a new environment and explorative behavior. Aggregations of sterlets below migration barriers, like the HPP Freudenau, highlight the need for the reestablishment of longitudinal connectivity, which would allow fragmented sterlet populations to reconnect.

Gulf Sturgeon and Paddlefish Use of the Pascagoula River System with an Emphasis Near the Only Known Gulf Sturgeon Spawning Reach

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Paddlefish and Gulf Sturgeon in the Pascagoula River (PR) system, MS, presumably use similar spawning habitat. For Gulf Sturgeon, the only known spawning reach occurs in the lower Bouie River in an area where gravel pit mining has turned the river into a series of small lakes with a weir separating the upper and lower pits. The spawning reach for sturgeon is approximately 300 m downstream of this weir. The Paddlefish population within the PR system is not well understood and poorly studied, but this population is presumed to be small, as it has been augmented with hatchery-reared fish. The PR Gulf Sturgeon population is estimated to be the smallest of the seven core rivers and potentially has higher mortality rates than other systems. The purpose of this preliminary study is to understand comparative use of these two species in the Bouie River and throughout the PR system. We implanted 13 Paddlefish (since 2022) and >80 adult Gulf Sturgeon (since 2016) with acoustic transmitters. Gulf Sturgeon spend an average of 24 ± 8 to 43 ± 11 days (depending on year) associated with the spawning reach, generally arriving late March and departing by the end of May. Paddlefish were continually detected within the Bouie River lower pits and have not been detected moving into another tributary of the Pascagoula River. Gulf Sturgeon were detected above the weir in all years monitored (2017–2022) suggesting that they are capable of assessing potential spawning habitat upstream of the upper pits. No Paddlefish were detected above the weir; however, we are still in the first year of monitoring for this species and will hopefully determine if both species are making spawning-like runs above this structure when sufficient flows occur.

Development of Genetic Parentage-Based Tagging in White Sturgeon (*Acipenser transmontanus*)

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Development of genomic resources for sturgeon species is facilitating exciting new tools for sturgeon conservation. In the Kootenai River in Idaho, an endangered population of white sturgeon (*Acipenser transmontanus*) is supported by a captive breeding program. Hatchery spawned white sturgeon are held in captivity for a year to reach sufficient size for physical marking, which allows the identification of hatchery versus wild origin fish to track recovery goals. In captivity, differential survival of fish selected for adaptation to the hatchery environment (domestication selection) may result in lowered survival rates once the fish are released. Furthermore, physical tags can be unreliable due to tag loss in this long-lived species, making it difficult to track population age structure and monitor the success of hatchery fish. Parentage-based tagging (PBT) uses genetics to identify the parents of hatchery origin fish after they are released and recaptured during routine monitoring. PBT solves the issue of domestication selection through using a genetic "tag" rather than a physical tag, allowing fish to be released at a younger life stage. We validated this technique by genetically sequencing 381 sturgeon offspring from the Kootenai Tribe of Idaho hatchery. Using 325 SNPs, we successfully assigned offspring to their parents with an average of 97% accuracy. We believe that PBT has a promising future as a conservation tool for endangered sturgeon in the Kootenai River and beyond through limiting domestication selection, improving our understanding of growth rates and population age structure, and monitoring the survival success of hatchery released sturgeon.

No One Sex Marker to Rule Them All: Development of Genetic Sex Markers in Sturgeon and Paddlefish

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Recently, several studies have reportedly identified genetic sex markers for the Acipenseriformes. After decades of failed attempts to identify a genetic marker that could be used for sex identification at any life stage, have high throughput sequencing technologies finally led us to the holy grail? Although these advances provide a critical first step, divergent results among labs suggests that no single genome region is linked to sex in all Acipenseriform species. In this talk, we will discuss recent efforts to identify a genetic sex marker for all sturgeon and paddlefish, describe our own tests of one of the proposed sex markers, put forth a novel hypothesis about genetic sex determination in ploidy class B species, and describe our progress in sequencing the green sturgeon genome (*Acipenser medirostris*) to characterize candidate sex determining regions for improved monitoring and conservation.

First Estimations of Sterlet (*Acipenser ruthenus*) Populations Based on Monitoring Data in the Austrian Danube

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Anthropogenic impacts like the construction of hydropower plants (HPP) and subsequent habitat loss led to a decline of sturgeon populations throughout Europe. A chain of ten HPPs in the Austrian Danube left only two free-flowing sections. The sterlet (*Acipenser ruthenus*) is the only remaining sturgeon species and classified as “critically endangered”. Its population size was estimated at <1000 spawners based on expert judgement. Monitoring-based estimations for the Austrian Danube are unavailable. This study aims to describe the population structure and to estimate the size of the remnant population in the free-flowing section east of Vienna using Capture-Mark-Recapture techniques and to estimate the population size below the HPPs Jochenstein and Freudenau based on population genetics. A four-year net fishing campaign at Freudenau resulted in 38 captured sterlets, wereas 126 individuals were captured below Jochenstein during a six-year sampling. The sampled population below Freudenau composed of 27 females, 7 males and 4 fish with unknown sex. Females were larger and heavier (total length (TL) = 800 mm (SE = 12 mm); weight (W) = 3294 g (SE = 265 g)) than males (TL = 660 (SE = 28 mm); W = 1350 g (SE = 135 g)). The estimated population size based on the POPAN model (53 individuals (SE = 8.36, 95% CI = 43-80)) and the closed population model Mt (48 individuals (SE = 4.98, 95% CI = 42-63)) overlapped to some extent. The population sizes estimated by population genetics amount to 43 individuals (95% CI = 29-68) for Freudenau and between 127-141 individuals for Jochenstein. This study provides the first monitoring-based population estimates for the Austrian Danube and represents a baseline for future monitoring. Low numbers of mature sterlets and missing evidence of natural reproduction pose an urgent need for action such as to re-open migration corridors and habitat protection.

Simulating Fish Passage Impacts on American Paddlefish Metapopulation Dynamics

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Riverine fish species have suffered massive population declines world-wide as a result of dam construction. Dams can destroy and block access to spawning habitat as well as divide populations into segments with potentially different dynamics. The viability of the resultant overall metapopulation then depends on connectivity between segments, particularly when spawning habitat and production varies across dams. Given this, demographic rates within segments may depend on passage rates across dams. We simulated the effects of dispersal across dams on metapopulation dynamics of a riverine species, American Paddlefish. Using an agent-based model, we evaluated the effects of different simulated passage rates across three dams in a reservoir chain on overall metapopulation stability in the system. Scenarios were designed based on recent passage rate data from the Alabama River, and modeled rates included the range from no passage to free-movement conditions. Juveniles were allowed to pass downstream via passive dispersal regardless of upstream passage probability at the dams. We found that under current demographics and current passage rates at the dams (estimated from telemetry studies by Auburn University), the metapopulation declined to 0 within 100 years in all simulations (n=10). The downstream-most population segments acted as population sinks, accumulating biomass over the time series until the upstream segments declined to the extent that they could no longer support production downstream via juvenile dispersal. Once upstream subsidies were depleted, the downstream segments declined to 0 as well. Metapopulation stability improved when passage rates at all dams were 30% or higher. Our model framework can be adapted to any species in any reservoir chain, as well as unimpounded systems with natural barriers.

Habitat Use and Other Critical Resource Needs for Anadromous Sturgeons in North America

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Sturgeon species (Acipenseridae) are considered among the most endangered fishes in the world and populations are facing declines throughout their native range. Resource limitations are common for endangered species research including lack of funding available for replication studies, limited access and availability to the species of interest, and small population sizes. Because of this, sturgeon are generally understudied and lack the species-specific information needed to inform management decision-making. Five species of sturgeon in North America are anadromous, exposing them to additional environmental and anthropogenic threats as well as increased challenges in monitoring and management. Information relating to habitat and life history are readily available for these species, but the typical small sample sizes and limited spatial extent make it difficult to make broader inferences. The goal of this research is to synthesize information across anadromous sturgeon throughout North America to identify species-specific knowledge gaps and do a quantitative comparison of species-habitat relationships across species and geographic regions. Physical, chemical, and biological features associated with habitat usage and suitability at different life history stages will be combined and analyzed using hierarchical approaches. Estimates for each species will be provided and variation among these estimates will be discussed further. From this research, managers will be provided with criteria that can be used to inform knowledge gaps about life history needs for anadromous sturgeon. In addition, this work will also contribute towards the development of decision support tools that are empirically ground and can be used to prioritize habitat restoration work for these difficult to monitor species.

Diversity in Habitat Use by White Sturgeon Revealed using Fin Ray Geochemistry

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Understanding life-history diversity in a population is imperative to developing effective fisheries management and conservation practices, particularly in degraded environments with high environmental variability. Here, we examined variation in habitat use and migration patterns of White Sturgeon (*Acipenser transmontanus*), a long-lived migratory fish that is native to the San Francisco Estuary, CA, USA. Annual increment profiles were combined with respective geochemical (87Sr/86Sr) profiles in sturgeon fin rays to reconstruct annual salinity chronologies for 112 individuals from 5-30 years old. Results indicated a complex and diverse amphidromous life history across individuals, characterized largely by estuarine residence, a general ontogenetic trend toward higher-salinity brackish habitats, and high variability in habitat use across all age groups. Hierarchical clustering based on fin ray geochemistry during the first 10 years of life, prior to sexual maturation, indicated at least four distinct migratory phenotypes which differed largely in the timing and duration of juvenile to subadult movements between fresh- and brackish-water habitats. This study provides information regarding habitat use and migration in sub-adult fish that was previously lacking. Different migratory phenotypes vary in exposure to stressors across time and space and populations. Understanding White Sturgeon habitat distributions through space and time at different life stages can help identify areas where habitat restoration would be most effective and develop management actions to reduce stressors associated with specific areas where White Sturgeon are present.

2016-2019 Upper Sacramento River Juvenile Green Sturgeon Outmigration Investigation

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US Fish and Wildlife Service

A benthic trawl and rotary screw traps were used to collect and tag age-0 wild juvenile Green Sturgeon in the upper Sacramento River to determine their temporal and spatial distribution patterns, observe and analyze outmigration attributes, and estimate annual survival rates to the legal Delta, rkm 170. Detections of juvenile sturgeon were used to confirm release, residence time, travel velocity, and estimated survival rates within the freshwater portion of the Sacramento River. Over the four years of study, a total of 98 juvenile Green Sturgeon were implanted with JSAT's micro acoustic tags. Median residence time was highest in the upper reach, followed by the middle reach and lower reach. Reach-specific median velocities were lowest in the upper reach and increased an order of magnitude as fish migrated through the middle and lower reaches. Comparisons of relocation velocity models indicated a significant interaction of gear type and reach, indicating dependence on both gear type and reach, with juveniles captured in the rotary screw trap having significantly higher upper reach velocities than any other gear and reach combinations. Survival estimates of age-0 juvenile Green Sturgeon to rkm 170 ranged from 36.4 to 94.5%. Across all years and river reaches, arrivals at a downstream receiver gate appeared to be correlated with increases in discharge and associated turbidity events. The distribution of arrivals was highest around the first few flow events of each season. Numerous juvenile Green Sturgeon were detected making a continuous migration from the upper river to rkm 170 during early fall and winter discharge events. Multiple juveniles made stepped migrations, stopping in the middle (n=11) and lower river reaches (n=4) before continuing their successful outmigration to the legal Delta.

Juvenile Green Sturgeon Movement During Fall and Winter in the Lower Sacramento River, 2016–2020

Amy Hansen, 2 Robert D. Chase, 3 Tobias J. Kock, 4 Russell W. Perry, 5 Josh J. Gruber, 6 William R. Poytress

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A collaborative acoustic telemetry study was conducted to describe behavior and movement patterns of juvenile Green Sturgeon (*Acipenser medirostris*) in the lower Sacramento River, California during 2016–2019. Juvenile Green Sturgeon were collected, tagged, and released in the Sacramento River between river kilometer (rkm) 467 and rkm 419 (as measured from the Golden Gate Bridge, San Francisco, California) near Red Bluff, California. Telemetry monitoring sites were located between rkm 464 and rkm 1 to detect tagged fish that moved downstream. This presentation will describe movement patterns of juvenile Green Sturgeon in the lower Sacramento River between rkm 167 and rkm 52. In total, 98 juvenile Green Sturgeon were tagged and released during the study and 46 of these fish moved downstream and were detected in the lower Sacramento River. Downstream movement appeared to be associated with periods of increasing river flow, and the greatest percent of tagged fish were detected moving downstream during the first period of increased streamflow each fall. Detections of tagged fish decreased in the lower reaches of the study area, however it is uncertain if it was due to mortality while moving downstream, if fish stopped moving downstream to rear in study reaches, or if their transmitters stopped working due to battery life limitations. We did find that several fish were detected moving upstream between telemetry monitoring sites in the lower reaches of the study area. This study provides new insights into movement patterns and behavior of juvenile Green Sturgeon in the lower Sacramento River, but additional research will be required to better understand factors such as survival and how fish respond to seasonal hydraulic conditions and estuarine conditions.

Using Side Scan Sonar and N-mixture Models to Estimate the Number of Adult Green Sturgeon (*Acipenser medirostris*) in the Sacramento River, California

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UC Santa Cruz/NOAA Fisheries, 2. UC Santa Cruz/NOAA Fisheries, 3. UC Santa Cruz/NOAA Fisheries, 4. UC Santa Cruz/NOAA Fisheries

We used a commercial grade side scan sonar and N-mixture model to estimate the number of adult green sturgeon (*Acipenser medirostris*) in the Sacramento River, California. We compare this method to the previous method used over the past decade with a dual frequency identification sonar (DIDSON) and a density-based estimation technique that combined the number of individuals detected and the area sampled. Sturgeon are found in a patchy distribution throughout the upper Sacramento river over 160 km between Chico and Redding with a large percentage of the population found in just a handful of locations. Using side scan sonar allows for more efficient data collection in the field and easier analysis or captured images compared to using a DIDSON which has a narrower field of view and captures videos. The N-mixture model estimates a detectability coefficient using variability in replicate samples, to adjust the count for a final abundance, providing for a more reliable population estimate. We tested a number of potential distributions to model the abundance and found an over dispersed Poisson distribution to fit our data well.

Potential Climate Change Effects on Estuarine Residence of Green Sturgeon

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Green sturgeon (*Acipenser medirostris*) undertake extensive coastal migrations and occupy estuaries during the summer and early fall. Warm water and abundant prey in estuaries may afford a growth opportunity. We used results from a bioenergetics model to predict whether increasing estuarine temperature would affect sturgeon residence time in a Washington estuary (Willapa Bay). Modeled consumption rates indicated that years with higher water temperatures required greater consumption to achieve the same growth as years with lower water temperatures. Hence, we predicted that in warm years green sturgeon would reside for shorter periods in Willapa Bay, WA than in cooler years. Although green sturgeon occur in Willapa Bay from May through September, acoustically-tagged individuals a decade ago were observed to stay in the Bay for an average of 34 d (standard deviation 41 d, n = 89). A decade later, data collected on a different group of acoustically-tagged green sturgeon but the same array of twelve acoustic receivers in Willapa Bay were used to compare residence times between the periods. For both periods, proxies for estuarine water temperatures and rainfall were also compared. This long-term dataset allows a first look at potential climate change effects on this ESA-listed sturgeon species.

XXIII Years of Green Sturgeon Spawning Induction: A Success Story

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Spawning of wild-caught Klamath River green sturgeon began in 1999 and the challenge of incubating the sensitive eggs was resolved during the first three years. The years 2002-2005 were the most productive years, with 7 out of 8 (88 percent) females ovulating. Egg fertility averaged 62 percent, (ranging 38 to 80), and larval hatch per female averaged 29,700 (12,500-42,000). Since 2007, a total of 38 captive-reared females at the University of California-Davis have been induced to spawn. Ovulation occurred in 68 percent (n=26), partial ovulation in 11 percent (n=4), and no ovulation in 21 percent (n=8) of the females. Eight of the 26 ovulations (31 percent) were considered good spawns (greater than 10,000 hatched larvae), which occurred during the spring. Egg fertility for the good spawns averaged 51 percent (ranging 41 to 83), with hatch averaging 19,000 larvae per female (10,000-30,500). There was also one good fall spawn (November 16, 2011) with a hatch of 13,500 larvae, as two of four males successfully spermiated. During fall 2012 another female was induced to ovulate, but four males did not complete spermatogenesis. The good females had some similar characteristics that will be considered in future spawning induction trials, including egg diameter greater than 3.7mm, a polarization index of 0.04-0.06 (ratio of the distance of the germinal vesicle from the animal pole, to the egg diameter) with a corresponding 100 percent germinal vesicle breakdown in a progesterone assay, and first injection within a few days after the last assay. Prolonged drought has likely contributed to marginal spawning success and reduced egg quality in recent years due to the lack of cold enough winter vernalizations (11-13C instead of 8-10C). Future strategies include the use of additional chilled water for vernalizing broodstock holding tanks.

Assessing Effects of Pesticide Exposure on Larval Green and White Sturgeon

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Aquatic contaminants are pervasive in the SFBD, and they are recognized as a potential threat to recruitment of California sturgeon. However, knowledge of the vulnerability of sturgeon to aquatic contaminants is limited. Our goal was to investigate sub-lethal effects of two pesticides (bifenthrin and fipronil) on early life stages of sturgeon. We conducted laboratory exposures of yolk-sac larvae to multiple concentrations of pesticides to identify concentration-dependent impacts on growth, motor-coordination, activity levels, and thermal-tolerance. We saw greater sensitivity in White Sturgeon (*Acipenser transmontanus*) than in Green Sturgeon (A. medirostris), yet both displayed marked loss of motor-control and reduced activity after three days at the highest exposure concentrations. White Sturgeon have been shown to be more sensitive to many contaminants when compared to other fish species commonly used in toxicity testing. Interestingly, in our study, the bifenthrin concentration at which sturgeon larvae demonstrated an observed effect was higher than concentrations at which effects were observed in fathead minnows or rainbow trout in the literature. This may suggest that sturgeon respond to aquatic contaminants in different ways than other fish taxa. While sturgeon exposed to low and moderate concentrations regained motor control after three weeks in clean water, bioaccumulation can be a concern and should be addressed in future work, along with the potential for synergistic effects with water temperature and contaminant mixtures. This increased knowledge about sturgeon responses to common contaminants will allow for more targeted management of the species and their habitats.

Evaluating the Timing and Distribution of Green Sturgeon in Washington's Coastal Estuaries

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Washington Department of Fish and Wildlife, 2. Washington Department of Fish and Wildlife, 3. National Oceanic and Atmospheric Administration, 4. National Oceanic and Atmospheric Administration

Green Sturgeon *Acipenser medirostris* are a highly-migratory anadromous species, native along the west coast of North America and made up of two genetically distinct populations—the Northern and Southern distinct population segments (DPS). In 2010, the Southern DPS of Green Sturgeon was listed as threatened under the U.S. Endangered Species Act, making it vitally important to evaluate threats to species recovery throughout its range. Through a multi-agency collaborative effort, we were able to analyze acoustic telemetry data from 272 Green Sturgeon detected within the lower Columbia River Estuary, Grays Harbor, and Willapa Bay, Washington from 2019 through 2021. The objectives of this study were to 1) evaluate movements within and between Washington's coastal estuaries, including residence time and peak density of tagged fish within each estuary, 2) assess handling effects by tracking differences in exit times between recently and previously tagged fish, 3) assess differences in timing and distribution by DPS, and 4) compare these results with findings from previous studies. Green Sturgeon aggregate in Washington's coastal estuaries in summer, with members of both DPSs represented. Previous studies have demonstrated that the timing of estuary use is similar for both populations, while tagged groups show distinct patterns of coastal movement and use multiple estuaries in consecutive years. These data may contribute to assessing potential threats and impacts to recovery within Washington's coastal estuaries. Moreover, comparisons with earlier studies may help to evaluate recovery actions to date and guide future monitoring efforts.

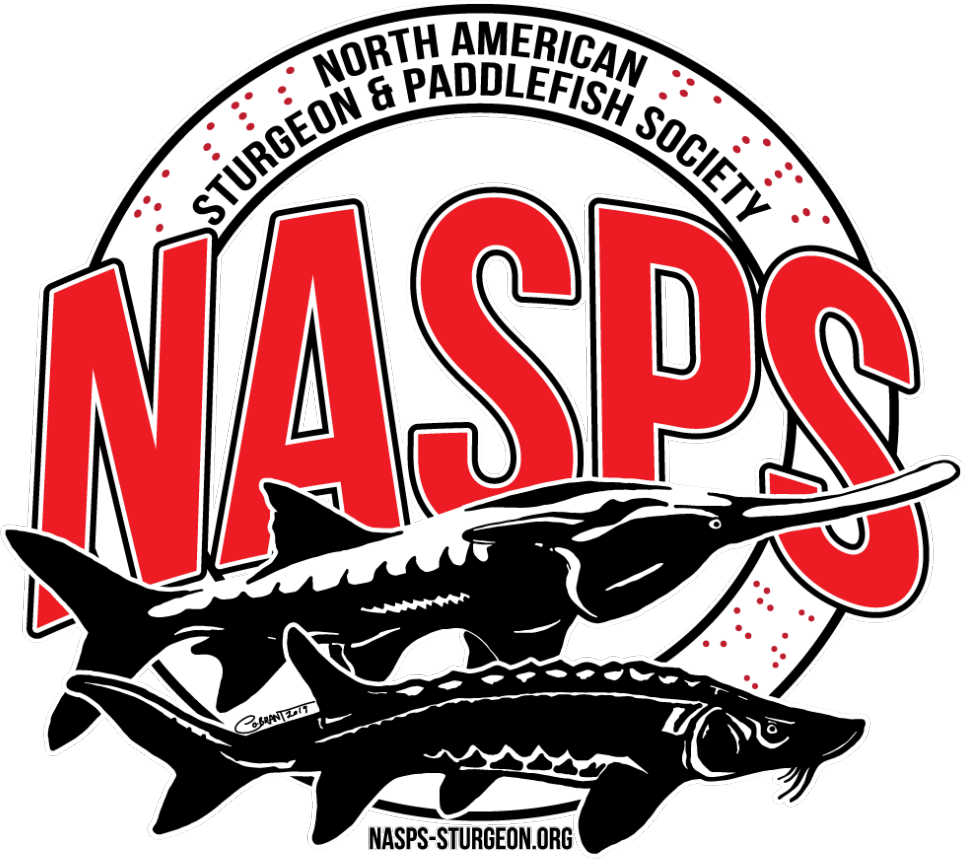
Consistency of Green Sturgeon Distinct Population Segment Genetic Assignments and Telemetry Data

Matt Sturza and Laura Heironimus

Washington Department of Fish and Wildlife,

Green Sturgeon *Acipenser medirostris* are an anadromous species native to the west coast of North America and are comprised of two distinct population segments (DPS). The Northern DPS are considered a Species of Concern by NOAA fisheries, and are known to spawn in the Klamath, Eel, and Rogue rivers in northern California and southern Oregon. The Southern DPS are federally listed as a threatened species under the U.S. Endangered Species Act, and are known to spawn only within the Sacramento River basin; including the Sacramento, Feather, and Yuba Rivers in southern California. After hatching and rearing in freshwater, Green Sturgeon of both DPS eventually move into marine waters where they will spend a substantial portion of their lives. Telemetric data indicates both DPS make seasonal migrations into Washington's estuaries and bays and nearby offshore areas. Upon reaching sexual maturity, Green Sturgeon make periodic migrations (estimated to occur every 2-6 years) to their natal rivers to spawn. Between 2003 and 2012 the Washington Department of Fish and Wildlife (WDFW) implanted 439 Green Sturgeon with acoustic transmitters in order to monitor their presence along the west coast. Of these tagged fish, 117 have been assigned as Northern DPS or Southern DPS based on genetic analysis. The purpose of this study is to 1) assess the consistency of genetic assignments with natal river acoustic detection data, 2) evaluate the frequency of potential spawning migrations, and 3) characterize the marine migrations of both DPS of Green Sturgeon. This work contributes to the body of knowledge on Green Sturgeon migration patterns and the potential risks imposed on these at-risk populations throughout the life cycle.

Abstracts for Poster Presentation
North American Sturgeon and Paddlefish Society 2022 Annual Meeting



Observations on Annual Recruitment, Movement Patterns, and Ocean Outmigration Timing of Juvenile Southern Distinct Population Segment (sDPS) Green Sturgeon (*Acipenser medirostris*) in the Lower Sacramento River and Sacramento-San Joaquin Delta

Marc Beccio, 2. Nick Bauer, 3. John Kelly, 4. Colby Hause

California Department of Fish and Wildlife,

Beginning in late 2015, California Department of Fish and Wildlife (CDFW) staff began a multi-year effort to capture juvenile Green Sturgeon within the Lower Sacramento River and tag them with 69 kHz acoustic transmitters. Fish detections were recorded by an array of 69 kHz acoustic receivers deployed throughout the lower Sacramento River, Sacramento-San Joaquin Delta, and at the Golden Gate Bridge. To date, CDFW staff have captured and tagged 184 juvenile Green Sturgeon with acoustic transmitters. Catch per unit effort (CPUE) was nearly 10-fold higher for Age-0+ juveniles following wet water years compared to CPUE following below normal, dry, or critically dry water years. Although these records are insufficient to produce an annual abundance index, this suggests that high Sacramento River outflows are an important factor in annual recruitment to the juvenile life stage. Analysis of the detection data is used to determine movement patterns, rearing habitat utilization, migratory behavior within the Delta, and outmigration to the Pacific Ocean. Telemetry detections suggest that juvenile Green Sturgeon range widely throughout much of the region, moving both up and downstream in the Delta including south into the lower reaches of the San Joaquin River, through the bays, and making forays into the ocean. These observations are valuable for species management and should be considered when planning water diversion operations, work windows for dredging operations, in-water construction projects, and potential habitat restoration projects.

Caught on Camera: Monitoring Adult Atlantic Sturgeon Breaching in the Hudson River

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Delaware State University, 2. New York State Department of Environmental Conservation, 3. Akima Systems Engineering, under contract to the U.S. Geological Survey, 4. U.S. Geological Survey, 5. University of Delaware

Although sturgeons have yet to attain the moniker as a high-performance fish, many species are capable of impressive feats of swimming performance including long-distance migrations and acrobatic breaching events. Airborne breaching events increase the probability of interactions (including injury and death) between sturgeons and humans, which can both complicate and slow recovery for imperiled species. While Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) breaching events have been documented since colonial times, quantitative data to understand the factors mediating this behavior are limited. In order to address this data gap, we mounted a remote high-definition camera system to document Atlantic Sturgeon breaching during the likely spawning period in the Hudson River. This camera system is part of a proof-of-concept effort to explore the viability of incorporating non-traditional data sources to track recovery in this enigmatic species. Our findings suggest that remotely sensed data can be used to monitor breaching events. We will discuss challenges to this approach as well as our plans to expand the project during the summer of 2023. Our collaborative approach includes state, academic, and federal scientists working in conjunction with private individuals and organizations and may provide a roadmap for improving recovery prospects in this species through citizen buy-in and engagement.

Characterizing the Effects of Environmental Variability and Individual Biological Characteristics on Green Sturgeon Recruitment Success

Erin Gilligan-Lunda, 2. James Peterson, 3. Adam Duarte, 4. Todd Swannack

Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, 2. US. Geological Survey, Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, 3. USDA Forest Service, Pacific Northwest Research Station, 4. U.S. Army Engineer Research and Development Center, Vicksburg, MS and Department of Biology, Texas State University, San Marcos, TX

Environmental variables during early life stages for sturgeon can have a great influence on recruitment success through survival, growth, and additional physiological processes. Failure to recruit has considerable impacts on relative year class strength and ultimately can lead to population declines. Thus, survival and growth of juvenile green sturgeon in the Central Valley of California has become a key information need for management decision making. This research will aim to understand how environmental variability, individual behavior, and biological characteristics impact recruitment success of juvenile green sturgeon, all while accounting for the great uncertainty regarding the species. An individual based model will be used to simulate how individuals might respond to their internal and external environments. Using this framework, we can evaluate fine-scale processes and identify key patterns and tradeoffs of how individuals interact with each other and their environment under different ecological hypotheses. Green sturgeon are known to be particularly sensitive to water quality stressors and contaminants in the Central Valley. Because of this, there will be an emphasis on exploring individual level responses to these factors and extrapolating those effects to evaluate population-level impacts that are useful for management. By identifying and providing mangers with the greatest impediments to recruitment success, informed decisions can be made that will aid in the recovery of this species.

Best Practices Utilizing Tetraploid SNPs for Family Reconstruction in Colony

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The program Colony's ability to characterize family structure of wild populations from genotype data, empowering estimates of census and effective numbers of reproductive adults, makes it a powerful tool in conservation and fisheries biology. Although developed for use with diploid organisms, the program has been successfully applied to polyploids, such as sturgeon, by coding microsatellite genotypes in pseudo-diploid dominant marker format, in which alleles are coded as present or absent. Although single nucleotide polymorphism (SNP) loci are less informative per locus than microsatellites due to having fewer alleles, they can be attained in far higher numbers, offsetting their lower individual power. The biallelic nature of SNPs gives the additional option of coding genotypes in pseudo-diploid codominant marker format, in which polyploid homozygotes are coded as diploid homozygotes and all polyploid heterozygote classes are reduced to the diploid heterozygote. We tested the accuracy of these two pseudo-diploid genotype formats for reconstructing families in the white sturgeon. A panel of 325 tetraploid SNPs was used to generate empirical data that were used to perform mating simulations that generated genotype sets with known sibship structure. We found dominant format far more accurate than codominant due to the latter commonly resulting in unrelated individuals being mistaken for siblings, such that the number or inferred parents was strongly underestimated. Further, pseudo-diploid formats require artificially high genotyping error rates set in Colony runs to account for the resulting difference between observed genotype frequencies and those expected according to Mendelian rules. In testing different error rates with our simulated data, we observed maximized accuracy with a value of 0.05, confirming another group's findings using empirical data. As SNP genotyping in polyploids becomes more commonplace, our findings demonstrate a most effective approach for using such data with Colony, bolstering its applications in conservation and fisheries biology for polyploids.

Trends in Abundance of California White Sturgeon

Dylan Stompe, Colby Hause, James Hobbs, John Kelly

California Department of Fish and Wildlife

The Sacramento-San Joaquin Watershed white sturgeon fishery has been actively monitored by the California Department of Fish and Wildlife (CDFW) since the recreational fishery reopened in 1954. CDFW conducts annual trammel net surveys of white sturgeon in Suisun and San Pablo Bays in which morphometric data is collected and high reward disk tags are applied to fish 95-150cm FL. Originally designed using Lincoln-Petersen mark-recapture methodology, the survey now employs a harvest-based estimator to estimate the abundance of white sturgeon within the legal harvest slot (101.6-152.4cm FL) using angler tag and report card returns. Estimates of "legal" white sturgeon abundance indicate a long-term decline, even under progressively tightened harvest restrictions. Despite apparent declines in abundance and an overall reduction in the number of harvested white sturgeon, angler catch per unit effort has not worsened, potentially due to advances in fishing technology and the rapid dissemination of fish reports via social media.

Status of Lower Columbia River White Sturgeon: Where We've Been and Where We're Going

Shaffryn Schade, 2. Colin Chapman, 3. Matthew Sturza, 4. Laura Heironimus

Washington Department of Fish and Wildlife, 2. Oregon Department of Fish and Wildlife, 3. Washington Department of Fish and Wildlife, 4. Washington Department of Fish and Wildlife

The Columbia River White Sturgeon *Acipenser transmontanus* population ranges throughout the Columbia River, upstream into Idaho and Canada. In the lower Columbia River, (downstream of RKM 470) White Sturgeon abundance collapsed at the end of the 19th century due to overfishing and remained depressed through the first half of the 20th century. The population began to rebound only after the adoption of management actions aimed at reducing overall harvest and protecting broodstock in 1950. With the construction of four hydroelectric dams, four distinct river reaches and spatially isolated populations were created. Three of these populations inhabit the impounded reaches between Bonneville and McNary dams and one inhabits the un-impounded reach downstream of Bonneville Dam. To evaluate the effects of hydro-system operations and fishery management strategies, the states of Oregon and Washington initiated research and monitoring programs in the mid-1980's. Among other things, these programs provide data necessary to estimate the annual abundance and productivity of White Sturgeon in each of the four lower Columbia River reaches. Size-specific abundance is estimated every three years in the impounded reaches between Bonneville and McNary dams, and annually in the free-flowing reach below Bonneville Dam. Productivity is estimated annually in each reach. These data allow us to see how abundance has changed over time and how different environmental conditions impact the segregated populations. It also informs when there is a need to employ adaptive management strategies to mitigate effects of anthropogenic and environmental stressors. Here we present a long time-series of abundance and productivity data for White Sturgeon in each of the four reaches of the lower Columbia River. Examining the current status of these fish within a historical context provides direction for future management actions and identifies data gaps to advise further research.

Angling Trends in the White Sturgeon Fishery

Colby Hause, Christina Parker, Dylan Stompe, James Hobbs, and John Kelly

California Department of Fish and Wildlife

The Sturgeon Report Card is part of a series of sport fishing regulations intended to monitor and manage California's year-round White Sturgeon (*Acipenser transmontanus*) fishery. In addition to aiding law enforcement efforts to enforce daily and annual bag limits, the Card provides critical data on angler trends in the fishery, such as spatiotemporal variation in catch and harvest. Since the onset of the Card program in 2007, the California Department of Fish and Wildlife (CDFW) has summarized Card data in annual reports and, more recently, is leveraging Card information to estimate abundance of legal-sized (101.6-152.4 cm FL) White Sturgeon from harvest reporting and angler reward tag returns. Long-term monitoring using Card data has revealed fishery trends that may provide insight into the health of White Sturgeon populations in the Sacramento- San Joaquin watershed. While the number of Cards purchased by anglers has remained relatively stable since 2015, total reported catch of White Sturgeon has decreased. However, the proportion of reported catch that is retained versus released has increased over time, indicating that anglers are harvesting more sturgeon relative to the total amount caught. These results have implications on the sustainability of the fishery, as additional data sources suggest that White Sturgeon abundance may be declining.

Monitoring Sturgeon Presence-absence with ARIS (Adaptive Resolution Imaging Sonar) in Tributaries to the San Joaquin River

Chris Diviney, Alisa Dahl, Steve Tsao

California Department of Fish and Wildlife

The San Joaquin River (SJR) is located in the southern part of the Central Valley and has three primary tributaries, the Merced, Tuolumne, and Stanislaus River. Sturgeon spawning has been documented in the SJR historically, but its status is largely unknown in these rivers and using sonar can help detect sturgeon in these habitats. In April 2021, the Department received photos of multiple sturgeon holding in a pool in the lower Tuolumne River after spring pulse flow had receded. By June, as stream temperatures reached 30C and river depth downstream of this pool made it improbable for sturgeon migration downstream, relocation of these fish became necessary. Three white sturgeon were successfully captured via trammel net, tagged with an acoustic tag and a PIT tag, and then released at Mossdale Crossing Regional Park. Further monitoring with the ARIS confirmed the presence of two more sturgeon holding in this pool until water hyacinth completely covered the pool. After pulse flows in October 2021, the hyacinth had passed downstream and the Department continued monitoring and found no evidence of sturgeon. In 2022, a sturgeon was witnessed and confirmed by ARIS in the Stanislaus River during another drought year after high peak flows and subsequent base flows. Riffles upstream and downstream may be impassable to this fish but riverine conditions are tolerable at this location. As environmental conditions change, tributaries may allow for better spawning and rearing than the SJR but may subject adult sturgeon to stranding or unwanted summer rearing due to quick recession back to base flows. The ARIS system can aid us in monitoring presence and absence of sturgeon throughout the year where capture or visual observation is not practical.

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