CALIFORNIA
SACRAMENTO-SAN JOAQUIN

GREEN AND WHITE STURGEON

A COMPREHENSIVE REVIEW

2023

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EXECUTIVE SUMMARY

Sturgeon are a long-lived fish that have adapted to its ever-changing environment. However, like most species—including ourselves—sturgeon are attempting to survive in a system that has been heavily altered within a very short window of time. This combination has made it difficult for sturgeon to adapt to their new environment, which is just one of the contributing factors to their reduced numbers. Without continued research, monitoring, and protections, sturgeon are likely to experience further declines.

This report was designed to assess our knowledge of Green and White Sturgeon life-stage performance and survivorship within the California San Francisco Sacramento-San Joaquin Delta Estuary. The intention is to outline what we know and document what is still unanswered into an accessible report to outline what management decisions are being made to conserve and improve the Green and White Sturgeon population.

This report is an independent review by California Sea Grant State Fellow, Sam Pyros, and is a collection of information specific to California Green and White Sturgeon from interviews and literature citations.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank all of those who have assisted in the creation of this report. I am very grateful for your support and assistance throughout this process. For those of you who took the time out of your schedule to meet with me and answer all my questions, as well as those who supplied me with several publications and references-- Thank you! I hope that this report is a valuable resource to you and your efforts in protecting and conserving White and Green Sturgeon.

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INTRODUCTION

Sturgeon (Family Acipenseridae) are long-lived, late maturing bony fish found in the Northern Hemisphere. Sturgeon reside in Europe, North America, East Asia and Siberia.[1] Even though they are a bony fish (Class Osteichthyes) they have very little true bone, while most of their internal skeleton is made up of cartilage.[2] They are commonly referred to as "ancestral" or "living dinosaurs", because they not only resemble creatures from a prehistoric era, but also because their lineage can be traced back between 55 to 141 million years ago.[3]

Generally speaking, sturgeon are difficult to manage because of their large-scale movements, benthic lifestyle, and our overall lack of life-stage specific population data. Sturgeon are anadromous, diadromous, and strictly freshwater (Lake Sturgeon, Shovelnose Sturgeon, Pallid Sturgeon, and Alabama Sturgeon); benthic feeders, and ubiquitous throughout their wide habitat ranges in North America. White Sturgeon range from the Gulf of Alaska to Ensenada, Mexico[4] and Green Sturgeon range from the Bering Sea to Ensenada, Mexico.[5] Adults and juveniles regularly move along the coast and aggregate in estuaries for extended periods for spawning and feeding; however, their habitat has contracted substantially due to alterations in the landscape. River blockages such as dams, water treatment plants, and other human infrastructure have resulted in restrictions in sturgeon migration to smaller ranges than what was historically available to them.

This report focuses on the San Francisco Estuary and Sacramento-San Joaquin Delta which is considered one of the most invaded estuaries in the United States by invasive species.[6] California has two species of sturgeon, Green (Acipenser medirostris) and White (Acipenser transmontanus). Currently, White Sturgeon are a part of a recreational sports fishery that has been operating since its second opening in 1954,[4] and Green Sturgeon (the Southern Distinct Population Segment or sDPS) are currently listed as Threatened on the federal Endangered Species Act (ESA) since 2006.[7]

Unfortunately, sturgeon populations are undergoing a global decline since 1999.[1] Due to minimal and poorly recorded historical data, it is difficult to determine how much the Estuary-Delta's sturgeon population has declined since the 1800s. For many years, Green and White Sturgeon were managed as a group and not as their separate species. However, in some historical reports, there are descriptions of a "golden sturgeon" alongside the White Sturgeon catches. This is assumed to be the Green Sturgeon, but there is no certainty. For example, one paper from 1928, Jordan et al., classified both *A. acutirostris* and *A. medirostris* as Green Sturgeon.[8]

Overall, our understanding of this perplexing fish has grown recently, but there is still much to be understood. This report addresses Sacramento-San Joaquin Delta White and Green Sturgeon population characteristics specifically, and more generally outlines continuing data needs to improve management efforts and outcomes.

WHITE STURGEON

Listing: California State Species of Concern

Habitat: White Sturgeon are more estuarian than Green Sturgeon. Their habitat ranges from the Gulf of Alaska to Ensenada, Mexico, with reproducing populations in the Sacramento-San Joaquin, Fraser, and Columbia River Basins.[8]

Cultural Importance: Recreational Fishery & Caviar

Natural Age of Mortality: Records state that White Sturgeon can live to be 100 years old, but no such historical specimen has been confirmed. However there have been catches in the Fraser River of individuals over 3.05 m and believed to be aged at 100+ years.[9]

Age of maturity: Males 9-25 years old and 1.01 to 1.8 m long[4], Females 14-30 years old and 1.4-2.0 m long[10][4]

Migration: Upriver migration can begin as early as late January and Downriver migration occurs in late May to June. Dependent on temperature and flow conditions to trigger their migrations, but White Sturgeon spawn earlier and migrate downriver faster than Green Sturgeon.

Spawning: Spawn from mid-February to late May. Broadcast spawners in deep holes and fast-moving water[13] .

Spawning frequency: Males every 1-3 years, Females every 2-11 years[12]

Fecundity: 64,000 to 469,000 eggs[13]

Side note: Although pectoral fin rays are currently the most practical and reliable aging structure for White Sturgeon, uncertainty exists regarding age estimates, especially for fish older than age 20.
[14] [15] [16]

GREEN STURGEON

Listing: Southern DPS are listed as Threatened per the Federal ESA

Habitat: Green Sturgeon range from the Bering Sea to Ensenada, Mexico

Cultural Importance: Yurok Tribe and Hoopa Tribe[17], found remains at historic Native American sites.

Age of Natural Mortality: 60-70 years old

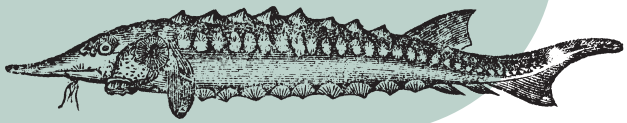
Age of maturity: Males 13-18, Females 16-27[18][19]

Migration: San Francisco Bay Delta, upriver migration has been observed entering the system in late January to May and migrating out of the system depending on flow from May to June and September to January.[20] The Klamath and Rogue River systems vary on upstream and downstream migration timings.

Spawning: Spawn from April to June, but it is highly influenced by flows. They are known to spawn regularly in three west coast river systems: California's Sacramento and Klamath systems, and the Rogue River in Oregon.

Spawning frequency: Males spawn every 1-3 years, and females spawn every 2-4 years

Fecundity: 59,000 to 242,000 eggs[21]



Southern DPS: originate from river systems south of the Eel River; spawning has only been confirmed in the Sacramento River system.

Northern DPS: originate from river systems north of and including the Eel River; confirmed spawning in the Klamath and Rogue Rivers

Note: There are other tribes outside of California that have a cultural significance to sturgeon.

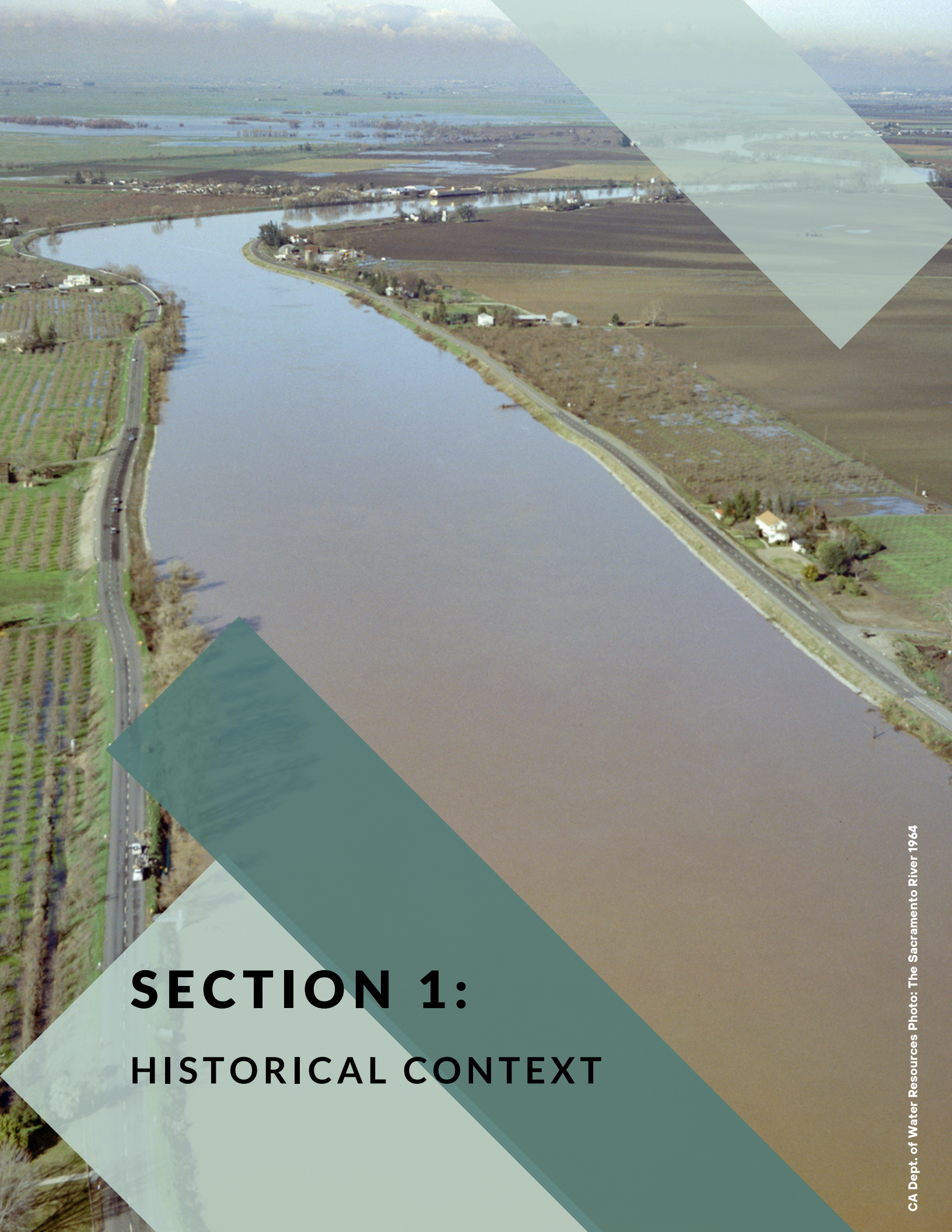
PART ONE

LIFE HISTORY FUNDAMENTALS

SECTION 1: HISTORICAL CONTEXT
SECTION 2: DIET
SECTION 3: MORTALITY
SECTION 4: SPAWNING
SECTION 5: AGE SPECIFIC INFORMATION

At the end of the following Sections there are 'Knowledge Gaps' and 'Questions' portions. The 'Knowledge Gaps' are short paragraphs that discuss the complexities of gathering answers to the mysteries of sturgeon behavior. These gaps will lead into the 'questions' that were brought up by the sturgeon specialists during their interviews.

The purpose of these 'Knowledge Gaps' and 'Questions' are to clearly state what needs to be addressed, and to provide researchers with directed studies to aid in management of the Sacramento-San Joaquin Green and White Sturgeon.



SECTION 1:

HISTORICAL CONTEXT

CA Dept. of Water Resources Photo: The Sacramento River 1964

THE CALIFORNIA FISHERY

1860 — San Francisco's Commercial Fishery began harvesting.

San Francisco's commercial sturgeon fishery began by the 1860's and harvested predominantly White Sturgeon.

1887 — Fishery Peaked at 1.65 million lbs. garnered, but quickly collapsed after that.

The fishery peaked in 1887 when 1.65 million pounds of sturgeon were garnered, and quickly collapsed in subsequent years. The fishery closed in 1901 only to reopen in 1909.

1917 — The Recreational Fishery closed its doors.

Small catches indicated that the population still had not recovered, but it was not until 1917 that the commercial fishery closed its doors for good.[22] [23] The sturgeon recreational fishery was closed alongside the commercial fishery in 1917, but was reopened in 1954 with a minimum size limit of 40 inches, and catch limit of one sturgeon per day.

1954 — The Recreational Fishery reopened with a minimum size limit of 40 inches, and one sturgeon per day.

The recreational fishery is still in operation, with slight modifications made over the years since its reopening. In 1954, California Department of Fish and Wildlife (CDFW) conducted a tagging survey recommending a 50-inch size minimum for anglers, but a 40-inch minimum was instated instead.

1990 — 72-inch Total Length maximum catch limit

In 1956, angling became the only allowed form of sturgeon fishing and a new size limit was instated.[24] In 1964, the size minimum was returned to 40 inches until concerns in the 80s when the Overbite clam was discovered in the Bay. This prompted surveys to be conducted, which led to a 72-inch total length (TL) maximum becoming effective in 1990.

1992 — Increased Size minimum to 46 inches

In 1992 the size minimum was increased to 46 inches, making the range of harvestable sturgeon 46-72 inches. The maximum TL size limit was then lowered in 2007 to 66 inches; thus, making the harvestable sturgeon range 46-66 inches.

2006 — Maximum harvestable range was lowered to 66 inches.

In 2006, the National Marine Fisheries Service (NMFS) determined that California's Southern Distinct Population Segment (sDPS) of Green Sturgeon was at risk for extinction and it was listed as Threatened under the Federal Endangered Species Act (ESA).[7]

2007 — Green Sturgeon were removed from the recreational fishery.

In 2007, Green Sturgeon were removed from the recreational fishery list by the California Fish and Game Commission (CFGC) per the recommendation of the California Department of Fish and Game (CDFG).[4]

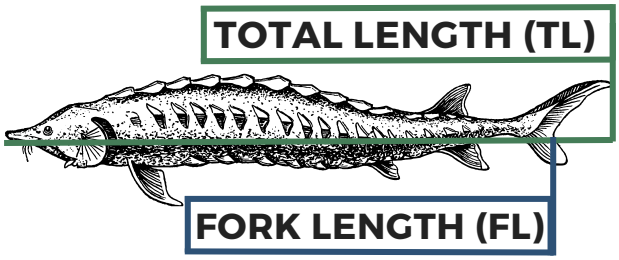
2007 — New White Sturgeon Regulations:

Following this closure was the new White Sturgeon regulations stating that, "annual limit of three White Sturgeon, a reduction in maximum size limit to 66 inches TL, a requirement to record all catch on a Sturgeon Fishing Report Card, and a requirement to tag all retained White Sturgeon."[25]

2013 — New slot limit is 40-60 in. FL, and no fish above 68 in. can be removed from the water.

In 2013, the slot limit for White Sturgeon changed to 40-60 inches fork length (FL), and fish larger than 68 inches FL are not permitted to be removed from the water. Gear restrictions changed which now prohibit the use of snares to help land fish, and only single barbless hooks are permitted.

The Sturgeon Fishing Report Card program (CDFW) collects the information on how many anglers are fishing sturgeon, how many fish are caught per year, and how many are released compared to those kept. [26] One sturgeon may be kept daily, but only a total of three kept annually. CDFW currently offers rewards of $20 to $150 if a sturgeon with a disk tag is reported and recorded. For more information about the Sturgeon Report Card Program see Part 2: Sections One and Two.



Sturgeon are a coveted sport species for anglers. Fishing for California White Sturgeon is marketed online as "fishing for dinosaurs" and many websites provide tips for catching these fish. There are commercial passenger fishing vessels (CPFV) that specialize in sturgeon fishing in San Francisco and San Pablo bays.[4] However, CPFV logs did not distinguish between White and Green Sturgeon, but since 2006 they are now required to document a distinction. Reported catches by anglers using the CPFV program has declined since the 1980s, and recently only a third of the Sturgeon Fishing Report Cards are being returned by the end of each season.[4] [27]

Fishing is closed for sturgeon between Keswick Dam and highway (Hwy) 162 bridge on the Sacramento River, the Yolo Bypass, Toe Drain Canal, Tule Canal upstream of the Lisbon Weir, and the North Coast District (Humboldt, Del Norte, Trinity, and Siskiyou counties).[26] There is also a seasonal closure of White Sturgeon fishing from January 1 to March 15 in the Central San Francisco Bay (between Pt. Chauncy and Pt. Richmond, the San Francisco-Oakland Bay Bridge, and between Pt. Lobos and Pt. Bonita) that coincides with herring spawning.

CAVIAR INDUSTRY BACKGROUND

Sturgeon can easily be overexploited for caviar harvesting. They have many, many eggs, spawn multiple times during their lifespan, and are long-lived. The sturgeon caviar harvesting/production industry began in Eurasia long before California's White Sturgeon were included; however, today California White Sturgeon has grown to be recognized as a national source of good caviar. By the late 1800s, there were fisheries for sturgeon meat and caviar from California and the West Coast, particularly to supply demands in the eastern United States.[4]

After the fishery's closure in 1917 waned until later in the 20th century, California's White Sturgeon caviar industry re-ignited when Professor Sergei Doroshov pursued research supporting White Sturgeon aquaculture in the late 1970s. By the early 1980s, there were a handful of White Sturgeon commercial farms in Northern California.[28] Cultivating farm-raised caviar began to expand quickly in California in around 1993, and as of 2015, Sacramento is home to several sturgeon farms that supply approximately 80% of United States' caviar.[28]

Due to Dr. Doroshov's research and findings regarding sturgeon reproductive physiology, commercially cultivated female sturgeon now take only a third to a half of the time to mature compared to what it takes in the wild. University of California, Davis has been, and continues to be a critical component to understanding the reproductive physiology of sturgeon. Since Green and White Sturgeon spawn in very deep, turbid waters, no spawning event has ever been seen in the wild. However, due to the dedicated researchers at UC Davis, we have a better understanding of the spawning and early life stages of these cryptic fish (see Section 4 and 5). Their labs continue to advance the science and technology for sturgeon caviar, genetics, and many more topics to improve population abundance.

USGS Photo: Juvenile White Sturgeon Columbia River, bottom trawl for yoy indexing

WHITE STURGEON: POPULATION ABUNDANCE

The monitoring enterprise in the San Francisco Estuary and Sacramento-San Joaquin Delta system has a data record that may not be useful for estimating sturgeon populations beyond indexing catch per unit effort (CPUE) or using catch feedback from angler surveys. Researchers have struggled to calculate abundance estimates in a timeframe for useful management decisions. In particular, life stage transition probabilities and survivorship estimates are difficult to construct using existing collected data. In 2011, DuBois and Gingras published an updated method to estimate the abundance of White Sturgeon.[29] Theirs was an attempt to simplify the algorithm and produce more accurate estimates in a shorter time. This algorithm is used by CDFW today for population management, and the most recent estimate puts the White Sturgeon population at 48,000 fish.[12] [29] Blackburn et al. (2019) calculated an estimated future abundance for ~2039 using currently available demographic data where the population estimate drops to 27,905 White Sturgeon (95% CI= 8,184—58,569).[30]

Of current interest and associated with a recent regional harmful algal bloom, the San Francisco Estuary experienced one of its largest recorded fish die offs in August 2022. White Sturgeon were noted to have experienced significant population losses as evidenced by carcasses viewed by survey staff, researchers, and the public. It remains to be seen whether current sampling programs that monitor sturgeon in the Estuary collect data that will be effective in estimating the impact of the die off. This issue is discussed in further detail below when examining the nature of the data our monitoring programs currently collect.

Additionally, the USFWS Anadromous Fish Restoration Program (AFRP) associated with the Central Valley Project Improvement Act (CVPIA) developed recovery goals for five anadromous fish species of concern.[1] White and Green Sturgeon were two of the five species listed, and population estimates for both were established. The objective of the AFRP was to double the abundance of age-15 fish during the mark and recapture period of 1967-1991. A mean annual abundance of 5,571 age-15 fish was estimated, and a goal of maintaining population abundance of 11,142 age-15 fish by 2002 was set.[31] This objective has yet to be reached. White Sturgeon continue to be a State Species of Concern, but are not listed as threatened or endangered by the California or United States Endangered Species Act.

GREEN STURGEON

Green Sturgeon spend a majority of their time in nearshore marine waters, and they spend considerably less time in the Estuary than White Sturgeon. Green Sturgeon are more anadromous than White Sturgeon, exhibit earlier saltwater tolerance, and are able to osmoregulate more readily than other sturgeon.[5]

North American Green Sturgeon consist of two distinct population segments (DPSs), a northern (nDPS) and southern (sDPS). The two DPS's are differentiated via genetic analysis resulting from low gene flow - the sDPS has a "distinct genetic composition from the northern group"[17] - as well as by the difference in spawning rivers between the two. Not only do they use different spawning habitat, but individuals return to their natal river to spawn year after year. The nDPS spawns in river systems north of and including the Eel River; spawning has been confirmed in the Klamath and Rogue Rivers. The sDPS spawns in river systems south of the Eel River; spawning has been confirmed in the Sacramento River system. The nDPS and sDPS both inhabit coastal estuaries in California, Oregon, Washington, and British Columbia and occur in marine waters from Baja California to Alaska. The sDPS is listed as threatened (in danger of becoming endangered in the foreseeable future) because they have been cut off from a majority of their spawning habitat in the Sacramento River system, such that spawning is concentrated in a small segment of the mainstem Sacramento River.

Photo of a Green Sturgeon: Oregon Department of Fish and Wildlife

Yurok Reservation & Ancestral Territory

On California's northern coast, Green Sturgeon have been of cultural significance to the Yurok Tribe for more than a thousand years.[32] There is a tribal fishery for Green Sturgeon on the Klamath River that is an essential part of the tribe's culture, subsistence, and economy.[32] The Yurok tribe harvest Green Sturgeon for their meat, eggs, cartilage, and bone. They bake "sturgeon bread" from the eggs, form parts to create a glue used to craft regalia and construct sturdier fragments into tools.[32] Green Sturgeon in the Klamath River are a part of the northern Distinct Population Segment (nDPS).

Map sourced from YurokTribe.org

Green Sturgeon were harvested within the San Francisco Estuary Sturgeon Fishery, but where they are sacred for some populations, they were considered taboo within others.

In a California Board of Fish Commissioners Report, Locking (1879) stated that fishermen had a prejudice against the Green Sturgeon and that they were considered to be poisonous even though "it was abundant as white sturgeon."[33] As such they were still frequently caught, although not in the numbers that White Sturgeon were. Unfortunately, contemporary Green Sturgeon suffer from high bycatch numbers in association with commercial, recreational, and tribal fisheries.[17]

Even though Green Sturgeon were not fished as heavily as White Sturgeon, their numbers declined due to a combination of factors. When the recreational fishery reopened in 1954, Green Sturgeon were allowed to be fished unabated until 2007. Several major hydraulic engineering projects were constructed across the Central Valley (See example image on page 22), and overall, the aquatic environment of the Estuary has changed over the past century, with dredging, short-circuiting of slough networks, infrastructure additions like marinas, docks, water intakes, etc. profoundly affecting the underwater nature of demersal habitat used by fish like sturgeon.

CDFW Photo of researcher Marc Beccio holding a Green Sturgeon. (Credits: IEP 'View from the Water' Blog)

Ultimately, the sDPS Green Sturgeon became listed due to the loss of spawning habitat that increased their population vulnerability to natural demographic stochasticity over time.[17] [34] One such major dam impeding access to spawning habitat was the Red Bluff Division Dam; however, its gates are now open year-round and allow for sturgeon to cross through and spawn above the dam.

After listing the sDPS in 2006, the NMFS designated critical habitat for the sDPS in 2009,[35] including: approximately 320 miles (mi) of freshwater river habitat in the Sacramento River; 897 mi2 of coastal estuarine habitat in California, Oregon, and Washington; 11,421 mi2 of marine habitat along the coast from California to Washington; 487 mi of habitat in the Sacramento-San Joaquin Delta, and 135 mi2 of habitat within the Yolo and Sutter bypasses.[5] The nDPS is considered a federal Species of Concern, but is not state or federally listed for further protection.

QUESTIONS

1.How do we manage tribal harvest for Green Sturgeon and fishery harvest for White Sturgeon to maintain what is equitable, sustainable, and thoughtful?

2.How do we equitably include all diverse parties' mission statements and visions, while having holistic ideas about managing and harvesting sturgeon and keep an open dialog about the challenges that are being faced?

SECTION 2:

DIET

CDFW Photo: IEP 'View from the Water' Blog-- Researcher with adult White Sturgeon

Sturgeon feed by suction with their ventral, protrusible mouths using their barbels for locating benthic food sources. They are opportunistic feeders, and as sturgeon grow their diet diversifies, and they are even known to become piscivorous.[36] [37]

LARVEA

Researchers in the Columbia River system have found that White Sturgeon larvae and young-of-year (YOY) consume gammarid amphipods (Corophium spp.), copepods (Cyclopoida), Ceratopogonidae larvae, and Diptera larvae.[38] Corophium also appeared to be the most important food source for Green Sturgeon larvae.[39] Cyclopoid copepods (Copepoda), baetid mayflies (Ephemeroptera), chironomids (Diptera), and simulids (Diptera) were also found to be common food items throughout ranges in temperature and discharge in the Sacramento River.[40]

JUVENILES

The Pacific States Marine Fisheries Commission in 1992 found juvenile White Sturgeon feeding on, "tube dwelling amphipods, mysids, isopods, Corophium spp., and other benthic invertebrates such as chironomids, and on the eggs of other fish."[41] [39] [42] [43] [37] [44]

Other reports found them to consume benthos, periphyton, and zooplankton[45] [46] [38] as well.
Green Sturgeon juveniles begin to show opportunistic feeding and diet diversity as they likely feed on seasonally abundant invertebrates that drift through the water column or are benthic. This includes, but is not limited to amphipods, bivalves, mysid shrimp, dipteran larvae, and Corophium.[41] [39]

SUBADULT/ADULTS

White Sturgeon subadults and adults feed on fish spawn, small fishes, invertebrates (such as crabs and bivalves), and amphipods. When they are larger, they can and will show piscivorous behavior and consume sockeye salmon and lamprey[47], mollusks, and crayfish.[48] [49]

Green Sturgeon are similar in their diet and predation of fish, amphipods (such as Corophium spp. and Photis californica), bivalves (Macoma sp.), macrocrustaceans (such as Neomysis sp. and Crangon franciscorum), and isopods (Synidotea laticauda).[50]

In Willapa Bay, Washington, Green Sturgeon have been observed creating pits in the inter- and subtidal when they feed on benthic infauna.[51] This behavior increased in density in the midsummer over high densities of Pacific ghost shrimp (Neotrypaea californiensis), which has also been found as a major food source for Gulf Sturgeon in Choctawhatchee Bay.[52]

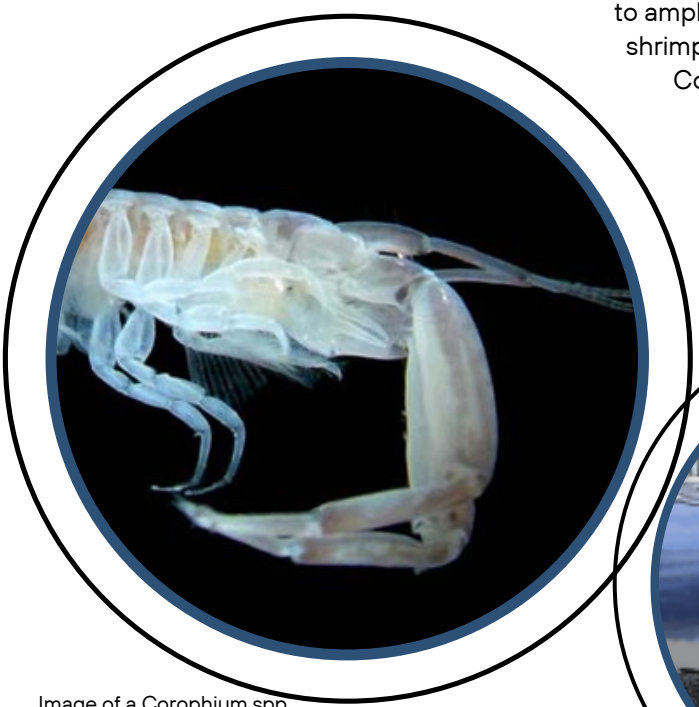
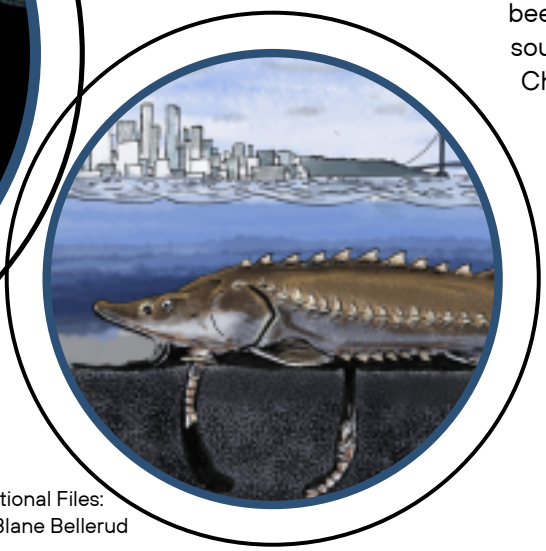


Image of a Corophium spp. Invasive to California. (Credit: George Brooks and the California Academy of Sciences).



NOAA Educational Files: Illustration--Blane Bellerud

In some systems, Gulf Sturgeon are displaying trophic dormancy (or temporarily stops in feeding), during their summer river residency.[53] [54] [55] Whether or not Green Sturgeon are feeding during their up-river migration is still unknown; however, there is speculation that Green Sturgeon in the Sacramento-San Joaquin system might be feeding on lamprey during their stay. Experts John Kelly, CDFW and Alicia Seesholtz, DWR say (personal communication), "When we sample fish they are thick and healthy, and lamprey transformers have been found in the same spots where sturgeon have been spawning in the Sacramento River." The question still remains: Are green sturgeon feeding on their upriver migrations; and if so, what are they feeding on?

It is also speculated that once Green Sturgeon are done spawning, they follow the herring downstream to feed on them. Currently, researchers are catching green sturgeon with herring as bait, but this does not prove that green sturgeon follow and feed on herring during their downstream migration. Researchers have noted it is much easier to catch them on their downriver run rather than on their upriver migration.

INVASIVE SPECIES

THE OVERBITE & ASIAN CLAMS

Non-native species introductions have been occurring for decades, and yet sturgeon have managed to persist. "The San Francisco Estuary (Estuary) is the most invaded estuary on the west coast of the United States," Zeug et al. (2014) stated.[56] Recently, expansion of aquatic vegetation has altered the nature of the open water and benthic areas of the Estuary, and may have important impacts to sturgeon feeding, movement, and rearing habitat. Introduced fish species, such as the Striped Bass (Morone saxatilis) prey on young Green Sturgeon and may have important demographic consequences.

Another abundant and impactful invader is the Overbite Clam (Potamocorbula amurensis) first described in the Estuary in 1986. Since then, this clam has become a dominant benthic species in the northern portion of the Estuary and in 1990 comprised 95% of the living biomass.[57] [58] [59] Clams are known to filter and feed on the early life stages of plankton[60], which has possibly altered the availability of phytoplankton in the Estuary and may have caused native fishes to alter their diets as well.[61]

Sturgeon are benthic feeders, and Overbite Clams have been observed in sturgeon stomachs, and even excreted whole-- sometimes still alive.[62] Richman & Lovvorn (2004) found that, "the overbite clam was more resistant to crushing than native San Francisco Estuary clams."[63] Zeug et al. (2014) found that the gut contents of White Sturgeon changed significantly after the invasion of the Overbite Clam.[56] Not only did the Overbite Clam make up a large portion of the White Sturgeon diet, but appeared to alter prey community structure around it. Unfortunately, Potamacorbula may be difficult to digest and may have an effect on sturgeon energy intake and growth rate, but these claims need to be studied further.

Where the Overbite Clam is found in brackish waters, the Asian Clam (Corbicula fluminea) is another invasive species that is found primarily in freshwater habitats. Zeug et al. found that these two invasive clams were the only clams found in the White Sturgeon diets, and clam species found prior to the Asian Clam introduction were not present.[56] In addition, filter-feeding bivalves accumulate contaminants more rapidly, potentially magnifying contaminant concentrations in sturgeon diets generally.

KNOWLEDGE GAPS

Much speculation exists regarding sturgeon diets and information is needed; however, at their core sturgeon are benthic and opportunistic feeders. They have a mouth that faces downward and barbels that act as feelers and tasters for finding live prey, which is potentially how they would waste energy encountering less beneficial prey like the Asian and Overbite Clams. Sturgeon are anadromous or diadromous so their diets need to vary between freshwater and saltwater habitats. Ocean-related diets are not discussed here due to low relevance to the Sacramento-San Joaquin Rivers ecosystems, but there are reports showing adult sturgeon feeding on crabs and small fishes in marine habitats.[5] [64] They are benthic, opportunistic, and cryptic in their movements which makes studying their eating habits difficult. Our knowledge of all life stage diets is minimal, but the following are some topics of interest that can be addressed when considering life-stage based monitoring and population viability estimates:

QUESTIONS

1.Is there a high food availability in wet years that causes higher recruitment seen in sturgeon?
2.Are green sturgeon feeding on their upriver migrations; and if so, what are they feeding on?
3.Are spawning adults eating during their "recovery" time in the river after spawning? If so, what are they eating?
4.Does either sturgeon consume anything that is endemic to the Delta?
5.Are larval sturgeon influenced to migrate in and out of salinity gradients by food availability or salinity tolerance? (This can especially be asked about green sturgeon)
6.If so, what are they eating in the marine environment in their early life stages?
7.Diversity in the diet promotes growth from exposure to diverse prey. How many sturgeon (or what percentage of sturgeon) migrate upriver to spawn verses feed in different habitats?
8·How does food availability or the quality of spawning habitat affect upriver migration?
Management Question: Diet plays a vital role in long-term success, and fewer nutrient dense prey available affects not just sturgeon, but the entire ecosystem as a whole. What resources are needed to conduct diet analyses in the Sacramento-San Joaquin (SSJ) Delta?

SECTION 3:

MORTALITY

CA Dept. of Water Resources Photo: Ship in the Delta

The age of natural mortality is unknown for both green and White Sturgeon; however, White Sturgeon are suspected to live over 100 years. Green Sturgeon life expectancy ranges between 60-70 years. Due to a lack of historical data and uncertainties associated with deciphering ages from fin rays, these estimates are approximate only.

SOURCES OF MORTALITY:

PREDATION

STRANDINGS

SHIP STRIKES & POACHING

DISEASE & BACTERIAL INFECTIONS

BYCATCH

CONTAMINANTS

ENTRAINMENT

HARMFUL ALGAL BLOOMS

PREDATION

Sturgeon can grow to be quite large (upwards of several meters), and due to their size and sharp bony scutes they tend not to be desirable prey. However, CDFW reports that, "Sculpins, Walleye, Common Carp (Cyprinus carpio), Smallmouth Bass (Micropterus dolomieu) and Chinook Salmon are known to prey on eggs and juvenile White Sturgeon less than 1 year old."[65][12] It has been suggested once sturgeon grow above 20 cm they are "safer" from predators, and even more so once they reach 75cm to a meter in total length (TL). Juvenile White Sturgeon typically reach 43-45cm TL and grow to 102cm before their growth rate begins to slow.[66] Unfortunately, juveniles are still prey for pinnipeds, Striped Bass (Morone saxatilis), and Largemouth Bass (Micropterus salmoides).[67] [30] Green Sturgeon are less desirable than White Sturgeon since their scutes are sharper. Adults are also less likely to be prey for other species, but when sea lions experience a decrease in their preferred food sources they have been known to pursue sturgeon. Recent observations include sea lion predation on White Sturgeon in the Sacramento-San Joaquin basin[12], and multiple reports of increased sea lion attacks on White Sturgeon have been reported in the Bonneville Dam tailrace.[68] [69] [70] The sea lion predation rate on the Delta adult White Sturgeon adult population is unknown, but for comparison in 2011 some 3,000 predation reports were recorded just south of the Bonneville Dam, in Oregon.[12]

SHIP STRIKES & POACHING

Ship strikes and angler fishing pressure are likely the greatest threat to adult sturgeon.[4] The San Francisco Bay-Delta's heavy boat traffic (recreational and commercial) leads to a greater probability of boat strikes; however, the rate of collision has not been quantified.[71] Poaching is also a concern, for both meat and caviar. Poachers have been caught with gravid females and carcasses of both species of sturgeon. This hinders sturgeon populations long term through continuous reduction in reproductive potential.

BYCATCH

Bycatch is an issue of concern for the Federally listed Green Sturgeon sDPS population. Bycatch occurs in the California Halibut Bottom Trawl Fishery, as well as in the White Sturgeon Fishery in the San Francisco Bay and Sacramento-San Joaquin Delta.

Linked HERE is the 2020 bycatch report for Green Sturgeon in the California Halibut Fishery, along with the link HERE to the CDFW Sturgeon Fishing Report Card reports and past reports HERE.

Further in this report (Part 2: Section 2), is a description of the National Marine Fisheries Service's effort to address the Green Sturgeon bycatch in the California Halibut Bottom Trawl Fishery. Along with this description is a linked publication to the previous study's report and what the possible next steps will be.

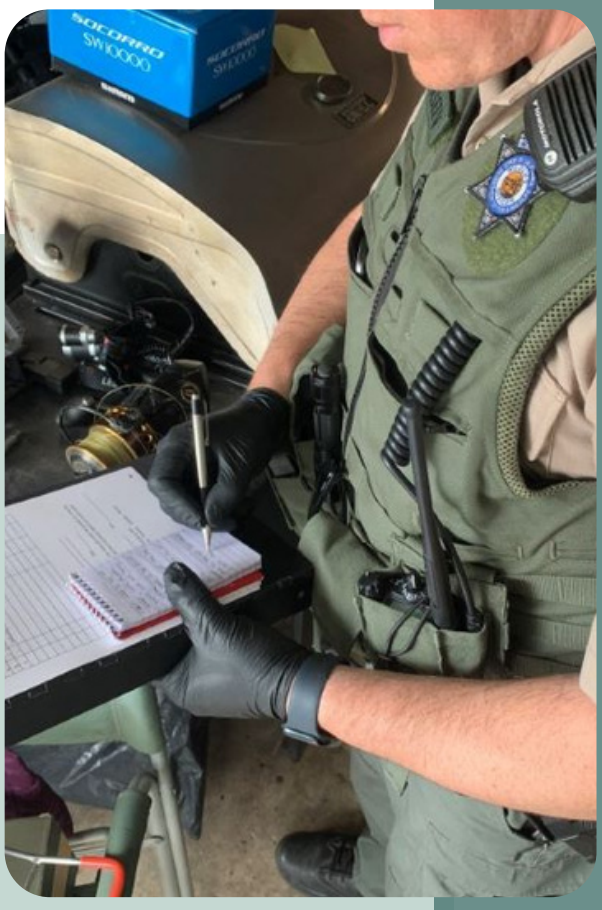
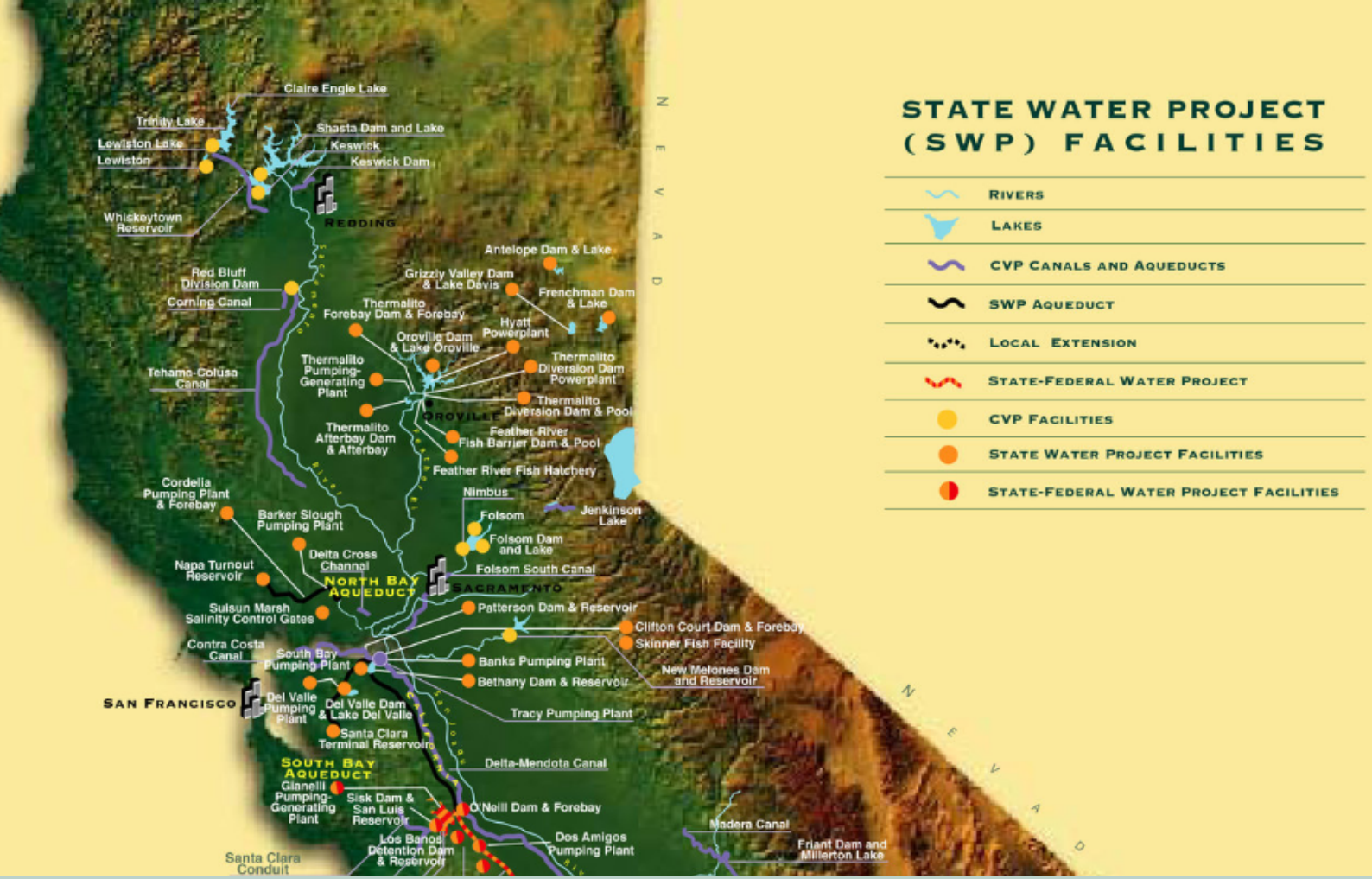


Photo: CDFW, Enforcement



ENTRAINMENT

[Figure: Map of the State Water System, which is a system of reservoirs, canals, and aqueducts that carries water across California. //Courtesy of the California Department of Water Resources]

The Bureau of Reclamation (Reclamation) defines fish entrainment as "fish being transported along with the flow of water and out of their normal river, lake or reservoir habitat into unnatural or harmful environments."[72]

The Sacramento-San Joaquin Delta is a heavily altered system that has caused entrainment and mortalities for many other migrating and native species. The Reclamation has established a research Division that develops projects for protecting and mitigating fish passage and entrainment. Unfortunately, sturgeon are not one of the top focused species in these efforts.

Sturgeon are susceptible to water diversion structures, have been killed, and become salvage in pumping operations throughout the San Francisco Estuary and Sacramento-San Joaquin Delta. It is understandable that sturgeon are a difficult species to construct a fish passage for due to their large size and benthic behavior. However, many of these dams and water project facilities have cut sturgeon off from a large portion of their native spawning grounds and have caused flow and discharge related changes to the spawning habitats that are accessible (see Section 4 for more information). For instance, Green Sturgeon spawning activity has been recorded in the Sacramento River near Glenn-Colusa Irrigation District (GCID) and are subject to altered flow and temperature caused by the pumping facility.[73]

Sturgeon, at any life stage, are susceptible to entrainment. Since 2011, the State Water Project has recorded 4 Green Sturgeon and 94 White Sturgeon as salvage from their facilities, and the Central Valley Project has recorded 12 Green Sturgeon and 540 White Sturgeon as salvage from their facilities (per CDFW Fish Facilities and Larval Entrainment Unit, Bay Delta Region 3). Juveniles and larvae are also at a high risk of being entrained, but there is no hard data, as these life stages can get picked up by the water projects and pushed into the agriculture fields without being detected.

STRANDINGS

Fish strandings are another consequence of California's hydrologic engineering projects. The floodplains surrounding the Lower Sacramento River have been altered to protect the communities that reside there, and while they have done an adequate job of providing protection from flooding events; it has left some migratory fish, such as sturgeon, stranded after high flow events. For example, in 2011 alone, 24 Green sturgeon, along with 32 White Sturgeon, were rescued from a stranding in two flooded areas near the Tisdale and Fremont Weirs (Yolo Bypass region) along the lower Sacramento River.[73]

Historically, adult sturgeon are periodically lost in the Yolo Bypass and near the Tisdale Bypass.[74] CDFW has occasionally supported rescues since the 1950s, as these fish can die or be taken by poachers. In 2019, there was a large over-topping (the "Tully Event"), and 6-7 sturgeon carcasses were found. The Tisdale Weir is being modified to help prevent such strandings in the future, and the "Big Notch" project to modify diversion structures on the Sacramento River leading into the Yolo Bypass is also nearing completion. The hope is that these modifications can minimize the effects of strandings after flood events and result in fewer strandings.

There have been multiple informal and more coordinated CDFW-organized sturgeon rescues at the Fremont Weir.[73] In one such incident in 2006, 26 unidentified sturgeon were rescued from Fremont Wier. The Wallace Weir has also been implicated in White Sturgeon strandings, as well as reports of stranding events on the Bear River associated with local agriculture diversions and water management.[33]

Regarding potential impacts of these and other stranding events on sturgeon communities Thomas et al. (2013) stated that, "Model projections over 50 years indicated that chronic stranding in flood control structures could have biologically significant impacts on the viability of the Sacramento River Green Sturgeon population" and that "monitoring and rescue operations could reduce the impact of strandings on the population viability."[73]

DISEASE & BACTERIAL INFECTION

Sturgeon are susceptible to bacterial and parasitic diseases, but none of these sources of mortality have been found to be widespread in the Sacramento-San Joaquin System.[75] [76] Since sturgeon are being commercially farmed for meat and caviar production using intensive aquaculture techniques, viral outbreaks are of concern on these farms.[77] White Sturgeon are susceptible to White Sturgeon iridovirus (WSIV), British Columbia White Sturgeon virus (BCWSV), acipenserid herpesvirus 1(AciHV-1), acipenserid herpesvirus 2(AciHV-2), White Sturgeon adenovirus 1 (WSAdV-1), infectious hematopoietic necrosis virus (IHNV), and Papova-like virus.[77] Green Sturgeon have not been found to be affected by any of the viruses reported, but this may be because they are not farmed as readily as White and other species of sturgeon.

CONTAMINANTS

Polychlorinated biphenyls (PCBs), mercury, chlorinated pesticides, selenium, polycyclic aromatic hydrocarbons (PAHs), polybrominated biphenyl ethers (PBDEs), and dioxins are some of the contaminants that are prevalent in the San Francisco Estuary, as are several metals and metalloids.[78] [79] Each of these chemicals have been shown to contribute to the decline of fish populations through impairment and direct mortality, and some have been shown to affect liver and gonad function in White Sturgeon.[80] [81] In particular, selenium is considered to cause larval defects; negative health effects of selenium have been documented as passing from mother to offspring during reproduction.[82] [83] [84] These contaminants add another challenge for the recovery and sustainability of the sturgeon populations in the San Francisco Estuary and Sacramento-San Joaquin Delta. Selenium uptake via ingestion of the invasive clam (Potamocorbula amurensis) has been documented in Sacramento splittail,[85] [86] another benthic feeder common to the San Francisco Estuary.

HARMFUL ALGAL BLOOMS

From late August to early September 2022 the San Francisco Estuary experienced a red tide algal bloom (specifically caused mainly by the species Heterosigma akashiwo). This algal bloom produced dangerous toxins and drastically reduced the levels of oxygen available in the water causing a massive fish die off. White Sturgeon were greatly affected, because their benthic lifestyle left them highly vulnerable to suffering from hypoxia. As of February 2023, the total sturgeon carcass count was 864; however, only 195 White Sturgeon and 17 Green Sturgeon were confirmed, leaving 652 unidentified sturgeon (Stompe, D., CDFW, personal communication). While this was the largest recorded fish die off in the Estuary, it was not the only regional fish mortality event occurring that summer. Idaho, Canada, and Europe also experienced sturgeon mortality events due to what could be anthropogenically-caused effects.[87] Unfortunately, these may not be isolated or unusual events in the future. H. akashiwo produces durable cysts, which can stay dormant in the environment and bloom during future periods of favorable conditions. Because the 2022 harmful algal event was so large (having a regional impact in the Estuary) there is speculation that there are abundant cysts throughout the system that may produce additional future blooms.

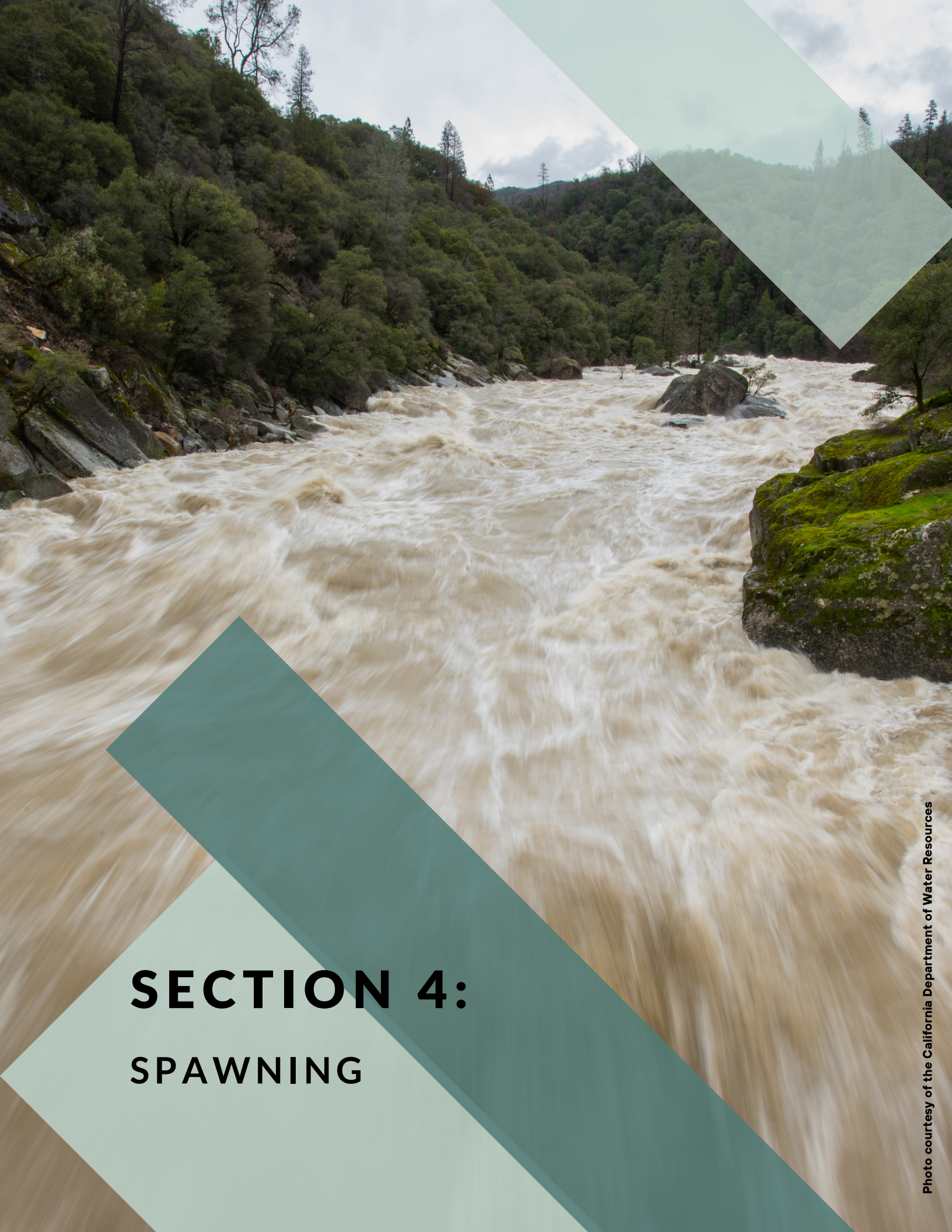
SIDE NOTE: See Part Two, Section One and Two for more information of the Sturgeon Carcass Survey and the HAB Carcass Count specifically.

Research and modeling needs have been outlined in response to the recent bloom (DSC Report Draft) and observational HAB-related effects on the White Sturgeon population (which remain largely unquantified). However, considerable change to management of the fishery and monitoring will be required to understand the full extent of environmental impacts to sturgeon populations.

Overall, mortality rates are difficult to document because sturgeon sink to the bottom of rivers and bays when they die, and we often can't know the cause of individual or mass mortalities.

QUESTIONS

1.What is the age of natural mortality?
2.Are there other sources of mortality that are not listed above?
3.Due to the HAB event that occurred there are cysts of H. akashiwo present in the system now. What does this mean for the sturgeon population in future years? Are we to expect another mass mortality event for sturgeon?
4.What can be done about the contaminants that are affecting recruitment levels?
5.Children, women of child-bearing age, and pre-menopausal women are cautioned against eating White Sturgeon from the San Francisco Estuary.[88] [89] How safe is it for anyone (not just these groups mentioned above) to be consuming sturgeon with these toxins present in their system?
6.Are sturgeon suffering from any diseases in the wild?
7.How can we protect green sturgeon from bycatch in fisheries, such as the California Halibut fishery?
8.Just as we saw a large sturgeon mortality event in the San Francisco Estuary in 2022, Washington state experienced sturgeon mortality event in the early 2000s. The cause is still not fully understood, but how can we prepare for future sturgeon mortality events? What is the likelihood that these events will occur again?
9.What threats are sturgeon being exposed to in the ocean and how can management reduce bycatch in fisheries, and the exposure to low dissolved oxygen, naval exercises, and wind farms?



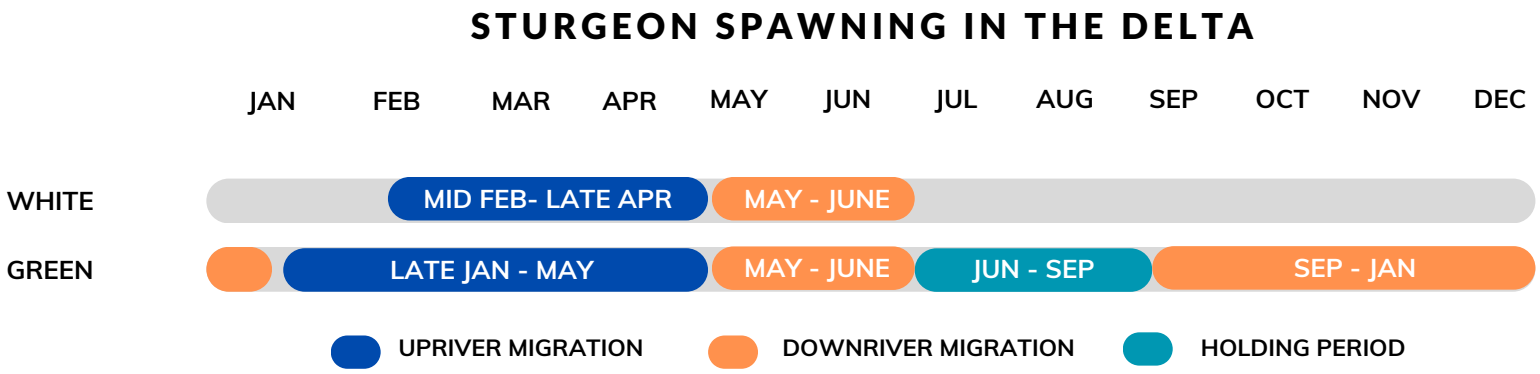
SECTION 4:

SPAWNING

Photo courtesy of the California Department of Water Resources

Although sturgeon are late maturing, female sturgeon show high fecundity. Males mature earlier and spawn more frequently than females, but individuals of both sexes do not necessarily spawn every year. Sturgeon are suspected to be broadcast spawners in deep holes and fast-moving water (as observed in Lake Sturgeon[90], and through sonar in the Sacramento River).

Some refer to sturgeon as "periodic" reproductive strategists, because spawning has been observed to be influenced by wet years, temperature (generally between 8-20°C[12]), and streamflow. [91] [4] [5] [92] [93] Researchers tend to see a rise in population numbers in the system during and after a wet year. Cobble or gravel are optimal substrates for eggs to adhere to, as well as providing protective areas for newly hatched sturgeon.[5] Sand or clay substrates are considered sub-optimal, because eggs cannot adhere to sand and float to the surface where they may get eaten[94], get suffocated by the sand[95][96], or do not get fertilized. Rivers with fast flowing waters promote gas exchange for the eggs and embryos[97][98], and can push larvae into optimal rearing habitats downstream.



Graph 1: White and Green Sturgeon annual spawning movements in the California Delta.

It is common to see sturgeon year-round in the San Francisco Estuary and Sacramento-San Joaquin Delta, but individuals don't stay year-round. Instead, White Sturgeon make spawning migrations into the rivers, but forage in the Bay and Delta, and while we cannot tell how often they use the ocean habitat they do travel into marine waters, but ocean migrations are not a part of their life history like it is for Green Sturgeon. Green Sturgeon are more anadromous moving between spawning in rivers, and foraging for food or making ocean migrations. Both Green and White Sturgeon display intraspecific variation among spawning years .[4] [5] [99]

WHITE STURGEON

Map of White Sturgeon historical distribution in North America// sourced from Hildebrand et al., 2016.

MATURE MALES

9-25 YEARS OLD

SPAWN EVERY 1-3 YRS

1.1-1.8M LONG

MATURE FEMALES

14-30 YEARS OLD

SPAWN EVERY 2-11 YRS

1.4-2.0M LONG

FECUNDITY: 64,000-469,000 EGGS

MIGRATION—In the Sacramento-San Joaquin system, some adults have been found moving into the Delta throughout the fall and winter, and then begin their upriver migration as early as late February.[100][101] Downriver migrations occur from late May to June depending on temperature and flow conditions to trigger their migrations, but White Sturgeon spawn earlier and migrate downriver faster than Green Sturgeon.

SPAWNING ACTIVITY—Spawning behavior has never been observed in the wild in the Sacramento-San Joaquin system. It is rarely observed at all because spawning is thought to occur in deep, turbid waters.[12] However, egg mat studies have recorded spawning events occurring from mid-February to late May. Females are thought to spawn every 2-11 years, while males spawn every 1-3 years.[12]

HISTORICAL SPAWNING LOCATION—White Sturgeon range from Ensenada, Mexico north to the Gulf of Alaska. Spawning habitats have been found in the Sacramento-San Joaquin, Fraser, and Columbia River Basins. There is no data available detailing the amount of habitat lost to White Sturgeon in the Sacramento-San Joaquin River system, and there is limited information on spawning sights prior to the 1960s. White Sturgeon migrated into the Shasta River, and spawned in the Pit River until they were blocked by Shasta dam. There is a remnant population present in Shasta Lake, and they are still sought by anglers (S. Baumgartner, CDFG). [102] The Keswick, Oroville, Folsom, and Friant Dams have all affected other reaches of sturgeon habitat via exclusion or streambed alteration.

CURRENT SPAWNING LOCATION—Much of the White Sturgeon spawning locations and movements are still unknown in the Sacramento-San Joaquin River system. Reports from the 1970s found that most of the sturgeon spawning sites were limited to the Sacramento River between Colusa to Verona.[103] Larvae were also captured between Collinsville and Suisun Bay, Rio Vista, and in Cache Slough.[104] "It is anecdotal, but [sturgeon] have been found spawning in the Feather and Bear Rivers (especially in wet years), possibly in the Yuba and Tuolumne; however, no eggs or early-stage larva have been found" (J. Kelly, CDFW, personal communication). White Sturgeon have been sighted as far up as Cow Creek on the Sacramento River, which leads researchers to believe that there is a strong possibility of spawning at that location.

Recovered and receiver-detected tags have documented sturgeon mainly in the Sacramento River as opposed to the San Joaquin. It is strongly suspected that sturgeon spawned on the San Joaquin in larger numbers before major water diversions lessened water flow. The same can be said for the Feather River, as it potentially supported a larger spawning population before construction of the Orville Dam. Jackson et al. (2016) is the only paper in the last decade that has published an update on White Sturgeon spawning. The paper reports finding eggs in all four sampling locations along the San Joaquin River, even though samples included drastically different water-year types.[93] They also found that spawning occurred on the river during a dry year, which was thought to be rare.

Marc Beccio (CDFW) is currently updating records on Sacramento River spawning, but it has been difficult to find suitable areas where egg mats can be set. "Studies by CDFW in the 1970s suggested White Sturgeon spawning areas that currently do not have optimal substrate. Is there gravelly substrate under the sand and mud? Or do these areas have optimal conditions in wet years? Right now, we do not have the answers" (A. Schreier, UC Davis, personal communication). In addition to the lack of spawning data, A. Seesholtz reports, "White Sturgeon are tough to locate due to their earlier spawning and migration patterns. Their movements do not align well with the monitoring efforts scheduled" (A. Seesholtz, DWR, personal communication).

White Sturgeon are hypothesized to live over 100 years and have lived in an ecosystem that is constantly changing. From contemporary movements we can speculate that they do not tend to spawn or visit the same location every time they migrate into the river. Flow, temperature, and substrate composition are environmental factors that influence sturgeon movements; however, they are not the sole variables useful for predicting spawning behavior.

Left Photo: White sturgeon hatch. (Credit: Joseph Warren, USGS, Western Fisheries Research Center. Public domain.)

Right Photo: Early life stage white sturgeon swimming in a laboratory tank. (Credit: Doug Hardesty, USGS. Public domain.)

NOAA FISHERIES
West Coast Region

GREEN STURGEON

MATURE MALES

13-18 YEARS OLD

SPAWN EVERY 1-3 YRS

MATURE FEMALES

16-27 YEARS OLD)

SPAWN EVERY 2-4 YRS

FECUNDITY: 59,000 TO 242,000 EGGS.
FECUNDITY IS LOWER BECAUSE OF A SMALLER BODY SIZE AND LARGER EGG SIZE.

FIG.: MAP OF GREEN STURGEON DISTRIBUTION IN NORTH AMERICA// SOURCED FROM NOAA FISHERIES, WEST COAST REGIONAL BRANCH

MIGRATION—Green Sturgeon have been observed entering the San Francisco Bay Delta system in late January to May and migrating out of the system—depending on flow—from May to June and September to January.[20] (In the Klamath and Rogue River systems, green sturgeon upstream and downstream migration timing may differ.[105])
Green Sturgeon display a bimodal outflow migration when exiting the river to swim back to the sea. This means that some spawning adults exit the river from May to June, while other individuals remain in the river until they are triggered to leave from September to January. This behavior is heavily correlated with flow and discharge.[99]

SPAWNING—Female Green Sturgeon tend to spawn every 2-4 years, while males spawn potentially every 1-3 years.[106][64][20][5] Van Eenennaam et al. (2008) suspect that females hold their eggs in an "advanced stage of ovarian maturation" until the optimal conditions for spawning and males are present.[32][5][107][108] And even though individuals do not spawn annually, spawning occurs every year from April through June, and is influenced by flows and temperature.[109][21][34][110] Polytress et al. (2015) writes, "...we cannot make any definitive conclusions about the length of the spawning season, except that annual variability will occur, depending primarily on water flow, temperature, and timing of the spawning run."[34]

HISTORICAL SPAWNING LOCATION—Sturgeon would travel vast distances throughout the Delta before access to much of this habitat was lost due to dams and other hydraulic diversions. Mora et al. (2009) constructed a model that calculated the areas of Green Sturgeon habitat and found that "dams block access to about 9% of historically-available habitat in the Sacramento River Basin, but it is likely that these inaccessible areas contained prime spawning habitat."[111] In addition, these dams have forever altered the flow and composition of the spawning habitat that is currently available. Relevant tributaries that were large enough for Green Sturgeon to spawn or reside in were "the Feather, American, Yuba, San Joaquin, Stanislaus, Tuolumne, and Merced rivers, and other combinations of associated tributaries" (per Historical State Water Rights Decisions dating back to 1927).[33]

SPAWNING LOCATION—Today, Green Sturgeon are primarily found spawning in the Sacramento, Klamath, and Rogue Rivers. Within the Sacramento-San Joaquin River Basin they are primarily found spawning in the main stem of the Sacramento River. There is limited documentation of spawning within the San Joaquin River tributaries; however, in the Sacramento River tributaries, eggs have been found in the Feather[110] and Yuba Rivers.[112]

Evidence suggests Green Sturgeon spawn during dry years, but only in the main stem and not in the tributaries. For example, in dry years, eggs have only been found in the Sacramento River mainstem and none in the Feather and Yuba Rivers. During these dry years, there are periods of extremely low flow which impedes sturgeon from making it to the Feather River. Green Sturgeon researchers in other systems have observed this pattern as well.

KNOWLEDGE GAPS

Understanding recruitment processes is a vital component for estimating the abundance trend and trajectory of a species. This area of sturgeon research is essentially a “black box,” and gaining knowledge characterizing recruitment can lead to more precise estimates of survivorship of early life stages. Equally important is understanding spawning habitat, and while we know available spawning habitat has decreased, our general or specific knowledge of their spawning habits in the wild has greatly improved. Monitoring within the Sacramento-San Joaquin River system has not robustly described spawning behavior, environment, duration, location, or other fundamental questions. There is also uncertainty about whether sturgeon spawn every year or if they avoid spawning during dry years.

Sturgeon are known for being cryptic and are difficult to find and record (both in spawning and in movement). Researchers have gathered eggs from the field, but this data is gathered at high risk of losing materials. Egg mats get washed away, there are too few of them, eggs get eaten or are washed downstream. It is important to note the University of California, Davis’ sturgeon-related research is a vital resource in understanding sturgeon reproduction in the laboratory, but there are critical life history-related needs that must be studied in the wild under existing field conditions to properly inform our population estimates and support real-world management experience.

QUESTIONS

1.What is the male to female ratio?
2.What are the adults doing in the rivers during their migration?
3.What is keeping them in the rivers besides recovering from migrating and spawning? Is it a food source or something else?
4.Age at maturity for sturgeon is still unclear. Why is the range so large?
5.Do sturgeon spawn throughout their life once they have matured or do they cease reproducing at a certain age?
6.How greatly does sedimentation affect Green Sturgeon eggs or where they spawn? Does this keep them from spawning in locations or does it just hinder recruitment?
7.Where are White Sturgeon spawning in the Sacramento-San Joaquin system?
8.What is critical spawning habitat for White and Green Sturgeon?
9.Are they resorting to spawn in unsuitable habitat because that is where they have historically spawned?
10. Is spawning taking place in the water column? Some resources state that they need fast flowing water and deep pools and towards the bottom,[113] but do they spawn close to the floor or more pelagic?
11. Is temperature a factor in triggering spawning?
12. Does streamflow have any impact on sturgeon spawning and movement? Does it affect sturgeon in various systems differently?
13. Some tributaries where eggs have been found have low flow (e.g., the Feather and San Joaquin). Is flow a true indicator for spawning success?
14. Defining the riverine flow regime—How does velocity, flow rate, frequency, duration, seasonality, and rate of change in freshwater discharge over time affect sturgeon?
15. What is the sufficient flow rate to keep eggs from suffocating, keep sturgeon spawning, and maintain optimal temperatures?
16. How will flow and sediment discharge affect migrations?

SECTION 5:

AGE SPECIFIC INFORMATION

David Dominguez/USFWS Photo: Green Sturgeon

EGG

Sturgeon eggs are negatively buoyant, and develop an adhesive upon contact with water that allows them to adhere to the substrate where, most likely, spawning has occurred (or slightly downstream).[114] [115] Egg incubation time is temperature dependent, and optimal temperatures for hatching are from 14-16°C, but above 20°C hatching rates decrease, and at 23°C embryonic development ceases. [115] [21] White Sturgeon eggs are also susceptible to fungal infection, predation, suboptimal water quality, low river flows, contaminants, and sandy/grainy substrate.[95] [116] [117] [118]

WHITE

White Sturgeon eggs are dark grey in color and 2.5-4.0 mm.[115] Length at hatching varies with temperature.[119] At hatching White Sturgeon are less developed than Green Sturgeon, and range from 11.2-13.0 mm TL from temperatures of 11-20°C.[119]

Laboratory studies describe that fin development is not complete at hatch, and subsequent to hatch White Sturgeon embryos disperse with currents along the bottom of water column for around six days.[114] They then seek benthic cover until they are ready to begin exogenous feeding, which is associated with yolk depletion.[120] [121] Temperature and rearing conditions influence growth, and typically range between 13.5-16°C -- temperatures on the lower end of this range are associated with increased survival.[12][114] [122] By the end of the yolk-sac depletion, larval sturgeon can range from 16.4 to 25.1 mm.[115] [121]

Much of this early life stage data was recorded within laboratory settings; wild growth parameters are largely unknown.

GREEN

Green Sturgeon eggs are larger (4.2-4.5 mm) than any of the other sturgeon species, and females show lower relative fecundity. Green Sturgeon eggs are less adhesive than White Sturgeon eggs and it is hypothesized that water quality has a greater impact on the success of reproduction.[121][117][123] Once eggs are fertilized their adhesive becomes stronger and they sink to the substrate where they incubate until hatching.[108] Green Sturgeon eggs are more dense than White Sturgeon eggs, which means they do not drift as far downstream in similar currents. Embryos hatch about a week after spawning at 12.6-14.5 mm and begin their first feeding between 10 to 16 days post hatch. [34]

QUESTIONS

·What level of recruitment is being seen?
·Where are sturgeon eggs typically found (habitat qualities)?
·How do sturgeon eggs affect the Delta ecosystem? How influential are they as a food source?

LARVAL

WHITE

Because White Sturgeon hatchlings are able to feed exogenously, they are considered "young of year" (YOY) or age-0 (which is the time from hatch to one year of age) for classification purposes. YOY are predominantly active at night and disperse over the bottom of the river foraging for food.[124] Their rearing habitats tend to be further downstream, so feeding larvae make a second, longer, active migration.[114][102] [94] Hildebrand et al. (2016) noted that "within 20-45 days post-hatch (dph) the metamorphosis is complete and larvae develop into juveniles with a full complement of scutes and fins".[12][46] [121] Brannon et al. laboratory studies indicated that White Sturgeon YOY grow rapidly, slowing growth as they age.[45]

GREEN

Green Sturgeon larvae in the Sacramento River system have been found to range from 1.8 to 18.8 cm fork length (FL).[123][125] They use riverine areas while developing osmoregulation, and continue to forage and rear.[126] After Green Sturgeon larvae begin feeding exogenously, they nocturnally migrate downstream for about twelve days until they reach more durable rearing habitat.[114] Growth is strongly dependent on water temperature, but appears to be "normal" between 19 and 24°C.[127]

QUESTIONS

·What level of recruitment is occurring annually?
·Where are sturgeon larvae occurring?
·What habitats are preferred for rearing larvae and by YOY White Sturgeon?
·What behavior do sturgeon larvae exhibit in different habitats?
·How do sturgeon larvae affect the Delta ecosystem? How influential are they as a food source?
·Where do larvae go after they hatch? Do they stay in the river? Flow downstream?
·What food resources are available, and which do they prefer or feed on?
·Are larvae being pushed into an appropriate rearing area? If so, what is special about the habitats that they reside in?
·What predators' prey in sturgeon larvae? What is the level of predation pressure and what factors affect predation pressure?

JUVENILE

WHITE

White Sturgeon in the Sacramento River reach 43-45 cm TL in the first year of growth; after attaining 102 cm they slow to grow about 2-6 cm year,-1 [45] a rate that declines even further to around age 17.[30] Juvenile White Sturgeon distribution depends on the seasonal fluctuations of temperature, dissolved oxygen, and salinity.[128] Juvenile White Sturgeon have been commonly found aggregating into groups including various year classes and sizes.[91] [129]

GREEN

Juvenile Green Sturgeon normally range from 60-75 cm TL from 1-3 years and mostly spend these early years in freshwater habitats.[130] Juveniles begin to seek out more saline environments by the end of their first year and are more frequently found in the brackish San Francisco Bay-Delta.[131]

QUESTIONS

·Why are some year classes being represented over others? What factors affect year class survival? What is making others vulnerable?
·What is occurring during these bottleneck events (wet year high recruitment years, large mortality events) in sturgeon? What is causing that population to survive?
·How does sediment affect juvenile sturgeon? Especially during high wet and dry years?
·How are they affected by variation in habitats?
·What is special about the habitats that they reside in?
·There's no evidence of juvenile Green Sturgeon moving into the Delta—which might be another divergence between whites and Greens—juvenile green sturgeon are in the Sacramento River for about 6-9 months; where do they migrate to after that?
·What food resources are available and which do they prefer or feed on?
·Are they following a food resource? (i.e., Herring or shrimp)
·What predators prey on juvenile sturgeon? What is the level of predation pressure and what factors affect predation pressure?
·How do dams affect juvenile sturgeon (e.g., passage habitat features)? How do water diversions affect juvenile sturgeon? What is the mortality rate for early life stages from entrainment?

WHITE

ADULT

The onset of sexual maturation marks the shift from juvenile to adult sturgeon. However, the sex, age, and size when maturation begins are all variable between individuals. Males typically mature between 9-25 years old or around 75-105 cm FL, while females range from 14-30 years old and 95-135 cm FL.[37] Chapman et al. (1996) reported that females in the Sacramento-San Joaquin Bay-Delta mature at a larger size than males, which suggests a sex-specific difference in growth rate.[13] There is uncertainty if White Sturgeon continue to grow at the same rate as they age or if there is a biological change in growth rate at a particular time. DeVore et al. (1995) found that White Sturgeon in different systems reach sexual maturity at different rates. One study determined that White Sturgeon in the Sacramento-San Joaquin system reach sexual maturity at a younger age than other northern populations on the west coast.[132]

As they become adults, White Sturgeon salinity tolerance builds, and they are able to move between marine and fresh waters more fluidly. They spend most of their time in brackish and seawater estuarine habitats and are found to be more estuarine than Green Sturgeon.[133] [134] Seasonal salinity levels influence White Sturgeon movement: adults were seen moving closer to the Delta in low flow years when salinity was higher in the San Francisco Bay. The inverse was true in during high outflow years.[101]

Adult White Sturgeon forage in San Francisco, San Pablo, and Suisun and their movements appear to be influenced by tidal and diurnal cycles.[100] [133] They are most abundantly found on or near feeding grounds in brackish waters when they are not undergoing spawning in rivers.[102] They spawn between mid-February and late-May. Spawning frequency can differ between the sexes where males can spawn between 1-2 years, females were found to spawn every 2-11 years.[13] Historic accounts have reported White Sturgeon exceeding 100 years old [135] [132]; however, Blackburn et al. (2019) observe we have not recently observed a White Sturgeon over 80 years old. Lower maximum ages are observed in the Sacramento San Joaquin system due to "sampling bias and exploitation".[136] [137] [117] "We probably aren't letting them get that old anymore," J. Kelly, CDFW (personal communication).

Left Photo: California Department of Fish and Wildlife.

Right Photo: Oregon Department of Fish and Wildlife

GREEN

ADULT

Green Sturgeon subadults and adults are known to make long migrations and enter northern coastal estuaries (in Washington, Oregon, and British Columbia) to feed in the summer. Adults enter the San Francisco Bay Delta from late January to May and migrate up the Sacramento River to spawn and feed.[20]

When finished spawning Green Sturgeon head back seaward in patterns triggered by outflow. The first migration out of the river occurs between May and June, while other individuals wait until September to December to initiate a second period of seaward migration.[20] [138] [106] [99]

However, a large percent of the Green Sturgeon population exhibits an annual migration in late fall (and some in the spring) to hold northwest of Vancouver Island, British Columbia near the Brooks Peninsula.[64] The purpose for this universal migration is yet to be understood. Some researchers have found that the relatively shallow waters north of Vancouver Island are warmer in the winter and are protected from storm waves due to their protected location. Others speculate that the highly productive waters off Vancouver Island's west coast yield high numbers of herring and groundfish. Outram (1965) found Pacific herring overwinter in dense schools near the bottom of these areas where Green Sturgeon are congregating.[139]

Israel et al. (2009) and Schreier et al. (2016) both demonstrate that many sDPS Green Sturgeon hang out in the Columbia River Estuary during non-reproductive times, as well as in Willapa Bay, and to a lesser degree, Gray's Harbor.[102] [140] Green Sturgeon are not the only sturgeon to make coastal migrations. Migrations have been observed for Atlantic sturgeon (A. oxyrinchus)[141] and Gulf Sturgeon (A. oxyrinchus desotoi).[142] It should also be stated that not every tagged individual was found migrating to Vancouver Island, and not every individual migrated every year.

However, it should be noted that a large number of the population do make these rapid, frequent long-distance migrations, which cause them to be vulnerable to multiple stressors and risks of mortality. These vulnerabilities should be addressed by the coastal states and provinces, as well as practical management implications that will be addressed in the latter half of this report.

Left Photo: Adult green sturgeon in Klamath River, CA. (Credit: Thomas Dunklin)), NOAA

Right Photo: Dylan Stompe, CDFW holding a Green Sturgeon

QUESTIONS

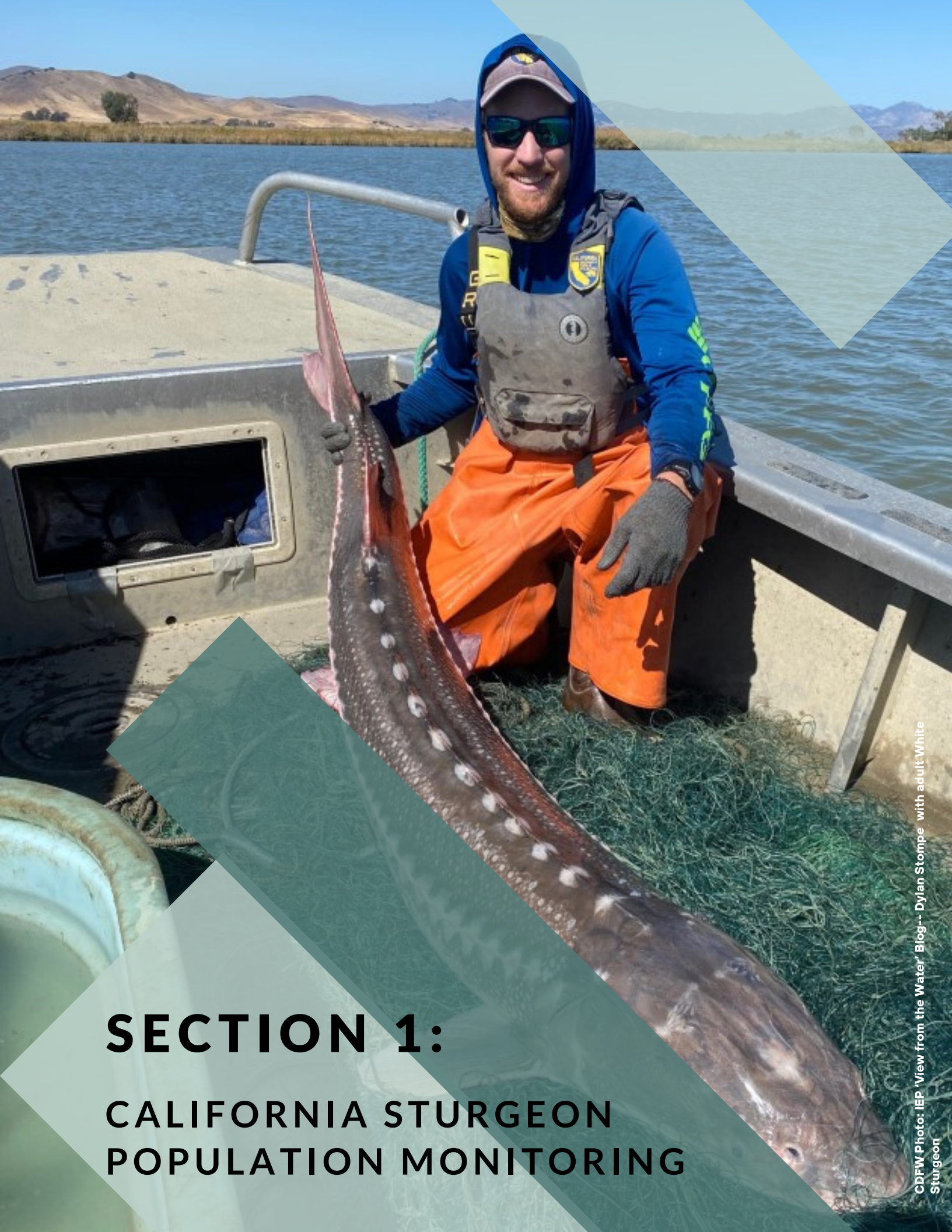
·How long can sturgeon live? What is their natural age of mortality?
·What age do they stop spawning?
·What are the key differences that alter the age of maturity in the wild versus the lab?
·Why is the range in age of maturity so large?
·What is the San Francisco Estuary and Sacramento-San Joaquin population size of Green and White Sturgeon?
·What harvest rate can the population sustain?
·How does sediment affect them? Especially during high wet and dry years?
·How many strong cohorts are there over the years?
·Certain systems know where their White Sturgeon are overwintering. Where are the White Sturgeon overwintering in the Sacramento-San Joaquin system?
·What percentage of the Green Sturgeon and White Sturgeon populations go into the Sacramento-San Joaquin system and how long do they stay?
·How are sturgeon affected by invasive species? How is their abundance affected?
·10 years is a small piece of this long-lived fish's life—how are they affected by these constant alterations to their habitat?
·How do we improve spawning and migrating habitat for them?
·What method is used for aging sturgeon with the most certainty?
·Why do Green Sturgeon make a northern (reverse migration) in the wintertime to non-natal estuaries? Is that for food resource? Better colder waters to get away from predators? Do they save energy? Does it trigger a physiological response? What is the big pay off? Why do some of them not migrate?
·MANAGEMENT QUESTION: What fisheries management measures have been established for Green Sturgeon within this migration route?
·How does low dissolved oxygen events in the coastal ocean affect them?
What is the ocean distribution on a finer scale?

PART TWO

DATA COLLECTION

SECTION 1: CALIFORNIA STURGEON POPULATION MONITORING
SECTION 2: DATASETS & DATA COLLECTION FORMS

The Sacramento-San Joaquin River System is a heavily impacted River Basin that is managed, to a certain degree, to benefit juvenile salmonids.[96] The management of flow and temperature for salmonid support has been linked to both increases or decreases in sturgeon spawning success[143] [144] [145] [34] and can have long-term effects on threatened populations such as the sDPS Green Sturgeon and the declining White Sturgeon population. Below is a summary of the monitoring surveys and projects that are currently focused on California White and Green Sturgeon.



CDFW Photo: IEP 'View from the Water' Blog-- Dylan Stompe with adult White Sturgeon

SECTION 1:

CALIFORNIA STURGEON POPULATION MONITORING

CA DEPARTMENT OF FISH AND WILDLIFE (CDFW)

YEAR-ROUND TAGGING AND MONITORING

of juvenile Green and White Sturgeon in the lower Sacramento River happens through capture and tagging at Sherman Island, but monitoring efforts exist throughout the San Francisco Bay Delta Estuary and across several surveys. The collected occurrence data is used to determine general movement throughout the San Francisco Bay Delta Estuary, juvenile outmigration, and to generate basic insight into habitat use in the Estuary.

EGG MATS

are placed in the Sacramento River upstream from Colusa to Tisdale in hopes of locating and documenting evidence of White Sturgeon spawning. This is a 5-year study that will likely continue.

THE 20MM SURVEY

samples 35 fixed stations (using oblique tows) from the Delta to Suisun Bay biweekly from March to July targeting pelagic larvae of all available species since 1995. Some White Sturgeon (10-33 mm TL) have been captured over time using this gear. Sturgeon are benthically-oriented fish so this survey is not useful for generating a robust recruitment index. However, the collected data can be leveraged to develop habitat suitability models based on water quality covariates for juvenile rearing sturgeon.

YUBA AND BEAR RIVER SPAWNING SURVEYS

target both Green and White Sturgeon eggs, larvae, and early-stage juveniles. This 5-year survey runs from mid-April through early September to determine temporal, spatial, and habitat parameters for spawning, and samples to estimate recruitment to the early juvenile life stage.

THE ADULT STURGEON POPULATION STUDY

ran from 1954-2022 before losing funding. It used trammel net gear to capture, tag, and release adult and juvenile sturgeon. It gathers catch per unit effort (CPUE) data.

SIDE NOTE: The trammel net survey is primarily used to generate absolute population estimates using Lincoln-Petersen and Lincoln harvest mark recapture models. It also provides metrics of year class strength through length frequency catch data.

THE STURGEON FISHING REPORT CARD

was formed in 2007 and cards have been available since March 1, 2007. Any angler fishing for sturgeon is required to have a Card. The intention is to aid in the protection of White Sturgeon while "adding resiliency to the conservation-dependent population, as well as increase protections for the federally threatened [sDPS] Green Sturgeon (Acipenser medirostris) population". [146] This regulation is a complementary piece to the additional CDFW research and monitoring of sturgeon, and card data is typically summarized in the spring and reported to the public in summer. Harvest data are taken from this survey and used for abundance measures along with the CPUE Adult Sturgeon Population Study data.

STURGEON RETAINED (Only white sturgeon 40-60 inches in fork length may be retained.)				
MONTH	DAY	LOCATION CODE	LENGTH	REWARD DISK # (if present)
4	8	18	55	

STURGEON RELEASED- NO REWARD DISK PRESENT				
MONTH	DAY	LOCATION CODE	WHITE	GREEN
4	7	03	X *or* 41	

STURGEON RELEASED- REWARD DISK PRESENT			
MONTH	DAY	LOCATION CODE	REWARD DISK NUMBER
4	7	03	HH3356

☐ CHECK HERE IF YOU DID NOT FISH FOR STURGEON

Photo: Sturgeon Fishing report Card, CDFW

Photo: Sturgeon getting tagged, CDFW

Photo: Tagged Sturgeon, CDFW

UNITED STATES FISH AND WILDLIFE SERVICE (US FWS)

01 SAN JOAQUIN RIVER WHITE STURGEON TAGGING

For White Sturgeon in the lower San Joaquin River (upstream of Grayson, CA) FWS is using acoustic tags to track subadults and adults to detail migration and passage behavior. This study is facing personnel and funding constraints.

02 SACRAMENTO RIVER GREEN STURGEON SAMPLING

The Fish and Wildlife Service samples seasonally for Green Sturgeon eggs from March to July, May to August for larvae, and October to December for juveniles in the Sacramento River between HWY 32 and Anderson Cottonwood Irrigation District (ACID).

USFWS COLLABORATIVE PROJECTS WITH US ARMY CORPS OF ENGINEERS (USACE)

03 JUVENILE GREEN STURGEON HABITAT USE AND TRANSITION TRIGGERS

A collaborative 4-year project with the US Army Corps of Engineers (USACE) to model juvenile Green Sturgeon habitat use and transition triggers to downstream habitats. This study is being run in the Sacramento River within putative spawning grounds from September through December or March depending on the water year-type.

04 GREEN STURGEON HABITAT MITIGATION AND MONITORING PLAN

Green Sturgeon Habitat Mitigation and Monitoring Plan is a 5-part study that is constructed from previous work, is being performed by the USACE, and is waiting for future approval. There are three current projects that are taking place on the Sacramento River. The first is the juvenile migration and benthic sampling, which is running from the previous work on juvenile migration in the Sacramento River above and below the Colusa area from 2016-2020. The second study is in the middle reaches of the Sacramento River and is adult tagging that is using acoustic telemetry to collect adult migration data. This study will document how long adults passing through the lower Sacramento River take to transit and when. A similar study awaits approval to monitor juvenile Green Sturgeon in the lower Sacramento River, which is part 4. The third current project is CESU/UC Davis studies for both juvenile and adults for swimming passage and screen criteria experiments and substrate preferences. And finally, the fifth part, and a future project is determining habitat preferences in the lower Sacramento River and Interior Delta for future restoration efforts.

See the next section (Datasets & Data Collection Forms) for relevant publications and reports.

CA DEPARTMENT OF WATER RESOURCES (CDWR)

GREEN STURGEON ARE SPAWNING IN THE FEATHER RIVER

Long-term study to determine if Green Sturgeon are spawning in the Feather River, identifying spatial and temporal distribution, habitat preferences, and egg viability. This project is an ongoing 22-year project, where sampling is conducted twice a week from April to December. See the next section (Datasets & Data Collection Forms) for relevant publications and reports.

A SECOND STUDY FOCUSED ON THE LOWER FEATHER RIVER, WITH THE PRIMARY OBJECTIVES AS FOLLOWS:

· Determine if there are adult migration barriers.
· Evaluate the effect of Oroville facilities operations on passage success and distribution.
· Evaluate migration patterns including residence times and factors affecting them.
· Identify distribution and habitat preferences.
· Estimate the annual abundance of adult Green Sturgeon.
· Identify potential spawning grounds that can be target areas for egg and larval surveys.
· Determine sturgeon spawning frequency in the LFR.

TO ADDRESS THESE OBJECTIVES PACIFIC STATES MARINE FISHERIES COMMISSION (PSMFC) IS CONTRACTED BY DWR TO PERFORM ALL LONG-TERM ANNUAL MONITORING OF STURGEON WITHIN THE LFR. MONITORING PROJECTS CONSIST OF THE FOLLOWING:

a) Bi-weekly (Jan-Dec) ARIS™/DIDSON™/Video surveys to document passage success, distribution, estimate population size and identify congregations of spawning adults.

b) Spawning surveys (Apr-Aug) using artificial substrates and d-nets to sample sturgeon eggs and larvae.

c) Adult sturgeon acoustic telemetry studies (Jan-Dec) that incorporate the capture, tagging and monitoring of adult sturgeon within the LFR using 69 kHz Vemco™ V16 acoustic tags and receivers.

NATIONAL MARINE FISHERIES SERVICE (NMFS)

01 GREEN STURGEON POPULATION DIDSON SONAR STUDY

NMFS is running a project using DIDSON sonar in the upper Sacramento River to estimate the Green Sturgeon population size of spawning adults and identify spawning habitats.

02 GREEN STURGEON BYCATCH STUDY

NMFS is collaborating with the CDFW and UCSC to evaluate the effects of bycatch and ways to reduce bycatch of sub-adult to adult Green Sturgeon in the CA Halibut Bottom Trawl fishery.

Satellite tag attached to the tail of a Green Sturgeon, illustrating the sharp, bony scutes. NOAA photo.

Green sturgeon ready for release after tagging, Photo courtesy of CDFW

UNIVERSITY OF CALIFORNIA, DAVIS (UCD)

01 Dr. Anna Steel, Dr. Nann Fangue, and Dr. Kelly Hannan are running a study to identify key swimming criteria for safe and timely passage of juvenile sturgeon. They are working with juvenile Green Sturgeon at the UC Davis campus to measure their endurance swimming capacity and physiological response to exercise stress.

02 Dennis Cocherell, Dr. Anna Steel, and Dr. Nann Fangue are researching methods to improve passage and determine impacts of diversion and flood control structures to Green Sturgeon. The study is run with juvenile to adult Green and White Sturgeon and sampling years are from 2022 to 2025.

03 USACE, Robert Chase, is collaborating with UC Davis to research juvenile to adult Green Sturgeon habitat mitigation and for a monitoring plan. The goal is to construct a conceptual spatial model of sediment size distribution for the Sacramento River, and identify potential juvenile rearing habitat that has low velocity and fine substrate.

04 Dr. Anna Steel, Dr. Nann Fangue, and Dr. Richard Connon are researching the effects of exposure to pesticides on ecological performance of early life stage green and white sturgeon.

05 Dr. Andrea Schreier, PhD student Aviva Fiske, and PhD student Peter Johnson are using a tetrasomic SNP panel to infer spawner number in a wild white sturgeon population (Snake River; Fiske) and a repatriation-based conservation aquaculture program (Upper Columbia River; Johnson). They are sampling juvenile white sturgeon from Hells Canyon reach of Snake River (Idaho), samples collected from Upper Columbia River conservation aquaculture program (British Columbia).

06 Dr. Andrea Schreier and PhD student Aviva Fiske are validating a parentage-based tagging program for the endangered Kootenai River white sturgeon population using the tetrasomic SNP panel.

07 Dr. Andrea Schreier, Dr. Nann Fangue, and Dr. Daphne Gille (CDWR) are using whole genome sequencing to develop a genetic sex marker for Green Sturgeon.

PRIVATE/MULTI-AGENCY STUDIES

STURGEON CARCASS SURVEY

The Sturgeon Carcass Survey is a stand-alone, multi-agency survey that began in January 2020. It is a volunteer run effort and is not consistent throughout the year. Within the Sturgeon Carcass Survey is the HAB Carcass Dataset, a (working) dataset for the sturgeon carcass count from the HAB event last year.

ERIN LUNDA

SIDE NOTE: the literature review and meta-analysis is in the process of being published.

Erin Lunda is a graduate student at Oregon State University who complied a literature review and meta-analysis of Green and White Sturgeon. The goal of this research was to 1) quantify habitat utilization for larval, juvenile, subadult, and adult life stages; 2) evaluate the effects of habitat conditions on survival, growth, and movement of green sturgeon; (3) characterize the effects of environmental variability and individual biological characteristics on sturgeon recruitment success, and (4) working with the SIT, incorporate data into DSM and evaluate tradeoffs in restoration strategies for green sturgeon to determine optimal actions under uncertainty. All of these goals were based on the Central Valley Project Improvement Act (CVPIA) Informational Needs that is further outlined in this report in Part Three, Section Two.

FIN RAY GEOCHEMISTRY

Kristen Sellheim (Cramer Fish Sciences) and Levi Lewis (UC Davis) reconstructed Green and White Sturgeon life histories and environmental exposure using fin ray geochemistry. Samples were taken for 3 to 5 years within the Delta and Suisun Bay-San Joaquin River from primarily White and Green adults. From this study, growth in year 1 can be back-calculated from fin ray growth patterns to analyze migrations, salinity preferences, and prey consumption non-lethally.

SECTION 2:

DATASETS & DATA COLLECTION FORMS

Photo: Night green sturgeon survey 2017-12-07, USFWS

OVERVIEW

The following Section is a breakdown of the monitoring surveys that have been previously mentioned in this report. The purpose of this Section is to list the data that are collected and discuss any potential parameters that might be added.

In addition, some of the datasets listed are marked with "No Dataset/Collection Form Received" which indicates no response to inquiries for dataset sharing were made.

CDFW Photo: CDFW measuring the length of a White Sturgeon

CA DEPARTMENT OF FISH AND WILDLIFE (CDFW)

TAGGING AND MONITORING JUVENILE STURGEON IN THE LOWER SACRAMENTO RIVER AND THE SFBDE SURVEY DATA: [DATA COLLECTION FORM RECEIVED]

Capture and tagging occurs year-round in the Lower Sacramento River at Sherman Island, and monitoring occurs throughout the San Francisco Bay Delta Estuary. This survey has been conducted from 2015 through 2023 using 2 data collection forms.

GILL NET FORM DATA RECORDED

i. Date
ii. General Location
iii. Crew
iv. Weather
v. Wind
vi. Latitude
vii. Longitude
viii. Water Temperature
ix. Depth
x. Dissolved Oxygen (mg/L)
xi. Dissolved Oxygen (% Saturation)
xii. Specific Conductivity (µS/cm)
xiii. Other
xiv. Net (A/B)
xv. Set Depth (ft.)
xvi. Time Set
xvii. Time Out
xviii. Total Minutes
xix. Species
xx. Number (2x)
xxi. Species (2x)
xxii. Comments

JUVENILE STURGEON TAGGING FORM DATA RECORDED

i. Date
ii. General Location
iii. Latitude & Longitude
iv. Capture Method
v. Capture Time
vi. Species
vii. Study ID
viii. Habitat Description & Depth
ix. Water Temperature at sampling site
x. Fork Length & Total Length (cm)
xi. Weight (g)
xii. Genetic Sample Taken/Location (fin)
xiii. Label in genetic sample vial
xiv. Tag Type
xv. Tag Serial #
xvi. Tag ID
xvii. Surgeon & Recorder
xviii. Scalpel Size
xix. Suture Size & Number of Sutures
xx. Surgery Start & Stop Time
xxi. Surgery Time (total min)
xxii. Release Location
xxiii. Release Time
xxiv. Total Handling Time (min)
xxv. Comments

WHITE STURGEON EGG MAT SURVEYS : [DATA COLLECTION FORM RECEIVED]

includes the Middle Sacramento River Spawning Survey from upstream Colusa to Tisdale Marsh where egg sampling has occurred from 2017-2023 and could possibly extend longer.

DATA RECORDED

i. Site Code
ii. Mat #
iii. Date Deployed
iv. Time
v. Waypoint
vi. Depth (ft)
vii. Water Temperature
viii. Date Retrieved
ix. Time
x. Water Temperature
xi. 3 of Sturgeon Eggs
xii. Comments

20MM SURVEY: [DATASET LINKED HERE]

monitors and provides information on delta smelt abundance and distribution in the upper San Francisco Estuary. Surveyors conduct larval fish surveys to determine the timing, distribution, and abundance of delta smelt larvae and their food supply. This data helps estimate larval delta smelt fish losses and determine the magnitude of entrainment of both larval and juvenile delta smelt at the Central Valley Project (CVP) and the State Water Project (SWP) intakes. This data could potentially estimate juvenile rearing and adult spawning habitat availability for Sturgeon.

BACKGROUND: Sampling began in 1995 and begins in early spring (March/April) and is conducted every other week and continues through mid-summer (July/August) when catch efficiency decreases or Delta Smelt are not in danger of being entrained at the CVP and SWP.

CDFW Photo: 20mm net being prepared

DATA RECORDED

i. Temperature
ii. Electro-conductivity
iii. Water Transparency
iv. Turbidity
v. Water Volume
vi. Tidal Stage
vii. Fish
viii. Zooplankton

YUBA AND BEAR RIVER SPAWNING SURVEYS

[DATA COLLECTION FORM RECEIVED; NO DATASET RECEIVED]

targets Green and White Sturgeon at eggs, larvae, and early-life stage juveniles. Sampling has been conducted from 2017-2023 from mid-April though early September.

EGG MAT DATA RECORDED

i. Site Code
ii. Mat #
iii. Date Deployed
iv. Time
v. Waypoint
vi. Depth (ft)
vii. Water Temperature
viii. Date Retrieved
ix. Time
x. Water Temperature
xi. 3 of Sturgeon Eggs
xii. Comments

ADULT STURGEON POPULATION STUDY

[DATASET NOW AVALIABLE AT: DATA PORTAL - DATA PACKAGE SUMMARY | ENVIRONMENTAL DATA INITIATIVE (EDI) (EDIREPOSITORY.ORG)]

sampling has occurred since 1954 until funding was cut at the end of 2022. Sampling occurred 4x per week from August to October for adults and juveniles. Predominantly White, with few Greens were caught and tagged from trammel net sampling for mark-recapture data. Tagging that primarily occurred at Suisun Bay (and some at San Pablo Bay).

BACKGROUND:
i. Catch Per Unit Effort (CPUE): calculated by how many fish were caught per hour for each 100 fathoms of net fished.

ii. Abundance estimates have been calculated through this dataset in combination with the Sturgeon Fishing Report Card data

1. Primary outputs (population abundance measures) are Harvest Rate and Abundance of legal sized fish (40-60 inches FL)
2. These calculations are what has been harvested in the past year

iii. Calculation methods for abundance estimates are currently being reviewed (time stamp June 5th, 2023). The goal is to revise the harvest rate calculations to better align with previously published data.
These calculations are what has been harvested in the past year, and from this data we can set future harvest rate targets, but that has not been done for this fishery.

STURGEON FISHING REPORT CARD DATASET

[DATASET REPORT ONLINE, ORGINIAL DATASET NOT RECEIVED DUE TO ANGLER PERSONAL INFORMATION]

Anglers are required to return their sturgeon cards by January 31st of the following year that they received them. From these cards, trends in sturgeon catch, harvest, and angler participation are documented. Anglers must report sturgeon catch, whether kept or released, while adhering to a bag limit of one White Sturgeon daily and three annually. If kept: "Anglers must record the day, month, and location for any sturgeon they catch and keep or catch and release, as well as length."

NOTE: From 2007-2017, CDFW produced single-year Card summary reports, available HERE entitled 'YYYY' Sturgeon Fishing Report Card: Preliminary Data Report. Updated annual summaries are found in this document, and CDFW will no longer produce single year summaries.

"Anglers continue to release more sturgeon than they keep, however this ratio is shifting over time. Since the onset of the card program, the proportion of total catch that is harvested has significantly increased while the proportion of catch that is released has decreased (Figure 3, $p < 0.001$). These results indicate that over time, anglers are harvesting more White Sturgeon relative to the total amount caught."

Trends that have been documented are into the following graphs are displayed as analyses of the retrieved Card data HERE: Annual Sturgeon Card Purchases, Kept vs. Released Sturgeon, White Sturgeon Catch, Catch by Harvest Level, and Catch by Month.

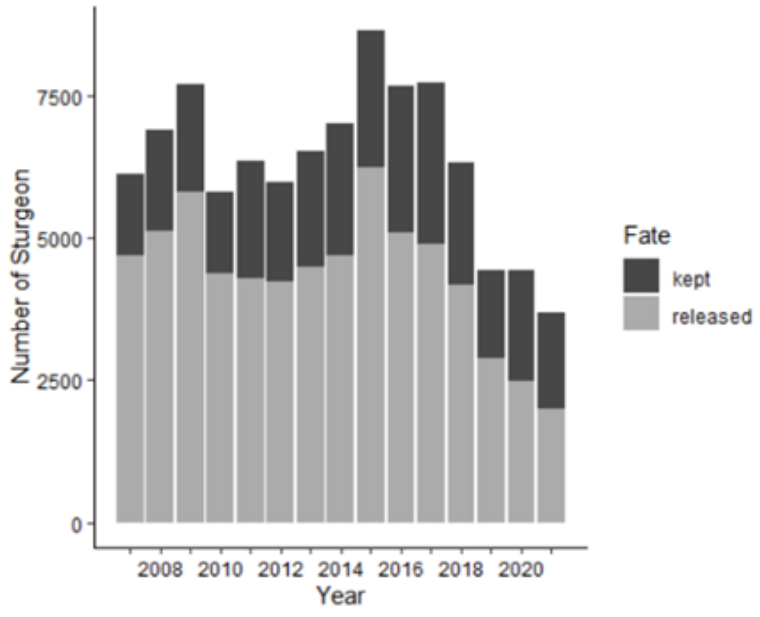


Figure 2. 2007-2021 Annual White Sturgeon catch (kept & released) from reported Card

Photo: Sturgeon Tagging, CDFW

DATA RECORDED

i. Year: calendar year for which Card was issued (or sold, post 2012)
ii. Issued: number of Cards issued (or sold)
iii. Total Returned: number of Cards returned
iv. No Effort: number of anglers reporting 'did not fish' (available from 2010)
v. No Catch: number of anglers reporting 'fished, but no catch'
vi. Catch: number of anglers reporting catching one or more sturgeon
vii. Return Rate: sum of the number of 'No Effort', 'No Catch', and 'Catch' divided by the number of cards 'Issued'
viii. Not Returned: number of Cards not returned
ix. CC: Control Center - Card mailed to CDFW and entered by CDFW staff
IS: Internet Submission - Card entered (reported) online by angler

US FISH AND WILDLIFE SERVICE (USFWS)

01 WHITE STURGEON ACOUSTIC TAGGING TO ASSESS MIGRATION AND FISH PASSAGE IN THE SAN JOAQUIN RIVER

[BLANK DATA COLLECTION FORMS RECIEVED]

tags and records telemetry movements of adult white sturgeon. Sampling occurs from the Lower San Joaquin River, just upstream of the Mossdale Boat Ramp to the town of Grayson. This data records how far they migrate upstream, where they are holding, and analyzes fish passage impediments. Documentation of passage through the Weir and if they are spawning past these passage areas or hitting a roadblock and turning around.

The following Datasheets are used:

- Sturgeon Adult Sampling Datasheet
- Sturgeon Tagging Datasheet
- VR2W Receiver Datasheet

BACKGROUND: The original project was initiated in 2012, but through funding shifts the project was stagnant, and then was halted for a time and picked back up in 2022. The San Joaquin Basin team is facing a time crunch on the V16 4f tags. They need to replace the ones that are about to go offline and implant new tags. Other data collection risks are entrainment, recreational harvest, and HAB events. However, if the project continues and gains additional funding the long-term goal for this data is expanding their sampling locations, begin to tag Green Sturgeon, and initiate a recruitment study.

Photo: San Joaquin Office, Brandon Honig/USFWS

NOTE: At the moment, retagging fish is the biggest priority so that there is a collection of data. Unfortunately, this year (2023) had unsafe working conditions on the rivers and so no tagging was done. CDFW conducts tributary monitoring, and they share data between the two agencies within the San Joaquin system.

STURGEON ADULT SAMPLING DATASHEET

i. Gear Type
ii. Net Length
iii. Net Height
iv. Mesh Size
v. GPS N
vi. GPS W
vii. Set Time
viii. Retrieve Time
ix. Start Temp
x. End Temp
xi. Start DO (mg/L)
xii. End DO (mg/L)
xiii. Habitat
xiv. Species (cm FL)

STURGEON TAGGING DATASHEET

i. Sampling Gear
ii. Net Set #
iii. Retriever Time
iv. Water Temp
v. GPS Location N
vi. GPS Location W
vii. Species
viii. Sex
ix. Length (cm)
x. Girth (cm)
xi. Sexually Mature (Y/N)
xii. PIT Tag Detected?
xiii. PIT Tag Inserted
xiv. AC Tag Detected?
xv. AC Serial #
xvi. VUE Tag ID
xvii. Surgery Start Time
xviii. Surgery End Time
xix. Total (minutes)
xx. Blade
xxi. Incision Length (cm)
xxii. Suture Size
xxiii. Suture Type
xxiv. # of Sutures
xxv. Tissue Sample # (XX-2_ _ _)
xxvi. Release Condition
xxvii. Surgeon
xxviii. Recorder
xxix. Comments

STURGEON TAGGING DATASHEET

i. Date
ii. Field Crew
iii. Recorder
iv. VR2W S/N
v. Receiver
vi. Site Name
vii. Folder (e.g., where was the file saved)
viii. Laptop/tablet used
ix. Actual Time
x. VR2W Start Time (previous)
xi. VR2W Stop Time
xii. VR2W Start Time (new)
xiii. Hardware Condition (g, f, p)
xiv. Cable Condition (g, f, p)
xv. VR2W Condition (g, f, p)
xvi. Last Battery Replacement/Volts
xvii. Comments

02 SACRAMENTO RIVER GREEN STURGEON SPAWNING GROUND AND LARVAL DRIFT, AND JUVENILE MIGRATION CHARACTERIZATION SURVEYS INVESTIGATION

use eggs mats, benthic D nets, fyke traps, screw traps, and benthic trawls. From March to July FWS looks for eggs, from May through August they target larvae, and from October through December juveniles are targeted. YOY are sampled and released, but eggs are collected. In 2012, larvae and juveniles are sampled for genetics, and 100 live fish were transferred for UC Davis's juvenile telemetry study. Juvenile fall migration was the focus from 2016-2019 and then habitat use from 2019 through 2023.

[DATASET NOT YET RETRIEVED]
[UNPUBLISHED TECHNICAL PAPER LINKED HERE]

Photo: Red Bluff Fish and Wildlife Office, Steve Martarano/USFWS

USFWS COLLABORATIVE PROJECTS WITH US ARMY CORPS OF ENGINEERS (USACE)

03 SACRAMENTO RIVER JUVENILE (AGE-0) GREEN STURGEON REARING AND HABITAT INVESTIGATION

is a benthic trawl with the goal of modeling green sturgeon use and transitional triggers to downstream habitats.

[DATASET NOT YET RETRIEVED]

Location(s): Upper Sacramento River (within putative spawning grounds)
Frequency: 5 nights per week
Years Sampled: 2019-2023; September-December or March (depending on the year)
Juvenile Green Sturgeon

04 GREEN STURGEON HABITAT MITIGATION AND MONITORING PLAN— JUVENILE MIGRATION AND BENTHIC SAMPLING

[PUBLICATIONS RECEIVED HERE][147]

monitors downstream migration juvenile movements focusing on the upper and middle Sacramento River. Benthic substrate sampling is taken from the lower and middle Sacramento River, and this is running from the previous work on juvenile migration in the Sacramento River above and below the Colusa area from 2016-2020.

05 GREEN STURGEON HABITAT MITIGATION AND MONITORING PLAN— SACRAMENTO RIVER ADULT TAGGING

[PUBLICATION RECEIVED HERE][148]

is being carried out in the Middle Sacramento River. This study is continuing the previous work that has been conducted since 2010 to collect migration data for adults passing through the lower Sacramento River.

CA DEPARTMENT OF WATER RESOURCES (CDWR)

01 LOWER FEATHER RIVER GREEN STURGEON SPAWNING SURVEY

[PUBLICATIONS RECEIVED; COLLECTION FORMS RECIEVED]

uses egg mats and Dual Identification Frequency Sonar (DIDSON) to identify potential spawning locations of Green Sturgeon. Collections are gathered twice a week from April through December and gather data on eggs, larvae, and YOY juveniles. This study is funded from 2010-2032.

This is a long-term study and has been published in Seesholtz et al. (2015).[110] And data is in the DWR's B132 Document,[149] the DWR's Division of Environmental Sciences 2011-2013 Lower Feather River Green Sturgeon Spawning Survey[150] and the 5-Year Review: Summary and Evaluation of the Southern Distinct Population Segment of the North American Green Sturgeon.[151]

Map of the Feather River Watershed

The Spawning Surveys from 2014-2019 are in the process of being completed, and the latest B132 Document was for 2019.

The following Datasheets are used:

- Sturgeon Adult Sampling Datasheet
- Sturgeon Tagging Datasheet
- VR2W Receiver Datasheet

ARIS™/DIDSON™/VIDEO SURVEYS

i. Date
ii. Location
iii. Start Time
iv. Stop Time
v. Elapsed Time (hr.min.sec)
vi. Max Beam Width/FOV (m)
vii. Flow (CFS)
viii. Temp (C)
ix. # Sturgeon Detections
x. Bycatch (Species/#)
xi. Staff
xii. Comments
xiii. Min Sturgeon Population Estimate #
xiv. File Name/Type

STURGEON EGG SAMPLING USING ARTIFICIAL SUBSTRATES (EGG MATS)

i. Location
ii. GPS N (dd)
iii. GPS W (dd)
iv. Set Time
v. Set Date
vi. Pull Time
vii. Pull Date
viii. Elapsed Time (hr.min.sec)
ix. Set Temp (C)
x. Pull Temp (C)
xi. Set DO (mg/L)
xii. Pull DO (mg/L)
xiii. Set Turb (NTU)
xiv. Pull Turb (NTU)
xv. Bycatch (Species/#)
xvi. Sturgeon Egg Size (XY) (mm)
xvii. Staff
xviii. Comments

LARVAL STURGEON SAMPLING (D-NETS)

i. Date
ii. Location
iii. GPS N (dd)
iv. GPS W (dd)
v. Set #
vi. Set Time
vii. Pull Time
viii. Elapsed Time (hr.min.sec)
ix. Set Velocity (m/s)
x. Pull Velocity (m/s)
xi. Flow (CFS)
xii. Total Volume Sampled (m^3)
xiii. Depth (m)
xiv. Set Temp (C)
xv. Pull Temp (C)
xvi. Set DO (mg/L)
xvii. Pull DO (mg/L)
xviii. Set Turb (NTU)
xix. Pull Turb (NTU)
xx. Sturgeon length (mm)
xxi. Sturgeon Species (GST or WST)
xxii. Bycatch (Species/#)
xxiii. Staff
xxiv. Comments

02 PASSAGE, ABUNDANCE, DISTRIBUTION, AND POTENTIAL SPAWNING OF ADULT GREEN STURGEON ON THE LOWER FEATHER RIVER SURVEY STUDY

[COLLECTION FORMS RECEIVED]

dataset aims to begin development and implementation of a monitoring and evaluation study that will estimate the annual abundance of adult green sturgeon in the Lower Feather River. Additionally, it will describe their distribution in time and space, and investigate the effect of Oroville Facilities operations on their passage success and distribution.

ADULT STURGEON ACOUSTIC TELEMETRY (ADULT TAGGING)

i. Date
ii. Location
iii. Capture Time
iv. Release Time
v. Species (GST or WST)
vi. Length (TL)(cm)
vii. Length (FL)(cm)
viii. Girth(G)(cm)
ix. Temp (C)
x. PIT #
xi. V16 Tag Code
xii. Staff
xiii. Comments

VEMCO™ 69KHZ ACOUSTIC RECEIVER ARRAY DOWNLOAD

i. Station Name
ii. Receiver Serial #
iii. Date
iv. Pull Time
v. Set Time
vi. Battery Volts
vii. Staff
viii. Comments
ix. File Name/Type

NATIONAL MARINE FISHERIES SERVICE (NMFS)

01 GREEN STURGEON FISH-GEAR INTERACTIONS IN THE CA HALIBUT BOTTOM TRAWL FISHERY

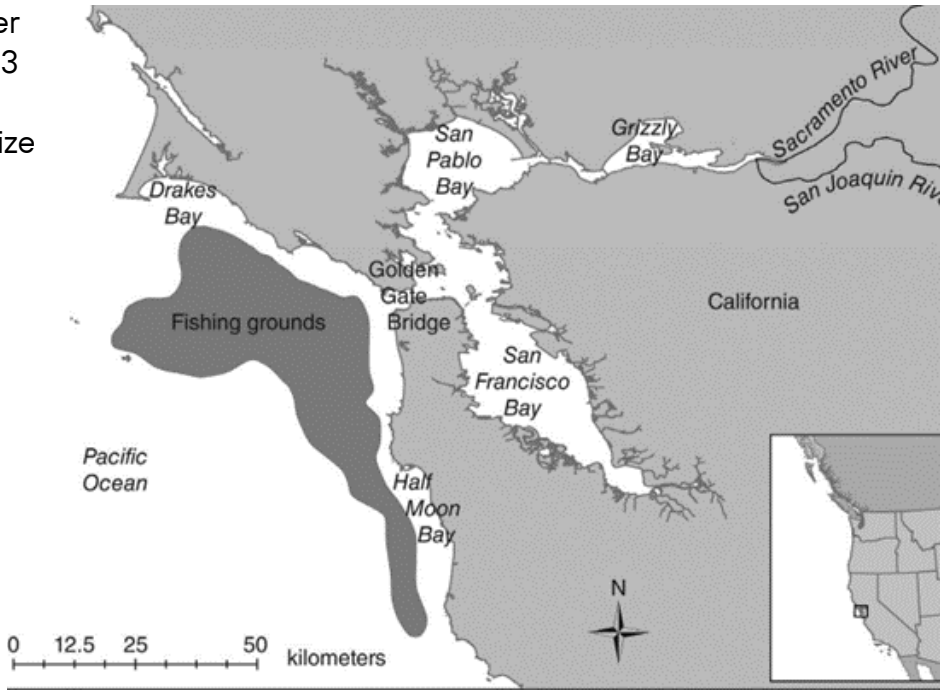
[COLLECTION FORMS RECEIVED]

NMFS, CDFW, and UCSC are working with fishermen to deploy a camera system on bottom trawl nets to capture behavioral footage in response to the net.

The CA Halibut Bottom Trawl Fishery is state regulated and managed, but because of the bycatch of federally managed species, such as Green Sturgeon and Groundfish, the fishery is observed by the Federal West Coast Groundfish Observer Program. The Observer Program records the green sturgeon caught in the fishery and various including: PIT tag or acoustic tag data, fish length, weight, and general condition. The camera footage is able to view fish coming in and how they respond to the net, but the camera does not see if they were caught. That information is gathered by the observers.

This study is part of a larger initiative that began in 2013 addressing how the CA Halibut Fishery can minimize Green Sturgeon bycatch.

First, researchers developed satellite tags on Green Sturgeon caught and released in the CA Halibut Bottom Trawl Fishery to estimate port-release survival rates. Results from the study are available in the publication by Doukakis et al. (2020) titled "Postrelease survival of green sturgeon (Acipenser medirostris) encountered as bycatch in the trawl fishery that targets California halibut (Paralichthys californicus), estimated by using pop-up satellite archival tags."[152]



[Figure 4 is from Doukakis et al. 2020 showing a map of the San Francisco Bay Delta and the approximate fishing grounds of the bottom trawl fishery that targets California halibut off San Francisco.]

Results from the satellite tagging study indicate a 20% post release mortality. The next questions to address were “how are the green sturgeon reacting to the net, and how are they being caught?” to inform bycatch reduction measures.

To address these questions, researchers have deployed cameras on CA Halibut Trawl vessels since 2021to record fish gear interactions. Video analysis is ongoing, but thus far researchers have obtained video footage of about 14 Green Sturgeon. Researchers are continuing to gather and analyze footage until the end of 2023. It is still too early to characterize the general behavior of Green Sturgeon in response to the nets. Once the footage has been analyzed and Green Sturgeon behavior evaluated, the research team will work with the fishermen to develop potential bycatch reduction measures (e.g., modifications to the gear) to test in the field.

The overall goal of this study is to reduce Green Sturgeon bycatch while maintaining the CA Halibut Fishery’s catch of target species (e.g., California Halibut and other flatfish).

WEST COAST GROUNDFISH OBSERVER PROGRAM (WCGOP) SAMPLING PROTOCOL DATA RECORDED: FOR GREEN STURGEON

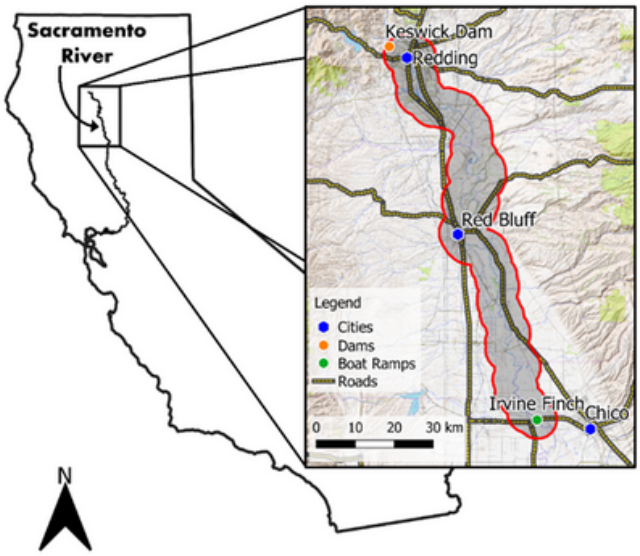
i. Observer name
ii. Species
iii. Barcode (for fin clip and fin ray samples)
iv. Trip No.
v. Haul/Set
vi. Date
vii. Fork Length (cm)
viii. Sex
ix. WT (lbs)
x. Sample Type: Fin Clip/Finn Ray/Other

CAMERA STUDY DATA RECORDED

i. Number of green sturgeon caught/observed
ii. Fork Length for each green Sturgeon
iii. Disposition (Dead/Alive and Released)
iv. Photograph of the Green Sturgeon
v. Date and Haul #
vi. Vessel Name
vii. Location (GPS)

02 DIDSON SONAR AND SUBMERSIBLE VIDEO TO ESTIMATE THE POPULATION SIZE OF ADULT GREEN STURGEON

[PUBLICATIONS RECEIVED]



Sampling and tagging has been conducted in the Upper Sacramento River during the summer months from 2010 to present and is ongoing.

Figure 5: Map showing the study site which covers the spawning area for the southern DPS of green sturgeon. The black outline is the state of California with the internal black line representing the Sacramento River up top Keswick Dam. In the zoom box, the red outline shows the area we surveyed. There are multiple spawning sites inside this area that shift location annually. The bottom (southern) end is the Irvine Finch Boat Ramp (near Chico, CA) and the top (northern) end is in Redding, CA [153]

Since this study began in 2010 the methodology has evolved as technology has advanced. A paper has been published on the data findings from 2010 through 2015[154] [155] and a draft report is out for the data from 2016 to 2018.[153]

The researchers use side scan sonar to make passes over sturgeon holes in the river that are 5 m (or 164ft) deep. “On the Sacramento River, we know where the holes are, and unfortunately, there hasn’t been a new hole found in 3 years,” personal communication with Peter Dudley, project lead at the NMFS Southwest Fisheries Science Center (SWFSC).

Peter and his team make a pass over every hole three times to scan for sturgeon, and if five or more sturgeon are found, then they do two more passes to inform the model more precisely. Previously, tagging was conducted to inform estimates of the number of spawners per year. Late comers into the system are common, as well as others who would leave early after spawning. Now that side scan sonar is used this method is more modern and efficient, which lessens the stress of tagging spawning adults.

A large benefit to this long-term study is the ability to conduct additional analyses with the data that is collected. For example, the data allows researchers to evaluate how sturgeon respond to flow and the habitat and geomorphic flow for spawning. In addition, the population estimates that results from this study are critical for assessing the status of Green Sturgeon and the effects of threats, such as bycatch in the California’s Halibut Bottom Trawl Fishery.

A future goal for this study is to continue developing the population size estimation data, and to identify the top spawning habitat for Green Sturgeon.

CRAMER-- FISH SCIENCES

UNDERSTANDING WITHIN- AND BETWEEN-BASIN MIGRATION IN WHITE STURGEON: A SYNTHESIS OF MORE THAN 10 YEARS OF ACOUSTIC TAGGING DATA.

[DATASET NOT YET RECEIVED]

Objectives: combine and leverage existing acoustic telemetry datasets to address high-priority research areas for White Sturgeon in the San Francisco Estuary system.

COLLECTIVE AGENCY INITIATIVES

STURGEON CARCASS SURVEY

is a stand-alone, multi-agency survey that began in January 2020. It is not a consistent monitoring effort, but rather a volunteer run effort.

[FULL DATASET NOT YET RECEIVED]

HARMFUL ALGAL BLOOM (HAB) CARCASS DATASET

is a (working) dataset for the sturgeon carcass count from the HAB event last year that is held within the Sturgeon Carcass Survey dataset.

[DATASET RECEIVED]

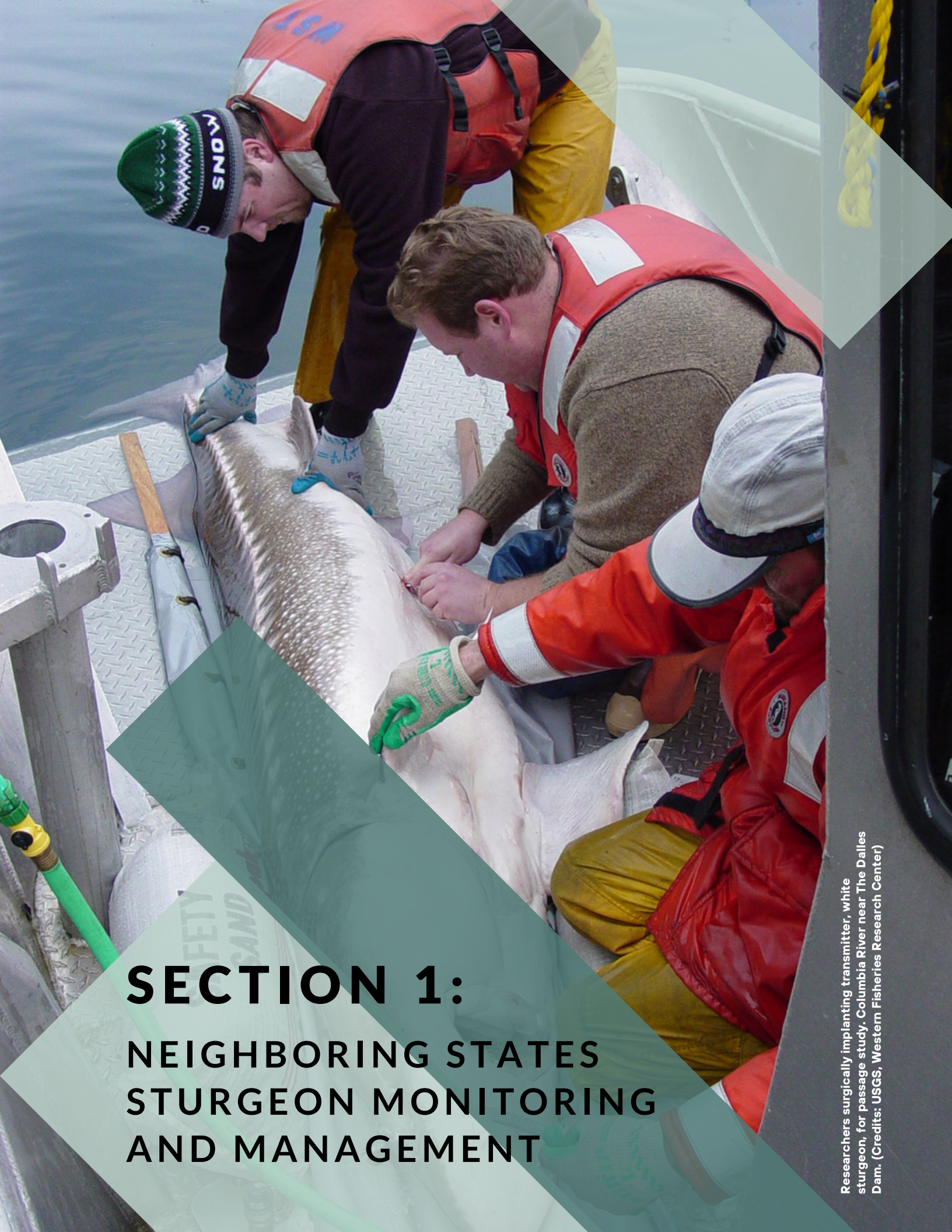
DATA RECORDED

i. ID Number
ii. Date
iii. Time
iv. Site
v. Latitude
vi. Longitude
vii. Name
viii. Count
ix. Species
x. Fork_length_cm
xi. Total_Length_cm
xii. Source
xiii. Notes

PART THREE

MANAGEMENT

SECTION 1: NEIGHBORING STATES STURGEON MONITORING AND MANAGEMENT
SECTION 2: CALIFORNIA STURGEON MANAGEMENT--INFORMATIONAL NEEDS
SECTION 3: RECOMMENDATIONS



SECTION 1:

NEIGHBORING STATES STURGEON MONITORING AND MANAGEMENT

Researchers surgically implanting transmitter, white sturgeon, for passage study. Columbia River near The Dalles Dam. (Credits: USGS, Western Fisheries Research Center)

As stated throughout this report, sturgeon migrate long distances throughout their habitat range from Mexico to Alaska, and some even into the Bering Sea. Oregon, Washington, Idaho, and the Province of British Columbia have sizable White Sturgeon populations in their river basins that they manage, and Green Sturgeon migrate into the Oregon and Washington river basins. California's neighboring states have experienced similar sturgeon population declines due to over harvesting and inadequate regulations. However, they have since established stricter regulations that have resulted in improved population abundance.

[MAP COURTESY OF: THE NORTHWEST POWER AND CONSERVATIVE COUNCIL[156]]

Some of these states and Province perform recruitment studies and know when their White Sturgeon population is suffering from juvenile versus adult mortality events.

Both nDPS and sDPS Green Sturgeon co-occur throughout their geographic range, outside of natal rivers. For example, acoustically tagged individuals from the nDPS and sDPS have been detected off the coast of Vancouver Island, the Columbia River Estuary, as well as in Willapa Bay, and to a lesser degree, Gray's Harbor[102][140] where they hold from late fall through the winter until they migrate out to their spawning grounds.[64]

This presents and opportunity for the States and British Columbia to collaborate on management and fishery regulations to protect and increase the abundance of sturgeon. Sturgeon are monitored annually, and joint discussions are made between the bordering states/province, and then those conversations are brought back to the respective state commissions.

Oregon and Washington already co-manage the sturgeon populations on the Columbia River. Idaho and Oregon also collaborate on shared management practices.

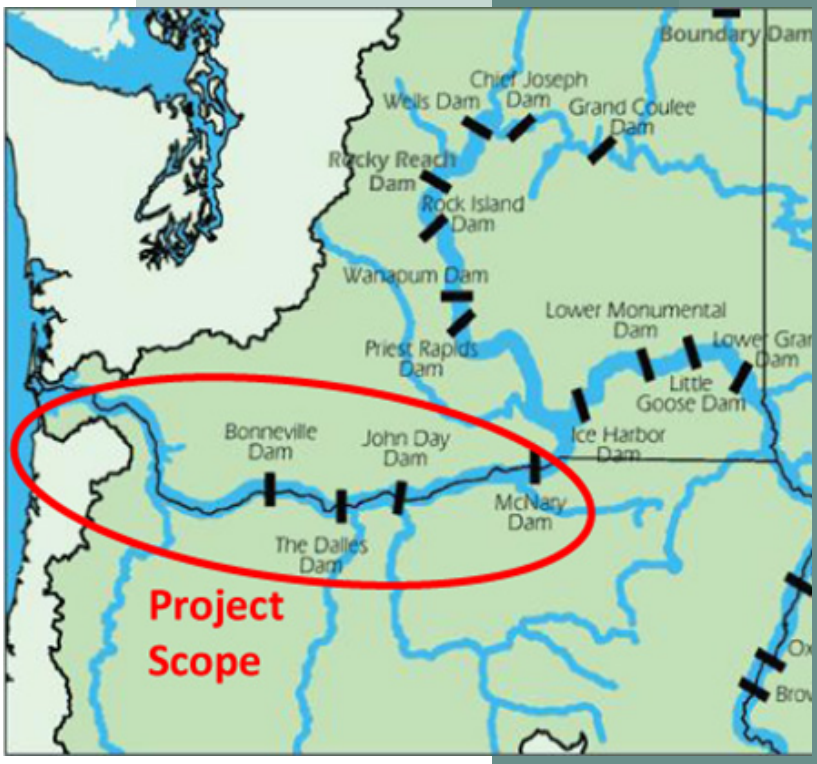
Reviewing the management practices and fishery regulations from other areas can inform California's approach to sturgeon management.

Researchers preparing to surgically implant transmitter, white sturgeon, for passage study. Columbia River near The Dalles Dam. (Credits: USGS, Western Fisheries Research Center)

OREGON

More than half of the Oregon and Washington state border sits on the Columbia River. In the area from Altoona, WA upstream to above McNary Dam (except near mainstem dams) the state line is in the middle of the ship channel that opens to the ocean near the shore of Washington state.[157] And so, these two states work together to co-manage the species that reside and migrate within the Columbia River Basin.

Oregon's Columbia River Sturgeon Fishery primarily operates as a catch-and-release recreational fishery with minor exceptions (ODFW and WDFW only allow for harvest on specified harvest days). The recreational fishery became catch-and-release in 2014.[157] The general regulations are that: retention of any Green Sturgeon is prohibited; any sturgeon that is unwanted or outside of the legal size range (from 38"—54" FL Bonneville Dam to Dalles Dam, 43"—54" FL Dalles Dam to McNary Dam) has to be returned to the water immediately; any sturgeon that is larger than 54-inch FL cannot be removed from the water; and sturgeon can only be fished with one single-point, barbless hook.



[Map: The EPA[158]]

SIDENOTE: compared to California's 68" FL max

SPECIFIC REGULATIONS FOR THE OREGON COLUMBIA RIVER STURGEON FISHERY INCLUDE:

- Open for White Sturgeon fishing from Jan 1 - until quota is reached.
- Bag limit is one White Sturgeon per day, two White Sturgeon per year.
- Bonneville Dam to The Dalles Dam: White Sturgeon must be between 38 inch minimum and 54 inch maximum fork length.
- The Dalles Dam to McNary Dam sturgeon must be between 43 inch minimum and 54-inch maximum FL.
- Only catch-and-release allowed for sturgeon from McNary Dam to the Oregon/Washington border.
- Catch-and-release for sturgeon is allowed after taking the daily or annual limit or the after quota is reached. Check myodfw.com for regulation updates.
- Angling for sturgeon is prohibited from May 1 through August 31 in the following areas:

1. A line projected from the east (upstream) dock at the Port of The Dalles boat ramp straight across to a marker on the Washington bank upstream to The Dalles Dam.
2. A line projected from the west end of the grain silo at Rufus straight across to a marker on the Washington bank upstream to John Day Dam.
3. A line projected from the east end grain elevators at Patterson Ferry Road straight across to a marker on the Washington bank upstream to McNary Dam.

- Closed to retention of White Sturgeon below Bonneville Dam, and:

1. Bonneville Dam upstream to a line across the river 1,000 ft from the dam as indicated by USACE signs;
2. Interstate Hwy 197 bridge at The Dalles upstream to the upper line of The Dalles Dam, except bank angling is permitted above the Hwy bridge for 1,100 ft to the cyclone fence;
3. John Day Dam downstream approx. 3,000 ft except that bank angling is permitted up to 600 ft below the fishway entrance;
4. From a floating device in USACE designated hazard zones above and below McNary Dam.

- In 2023, the fishery is catch-and-release only at the Bonneville Pool, the Dalles Pool, and the John Day Pool.

For more up to date information, visit myodfw.com

WASHINGTON

As stated above, Oregon and Washington co-manage the sturgeon fisheries, because they share the Columbia. The Washington fishery also experienced a collapse at the end of the 19th century due to overfishing. Through management actions to reduce harvest and protect the brood stock (a maximum length of 6 feet for White Sturgeon in 1950), the sturgeon population was able to rebound through the 1990s. Washington was able to support both commercial and recreational fisheries until subadult and adult abundances began declining in the mid-2000s. Changes in harvest quotas and retention seasons were implemented in response to a decline in juvenile sturgeon abundance in 2010 and the lack of improvement in sturgeon abundance in 2013.

In 2014, Washington and Oregon changed the Columbia River sturgeon fishery in the Columbia River and its tributaries to a catch-and-release fishery. Periodic emergency rulings opened the fishery for catch and release for short durations from 2015 to 2016, because the population recruitment data showed a strong year class of juveniles. Washington Department of Fish and Wildlife (WDFW) (2023) also found that "the abundance of non-juvenile fish (96 cm and larger) has remained relatively stable, with estimates ranging from around 123,000 fish in 2010 to 108,000 fish in 2022."[159]

WDFW has established a smaller slot length limit to protect reproductively mature fish and a reduced harvest rate. Since 2017, the harvest rate has been 3-5% of the population. With these regulations, there has been an increase in adult abundance, but the increase has been limited due to a decade of poor recruitment. The main issue is that the young of the year (YOY) are not surviving at a high enough rate and researchers are attempting to identify the cause of this juvenile mortality. In 2023, the fishery was closed to increase the survival of juveniles and spawning adults.

Researchers with a young White Sturgeon. (Credits: Laura Heironimus/Washington Department of Fish and Wildlife)

THE WASHINGTON STATEWIDE PERMANENT STURGEON REGULATIONS ARE LISTED BELOW:[160]

During Fishing Seasons:

- Anglers may not fish for or retain Green Sturgeon
- Columbia River from Bonneville Dam downstream: Catch-and-release only. Open only during open game fish or salmon seasons unless specifically noted in special rules.
- Columbia River from Bonneville Dam upstream to McNary Dam including tributaries: Minimum size 38" fork length in waters downstream of The Dalles Dam, and minimum size 43" fork length in waters upstream of The Dalles Dam. Maximum size 54" fork length. Daily limit 1. Possession limit: is 2 daily limits in a fresh, frozen or processed form. Annual limit 2 sturgeon statewide per license year (April 1-March 31). Unless specifically noted in special rules, open only during open game fish or salmon seasons.
- Columbia River from McNary Dam to Chief Joseph Dam, Snake River, coastal, and Puget Sound waters including their tributaries: Catch-and-release only. Open only during open game fish or salmon seasons unless specifically noted in special rules.
- Columbia River from Chief Joseph Dam upstream, including Lake Roosevelt: closed.

Additional Regulations:

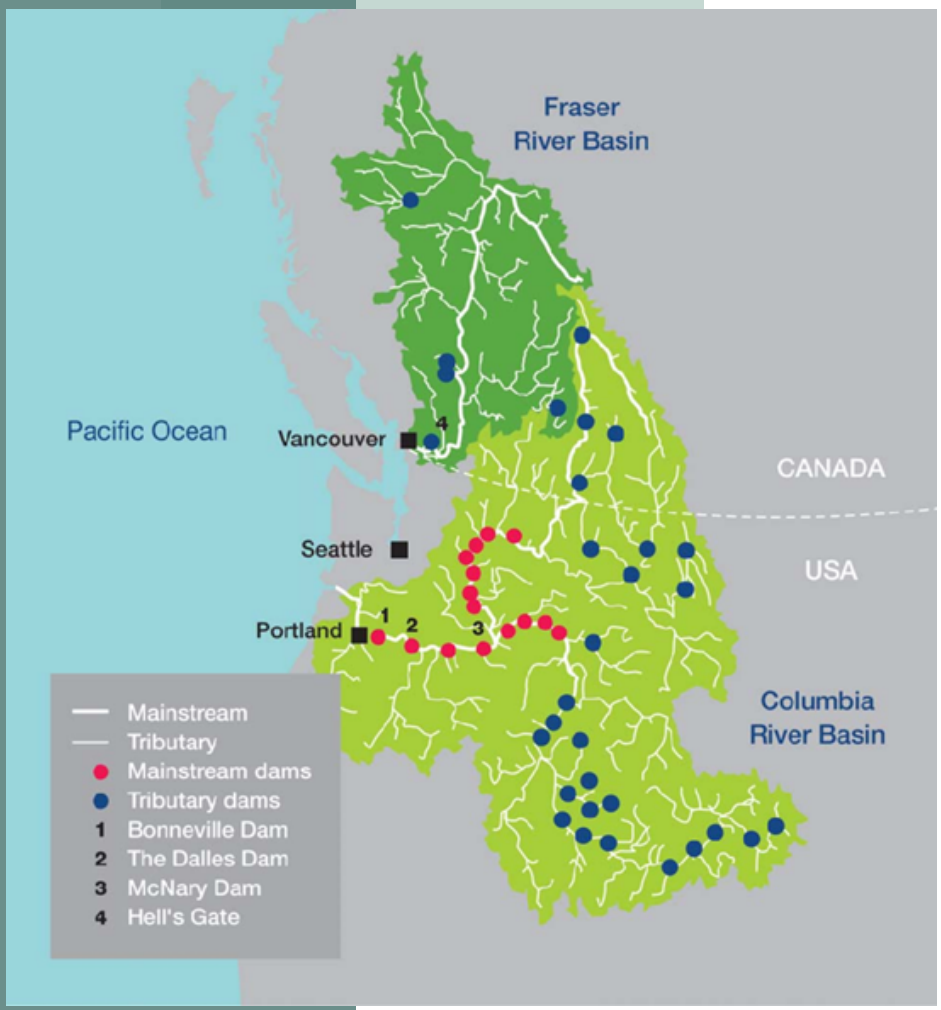
- Annual white sturgeon limit is 2 fish even if the angler holds both a Washington and Oregon license.
- Anglers may continue to fish catch-and-release after retaining a daily limit.
- After an annual limit has been retained, catch-and-release fishing is allowed in waters open to catch-and-release fishing.
- Catch Record Cards are required statewide to fish for sturgeon.
- Only one single-point barbless hook and bait is allowed when fishing for sturgeon. In the field, eggs must be retained with intact carcass of fish from which they came. Night closure in effect for all sturgeon. Any sturgeon not to be retained must be released immediately. Sturgeon over 55" fork length cannot be removed totally or in part from the water.

For 2023, due to the decline in White Sturgeon abundance, the retention of sturgeon downstream of Bonneville Dam was prohibited for both commercial and recreational fisheries.

BRITISH COLUMBIA

White Sturgeon are found in multiple places in British Columbia, Canada. The Columbia River Basin stretches down from British Columbia into Washington, Oregon, and Idaho. White Sturgeon can also be found in the Fraser River, which opens to the ocean in Vancouver.

Map[162]: Location of dams in the Fraser and Columbia River Basins (source: Ferguson and Healey, 2009)[163].]



Fishing for sturgeon is not allowed anywhere but the lower and middle portions of the Fraser River. The sturgeon fishery has been a catch-and-release fishery since 1994; a freshwater fishing license, as well as a White Sturgeon Conservation License are required. "The Middle Fraser includes the section from the confluence of the Fraser River and its Williams Lake River tributary in the Cariboo, down to the city of Hope in the Lower Mainland. The Lower Fraser is comprised of the non-tidal portion of the Fraser River from Hope down to the Mission CPR Bridge, as well as the tidal portion which flows from the Mission CPR Bridge down to the Strait of Georgia in Vancouver."[161] Everywhere else in British Columbia, the White Sturgeon are protected under the federal Species at Risk Act and are closed to recreational angling.

BRITISH COLUMBIA HAS DEDICATED GUIDELINES FOR ANGLING WHITE STURGEON:

1. Use only single barbless hooks, with heavy rod and reels that are at least 130 lb. manufacturer rated tested line
2. Play and release sturgeon as quickly as possible
3. Choose your fishing location carefully and keep sturgeon in the water
4. Remove hooks quickly but gently
5. Handle and recover sturgeon with care

Green Sturgeon are prohibited from being fished. However, they can be sighted northwest of Vancouver Island, British Columbia near the Brooks Peninsula, [64] as well as in Willapa Bay, and Gray's Harbor in Washington.[102] [140] This is where some Green Sturgeon exhibit a migration in late fall (and some in the spring). This holding behavior along the coast of Washington and British Columbia has management ramifications because the Green Sturgeon may encounter and be incidentally caught in coastal fisheries during their migrations. As previously discussed, fisheries bycatch poses a threat to the population due to potential lethal and sublethal effects.

IDAHO

From the early 1900s to 1970, dams were constructed along the Snake River isolating sturgeon populations and limiting their food sources. Dam construction combined with unregulated harvest severely reduced sturgeon numbers until in 1971 catch-and-release regulations were adopted in the Snake River.[164] This regulation shift led to a partial population recovery.[165]

Major regulations:

- Sturgeon must not be removed from the water and must be released upon landing
- Barbless hooks are required
- Use of a sliding swivel device to secure a weight, and a lighter test line to secure weight to sliding swivel device is required.

Idaho Fish and Game report that "angling for these giant fish has become very popular," and has created guidelines to aid in minimizing the effects of increased fishing. Attached is a link to the Low Impact Fishing Rules and Tips that is posted on the Idaho Fish and Game website.[164] The page also states that there are healthy populations of White Sturgeon that reside in the Snake River between the Bliss Dam and the upper end of C.J. Strike Reservoir in southern Idaho, from Lewiston upstream to Hell's Canyon Dam, and a smaller population below the American Falls and C.J. Strike dams, but targeting sturgeon in the Kootenai River is illegal.

Idaho Fish and Wildlife Photo

SUMMARY

Washington, Oregon, Idaho, and British Columbia have re-evaluated and revised their fisheries regulations to sustain and improve the White and Green Sturgeon populations that reside in their waters. The effectiveness of these regulations must be evaluated over time, as other states (Mississippi[1] and Florida[2]) have reported even low harvest rates will negatively affect the long-term persistence of sturgeon populations. Harvest and retention of Green Sturgeon is now prohibited in all states and in British Columbia. Oregon and Washington primarily operate as a catch-and-release recreational fishery with minor exceptions for White Sturgeon, Idaho is a catch-and-release fishery on the Snake River, and British Columbia is strictly a catch-and release fishery on the middle and lower reaches of the Fraser River.

In summary, the combined regulations are:

OREGON

- Open for White Sturgeon fishing from Jan 1 - until quota is reached.
- Bag limit is one White Sturgeon per day, two White Sturgeon per year.
- Bonneville Dam to The Dalles Dam: White Sturgeon must be between 38 inch minimum and 54 inch maximum fork length.
- The Dalles Dam to McNary Dam sturgeon must be between 43 inch minimum and 54-inch maximum FL.
- Only catch-and-release allowed for sturgeon from McNary Dam to the Oregon/Washington border.
- Catch-and-release for sturgeon is allowed after taking the daily or annual limit or the after quota is reached. Check myodfw.com for regulation updates.
- Angling for sturgeon is prohibited from May 1 through August 31 in the following areas:

  I. A line projected from the east (upstream) dock at the Port of The Dalles boat ramp straight across to a marker on the Washington bank upstream to The Dalles Dam.
  II. A line projected from the west end of the grain silo at Rufus straight across to a marker on the Washington bank upstream to John Day Dam.
  III. A line projected from the east end grain elevators at Patterson Ferry Road straight across to a marker on the Washington bank upstream to McNary Dam.

- Closed to retention of White Sturgeon below Bonneville Dam, and:

  I. Bonneville Dam upstream to a line across the river 1,000 ft from the dam as indicated by USACE signs;
  II. Interstate Hwy 197 bridge at The Dalles upstream to the upper line of The Dalles Dam, except bank angling is permitted above the Hwy bridge for 1,100 ft to the cyclone fence;
  III. John Day Dam downstream approx. 3,000 ft except that bank angling is permitted up to 600 ft below the fishway entrance;
  IV. From a floating device in USACE designated hazard zones above and below McNary Dam.

- In 2023, the fishery is catch-and-release only at the Bonneville Pool, the Dalles Pool, and the John Day Pool.

WASHINGTON

- Anglers may not fish for or retain Green Sturgeon
- Columbia River from Bonneville Dam downstream: Catch-and-release only. Open only during open game fish or salmon seasons unless specifically noted in special rules.
- Columbia River from Bonneville Dam upstream to McNary Dam including tributaries: Minimum size 38" fork length in waters downstream of The Dalles Dam, and minimum size 43" fork length in waters upstream of The Dalles Dam. Maximum size 54" fork length. Daily limit 1. Possession limit: is 2 daily limits in a fresh, frozen or processed form. Annual limit 2 sturgeon statewide per license year (April 1-March 31). Unless specifically noted in special rules, open only during open game fish or salmon seasons.
- Columbia River from McNary Dam to Chief Joseph Dam, Snake River, coastal, and Puget Sound waters including their tributaries: Catch-and-release only. Open only during open game fish or salmon seasons unless specifically noted in special rules.
- Columbia River from Chief Joseph Dam upstream, including Lake Roosevelt: closed.

Additional Regulations:

- Annual white sturgeon limit is 2 fish even if the angler holds both a Washington and Oregon license.
- Anglers may continue to fish catch-and-release after retaining a daily limit.
- After an annual limit has been retained, catch-and-release fishing is allowed in waters open to catch-and-release fishing.
- Catch Record Cards are required statewide to fish for sturgeon.

- Only one single-point barbless hook and bait is allowed when fishing for sturgeon. In the field, eggs must be retained with intact carcass of fish from which they came. Night closure in effect for all sturgeon. Any sturgeon not to be retained must be released immediately. Sturgeon over 55" fork length cannot be removed totally or in part from the water.

BRITISH COLUMBIA

- Fishing for sturgeon is not allowed anywhere but the lower and middle portions of the Fraser River
- A White Sturgeon Conservation License are required.
- Use only single barbless hooks, with heavy rod and reels that are at least 130 lb. manufacturer rated tested line.

IDAHO

- Sturgeon must not be removed from the water and must be released upon landing.
- Barbless hooks are required.
- Use of a sliding swivel device to secure a weight, and a lighter test line to secure weight to sliding swivel device is required.
- Targeting sturgeon is only allowed on the Snake River, but illegal on the Kootenai River.

Going forward, if California remains a White Sturgeon recreational fishery, it might be beneficial to adopt similar regulations to improve abundance and population performance and increase the likelihood of a sustainable fishery for future generations.

As of November 16th, 2023, the CA Office of Administrative Law approved the emergency regulations and went into into immediate effect for the Sturgeon Fishery.

Under the emergency regulation, the following changes will be made (this applies to cards already sold, new cards for 2023, and new cards for 2024):
SEE THE FOLLOWING PAGE

CALIFORNIA EMERGENCY REGULATIONS

- Report cards are still required and all existing regulations apply other than noted below (e.g. existing closures, gear restrictions, etc.).
- The slot limit will change to 42-48" FL (from 40-60" FL)
- The annual bag limit will be reduced to 1 fish (from 3)
    - For 2023 tag holders, if they have already tagged a fish, they are not permitted to harvest any more for the year. If they have not yet tagged a fish, they can tag one. Any remaining tags are invalid
    - 2024 cards will only come with one tag
- There is a maximum vessel harvest limit of two fish per boat per day. Anglers that have not harvested a fish may continue to fish catch and release when the vessel limit is reached.
- Anglers must stop fishing for sturgeon for the day after they tag a fish. They may continue to fish catch and release the rest of the year.
- Seasonal migration and spawning closures on the Sacramento and San Joaquin rivers/tributaries – upstream of the Hwy 50 bridge on the Sacramento River and I-5 bridge on the San Joaquin River:
    - Closed January 1 – May 31 to protect spawning
    - Catch and release June 1 – December 31

No harvest-based sturgeon derbies are permitted going forward, but catch-and-release are fine. This is not included in the emergency regulation, because CDFW already has the authority to manage derbies under other regulations and statutes.

The emergency regulations are expected to last through 2024, though CDFW will have to formally request some extensions with the FGC. The goal is to have new long-term regulations proposed to the FGC in time to start 2025. Those regulations will cap exploitation at 4% of the legal abundance estimate and will include adjustments to slot limit, season/geography, etc.

SECTION 2:

CALIFORNIA STURGEON MANAGEMENT-- INFORMATIONAL NEEDS

Photo courtesy of the California Department of Water Resources

California's two sturgeon species, Green (Acipenser medirostris) and White (Acipenser transmontanus) both face population threats. Both the nDPS and sDPS Green Sturgeon live in two large California river systems (Sacramento-San Joaquin, and Klamath) and some smaller coastal rivers (e.g., Eel River and Klamath River). The nDPS Green Sturgeon is a NMFS Species of Special Concern, whereas the sDPS Green Sturgeon spawning in the Sacramento-San Joaquin system has been federally listed as Threatened by the NMFS under the ESA since 2006.[7] Similarly, the White Sturgeon in California is a Species of Concern, but it is a part of a recreational sports fishery that has been operating since its second opening in 1954. [4]

Declining sturgeon populations have been documented globally since 1999.[1] Due to a lack of, or otherwise poorly recorded, historical data, it is difficult to determine how much the Estuary-Delta's sturgeon population has declined since the 1800s. Fortunately, there are groups dedicated to and passionate about managing and conserving California's sturgeon species. Several of these are discussed below.

THE NORTH AMERICAN STURGEON AND PADDLEFISH SOCIETY (NASPS)

is an affiliate of the World Sturgeon Conservation Society (WSCS). Founded in 2012, the NASPS addresses the current declines in sturgeon and paddlefish populations across North America. The NASPS is "dedicated to promoting the conservation and restoration of sturgeon species in North America by developing and advancing research pertaining to their biology, management, and utilization."[168]

In California, the Interagency Ecological Program (IEP) has a Sturgeon Project Work Team (PWT) that "provides a technical forum to discuss Central Valley sturgeon issues and encourages, facilitates, and coordinates sturgeon monitoring, research, and information dissemination."[169]Many of the researchers are involved in the monitoring efforts conducted by the CDFW, USFWS, NMFS, USACE, CDWR, and UC Davis are members of the NASPS and the IEP Sturgeon PWT.

As previously mentioned, the USFWS Anadromous Fish Restoration Program with the Central Valley Project Improvement Act (CVPIA) was formed to improve natural spawning conditions for five anadromous fish species. Recently, the CVPIA released their Near-term Restoration Strategy for the CVPIA's Fish Resource Area. [72] With guidance from the USFWS and the Sturgeon PWT, five informational needs were identified as priority.

Sturgeon Informational Needs	Duration
Info Need 1: Early juvenile survival and growth of wild fish (larvae to age-1).	>5 years
Info Need 2: Adult and subadult survival and movement (system wide).	>5 years
Info Need 3: Spawner abundance monitoring.	>5 years
Info Need 4: Estimate juvenile rearing and adult spawning habitat availability (system wide).	2-3 years
Info Needs 5: White Sturgeon spawning distribution.	2-3 years

Table 1: Sturgeon Informational Priorities.
The information needs for Green and White Sturgeon represent short and long-term priorities for improving the sturgeon Decision-support models (DSMs) and the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.
This table was designed from the CVPIA's Near-term Restoration Strategy Table ES-4 on pg. 45

The Informational Needs were divided into long-term and near-term priorities, with the long-term priorities likely requiring more than 5 years to properly study.

The Sturgeon PWT then further outlined how each of the current monitoring efforts (See the following pages) and University funded studies (listed above in Part 2, Section 1) could assist in gathering the data to address these informational needs. However, many of these Informational Needs will require more data than what is being collected from the current monitoring efforts and studies.

For example, California does not currently have a recruitment study for White Sturgeon, which is critical to meet Need 1. In large part, this information is missing because we do not know where the juveniles are rearing, which is vital to Need 4. Furthermore, these two large gaps of information will affect data for Need 5, 3, and 2 in the future. Overall, more direct monitoring studies are needed to fill these data gaps.

The following pages outline how the current projects listed in Part 2 (Data Collection) can address each informational need. These survey efforts are organized in to “Informational Needs” by sturgeon life stage or other useful management-relevant groupings.

INFORMATIONAL NEED #1

EARLY JUVENILE SURVIVAL AND GROWTH OF WILD FISH (LARVAE TO AGE-1)

Data Collection Efforts:

1. CDFW Yuba and Bear River Spawning Surveys (Green and White)
2. CDFW Tagging and Monitoring of Juvenile Green and Juvenile White Sturgeon in the Lower Sacramento River and SFBDE
3. USFWS and USACE Sacramento River Juvenile (age-0) Green Sturgeon rearing habitat investigation
4. USFWS and USACE Green Sturgeon Habitat Mitigation and Monitoring Plan--Sacramento River Adult Tagging
5. USFWS and USACE Green Sturgeon Habitat Mitigation and Monitoring Plan--juvenile tagging in Lower Sac
6. DWR Lower Feather River Green Sturgeon Spawning Study
7. UC Davis researching methods to improve passage and determine impacts of diversion and flood control structures to Green Sturgeon (Dr. Dennis Cocherell, Dr. Anna Steel, Dr. Nann Fangue)

Data Meta-Analyses:

1. CDFW Reconstructing Green and White Sturgeon life history and environmental exposure using fin ray geochemistry (Kristen Sellheim and Levi Lewis)
2. OSU Erin Lunda Graduate Work (Green and White Sturgeon)

Potential Future Studies:

1. USACE and CESU/UC Davis Studies Green Sturgeon Habitat Mitigation and Monitoring Plan
2. UC Davis Improvements to tank-spawning protocol for captive Green Sturgeon (Dr. Dennis Cocherell, Dr. Nann Fangue)

EFFORT BREAKDOWN/SUMMARY for NEED #1
7 Monitoring Data Collection, 2 Data Meta-Analyses, 2 Potential Data Studies—11 Total

- The CVPIA anticipates this will be met with 5+ years of data collection.
- 7 Monitoring Data Collection: 5 Green Sturgeon, and 2 for both species.
- 2 Data Meta-Analyses: Both assess Greens and Whites.
- 2 Potential Studies: Both Green Sturgeon Focused

INFORMATIONAL NEED #2

ADULT AND SUBADULT SURVIVAL AND MOVEMENT (SYSTEM WIDE)

Data Collection Efforts:

1. USFWS and USACE Green Sturgeon Habitat Mitigation and Monitoring Plan--Sacramento River Adult Tagging
2. UC Davis Researching methods to improve passage and determine impacts of diversion and flood control structures to Green Sturgeon (Dr. Dennis Cocherell, Dr. Anna Steel, Dr. Nann Fangue)
3. NMFS Green Sturgeon fish-gear interactions in the CA Halibut bottom trawl fishery
4. Multi-Agency Sturgeon Carcass Survey

Data Meta-Analyses:

1. Cramer, Fish Sciences Understanding within- and between-basin migration in White Sturgeon: A synthesis of more than 10 years of acoustic tagging data.
2. OSU Erin Lunda Graduate Work (Green and White Sturgeon)

Potential Future Studies:

1. USFWS White Sturgeon Acoustic Tagging to assess migration and fish passage in the San Joaquin River

EFFORT BREAKDOWN/SUMMARY for NEED #2

6 Monitoring Data Collection, 2 Data Meta-Analyses, and 1 Potential Study—7 Total

- The CVPIA anticipates this will be met with 5+ years of data collection.
- 4 Monitoring Data Collection: 3 Green Sturgeon + Carcass Survey
- 2 Data Meta-Analyses: 1 for White Sturgeon, and the other for both species.
- 1 Potential: White Sturgeon Focused

INFORMATIONAL NEED #3

SPAWNER ABUNDANCE MONITORING

Data Collection Efforts:

1. DWR Passage, Abundance, Distribution, and Potential Spawning Areas of Adult Green Sturgeon in the Lower Feather River
2. NMFS DIDSON sonar and submersible video to estimate population size of adult Green Sturgeon
3. UC Davis/Idaho/British Columbia Using a tetratomic SNP panel to infer spawner number in a wild White Sturgeon population (Snake River; Fiske) and a repatriation-based conservation aquaculture program (Upper Columbia River; Johnson) -- (Dr. Andrea Schreier, PhD student Aviva Fiske, PhD student Peter Johnson)

Potential Future Studies:

1. UC Davis Using whole genome sequencing to develop a genetic sex marker for Green Sturgeon (Dr. Andrea Schreier, Dr. Nann Fangue, and Dr. Daphne Gille (CDWR))
2. Refunding CDFW Adult White Sturgeon Population Study

EFFORT BREAKDOWN/SUMMARY for NEED #3
3 Monitoring Data Collection, and 2 Potential Study—5 Total

- The CVPIA anticipates this will be met with 5+ years of data collection.
- 3 Monitoring Data Collection: 2 Green Sturgeon, 1 White Sturgeon

o Note: The White Sturgeon Study is sampling from Idaho and British Columbia and not from the San Francisco Sacramento-San Joaquin system

- 2 Potential: 1 Green Sturgeon, 1 White Sturgeon

INFORMATIONAL NEED #4

ESTIMATE JUVENILE REARING AND ADULT SPAWNING HABITAT AVAILABILITY (SYSTEM WIDE)

Data Collection Efforts:

1. CDFW Yuba and Bear River Spawning Surveys (Green and White)
2. USFWS and USACE Sacramento River juvenile Green Sturgeon rearing habitat investigation
3. USACE and UC Davis Green Sturgeon Habitat Mitigation and Monitoring Plan: CESU/UC Davis Studies
4. DWR Lower Feather River Green Sturgeon Spawning Study

Data Meta-Analyses:

1. CDFW Reconstructing Green and White Sturgeon life history and environmental exposure using fin ray geochemistry (Kristen Sellheim and Levi Lewis)
2. OSU Erin Lunda Graduate Work (Green and White Sturgeon)

Potential Future Studies:

1. CDFW Tagging and Monitoring of Juvenile Green and Juvenile White Sturgeon in the Lower Sacramento River and SFBDE
2. CDFW 20mm Survey: SF Bay Study for Juvenile White and Green Sturgeon
3. USACE Green Sturgeon Habitat Mitigation and Monitoring Plan--habitat preferences in the Lower Sacramento River
4. Future Study to better determine habitat preferences in Lower Sac River and Interior delta for future potential restoration efforts.
5. 4.UC Davis Improvements to tank-spawning protocol for captive nDPS Green Sturgeon Adults (Dr. Dennis Cocherell and Dr. Nann Fangue)

EFFORT BREAKDOWN/SUMMARY for NEED #4

5 Monitoring Data Collection, 2 Data Meta-Analyses, and 3 Potential Study—10 Total

- The CVPIA anticipates this will be met with 2-3 years of data collection.
- 4 Monitoring Data Collection: 3 Green Sturgeon, and 1 for both species.
- 2 Data Meta-Analyses: Both assess Greens and Whites.
- 4 Potential: 2 Green Sturgeon, and 2 for both species.

INFORMATIONAL NEED #5

WHITE STURGEON SPAWNING DISTRIBUTION

Data Collection Efforts:

1. USFWS White Sturgeon Acoustic Tagging to assess migration and fish passage in the San Joaquin River
2. CDFW Middle Sacramento River Spawning Survey (White Sturgeon)

Data Meta-Analyses:

1. Cramer, Fish Sciences Understanding within- and between-basin migration in White Sturgeon: A synthesis of more than 10 years of acoustic tagging data.

Potential Future Studies:

1. UC Davis/Idaho/British Columbia Using a tetratomic SNP panel to infer spawner number in a wild White Sturgeon population (Snake River; Fiske) and a repatriation-based conservation aquaculture program (Upper Columbia River; Johnson) -- (Dr. Andrea Schrier, PhD student Aviva Fiske, PhD student Peter Johnson)

EFFORT BREAKDOWN/SUMMARY for NEED #5
2 Monitoring Data Collection, 1 Data Meta-Analyses, and 1 Potential Study—4 Total

- ·The CVPIA anticipates this will be met with 2-3 years of data collection.
- ·This section is entirely for White Sturgeon

DESCRIPTION OF INFORMATIONAL NEEDS AND POTENTIAL PRIORITIES FOR AGENCY INVESTMENT

In Summary, we notice the unevenness between Green and White Sturgeon data collection to address these Informational Needs.

Informational Need #1

"Early juvenile survival and growth of wild fish (larvae to age-1)"

has 5 out of the 7 studies focused on Green Sturgeon, and the other two collect data for both species. Furthermore, the two CDFW led monitoring efforts that collect data on both species (the Yuba and Bear River Spawning Surveys; the Tagging and Monitoring of Juvenile Green and White Sturgeon in the Lower Sacramento River and SFBDE) have only one individual and their crew out collecting data.

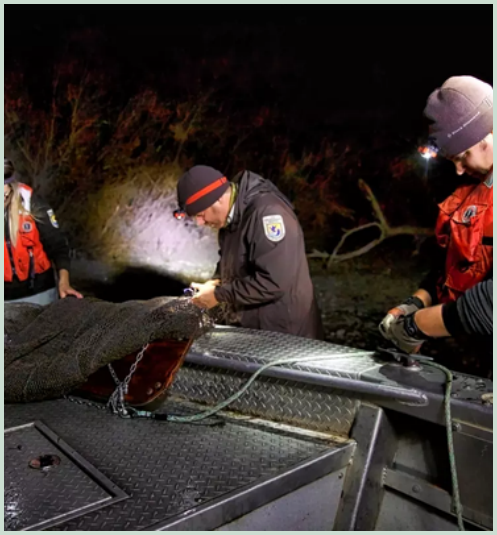
Similarly, there are no monitoring efforts that focus on meeting **Informational Need #2 "Adult and subadult survival and movement (system wide)"** for White Sturgeon. Neither is there one for the SFBDE White Sturgeon for **Informational Need #3 "Spawner abundance monitoring."** **Informational Need #4 "Estimate juvenile rearing and adult spawning habitat availability (system wide)"** is only addressed by the Yuba and Bear River Spawning Surveys for current White Sturgeon data collection. And,

Informational Need #5

"White Sturgeon Spawning Distribution"

is addressed by two monitoring efforts: the USFWS White Sturgeon Acoustic Tagging to assess migration and fish passage in the San Joaquin River and the CDFW Middle Sacramento River Spawning Survey. There is one data analysis study (Cramer Fish Sciences) that is forming a synthesis of more than 10 years of acoustic tagging data to understand within- and between-basin migration in White Sturgeon.

CDFW Photo,
White Sturgeon



Red Bluff Fish and Wildlife Office,
Steve Martarano/USFWS

CDFW Photo by Mike Healey,
Green Sturgeon

OVERALL, our evaluation posits that if there is little or no data collected for White Sturgeon system-wide adult and subadult survival and movement, nor much spawner abundance monitoring, and only limited data collection for system-wide juvenile rearing habitat, early juvenile survival and growth, and spawning distribution, then performance of the species and their abundance cannot be properly characterized, appraised or attributed to supposed beneficial actions like stream restorations, passage improvements, or reductions in stranding or entrainment. Without commensurate investments in improvements to life stage transition probabilities or stage survivorship rates across the Sturgeon life cycle, declines in the San Francisco Bay Delta Estuary White Sturgeon population are likely to continue. Knowing where, when, and how to improve sturgeon life cycle performance depends upon adequate documentation of how the species is performing now, and how they will respond (or are likely to respond) to habitat improvements in the future (for example, removing barriers to adult migration).

Additionally, it has been a decade since fishing restrictions regarding the White Sturgeon fishery have been updated, and even then, they were much delayed compared to neighboring states as a regulatory action to improve the population. California's White Sturgeon sports fishery will continue to suffer abundance declines until more effective management actions are taken. In addition, due to the likely impact that the 2022 HAB event had on the White Sturgeon population and the defunding of the Adult Sturgeon Population Study, the CDFW is searching for further resources to make full and reliable population estimates using fisheries-independent abundance monitoring calculations rather than only relying on angler report card data to gauge catch incidents.

In May of 2023, the CDFW hosted a sturgeon-related virtual public meeting to support the development of a management plan where the goal is to support a sustainable sturgeon fishery consistent with an annual harvest rate that allows some angling-related harvest per year. CDFW is conducting an evaluation of the current regulations and the different aspects of the monitoring and management of the fishery. Possible alternatives to consider, as modifications, include: additional seasonal and geographic closures, catch-and-release and/or harvest seasons, and harvest quota system. None of these alternatives have yet been formally proposed for implementation, but the goal is to have new regulations established in 2025.

Since 2013, sturgeon fishing has been prohibited between Keswick Dam and the Highway 162 bridge on the Sacramento River, the Yolo Bypass, the Toe Drain Canal, the Tule Canal upstream of the Lisbon Weir, and the entire North Coast District (Humboldt, Del Norte, Trinity, and Siskiyou counties).[22] There is a seasonal closure of White Sturgeon fishing from January 1 to March 15 in the Central San Francisco Bay (between Pt. Chauncy and Pt. Richmond, the San Francisco-Oakland Bay Bridge, and between Pt. Lobos and Pt. Bonita) that coincides with herring spawning season. Herring is thought to be one of Green Sturgeon's desired prey, so this closure was established to lessen the possibility of Green Sturgeon bycatch. Unfortunately, there is no formal data collection effort to analyze and demonstrate the effectiveness of these closures.

Photo: Measuring young-of-year White Sturgeon length on the lower Columbia River. Photo by USGS. (Public domain.)

It was stated during the May 2023 virtual public meeting that the existing population cannot support current harvest rates, based on the combination of data, trends, the likely impact of the HAB event in August 2022, and what we know about sturgeon life history in the Estuary. In fact, the recent HAB-related mortality event may indicate a need for further protection since existing and future generations (cohorts) will experience longer-term life-stage related population effects (such as depressed egg production numbers or alterations to spawning behavior or timing). As Blackburn et al. (2019) state, "The results of this study suggest that population growth was most influenced by the survival of sexually mature adults, and low levels of exploitation are needed to maintain a stable population." This statement should be especially important in light of the HAB-related mass mortality event White Sturgeon experienced last year (August 2022). By updating harvest limits, regulations can help mitigate the other negative environmental pressures that are suppressing White Sturgeon populations. As Doukakis et al. (2020) concluded, "mortality due to incidental capture still threatens the recovery of depleted populations."[152]

Improvements to fishing-related technology is making it easier to find fish, and even though it is difficult to demonstrate any impacts of higher catch efficiency per unit of effort given current data collection methods, it is apparent that the harvestable sturgeon population size is decreasing (as a function of effort) over time. Interim Emergency Regulations for a "catch-and-release only" fishery is being considered by fishery managers as a tentative solution until harvest rates can be effectively quantified and appropriately managed via better-informed analysis and updated regulation. CDFW is considering additional ways to incentivize anglers to return the sturgeon reward tags within the year that they catch them, and to return their harvest report cards to CDFW more consistently. CDFW is also working to collect fishery-independent data to combine with angler-supplied data.

As previously mentioned CDFW is identifying potential resources needed to calculate scientifically credible and reliable population estimates in addition to using angler supplied data. Current abundance estimates rely on released tags and mailed in angler returns, which normally only 30% are returned. Alternative analysis schemes and abundance estimate calculations (e.g., design-based estimators) are under review and may be revised to characterize previously published population numbers more accurately. These updated methods are intended to be used as inputs the number of fish that have been harvested in the previous year, but this revision has yet been accepted or initiated as a management tool. Ultimately, accurate abundance estimates, combined with more reliable harvest rate numbers, will be used to assess needed adjustments to future harvest and size-class limits to the fishery.

Overall, this is a critical time for California's wildlife management and regulatory agencies to consider management program adjustments to preserve the White Sturgeon population and associated fishery. The California Sport Fishery is a vital participant in this regulation adjustment, but monitoring efforts need to be updated and improved with more targeted and reliable data collection efforts as well.

USGS scientist helped the U.S. Army Corps of Engineers and FISHBIO to collect and tag adult green sturgeon on the Sacramento River. (Credits: Michael Hellmair, FISHBIO)

Green Sturgeon generally receive more directed analytical and managerial focus from the scientific and regulatory communities since Green Sturgeon sDPS are listed as Threatened under the Federal ESA. Nonetheless, there remain important unmet Informational Needs to support the restoration efforts called for within the Central Valley Project Improvement Act to meet desired goals for this imperiled fish.

Sturgeon **Information Need 1 "Early juvenile survival and growth of wild fish (larvae to age-1)"** describes 5 studies that currently address portions of this information gap. However, the NMFS stated "there are no studies that address juvenile and subadult abundance of sDPS Green Sturgeon."[151] This is a critical element in any effort dedicated to creation of a long-term recruitment study. From such a study, researchers should be able to distinguish causes of the intermittent recruitment patterns, understand the effects of flow on recruitment, and develop a long-term strategy for maintenance of conditions contributing to consistently higher recruitment rates – vital to recovery of sDPS Green Sturgeon.

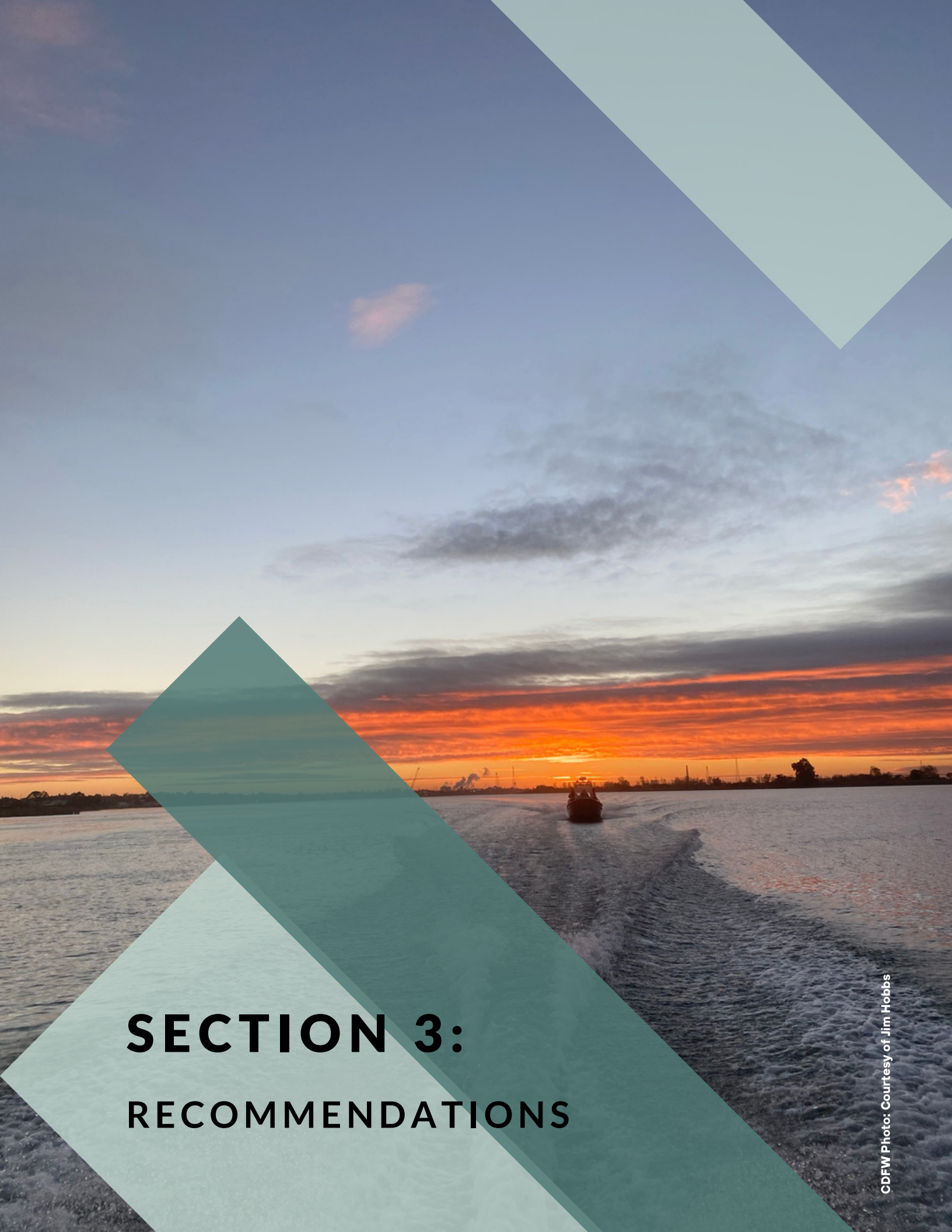
Two out of the three studies that are researching **Informational Need #2 "Adult and subadult survival and movement (system wide)"** for Green Sturgeon are monitoring movements by acoustic tags, while the third study is a research study conducted in the UC Davis lab. Unfortunately, these three studies alone, do not adequately address Informational Need #2 that the CVPIA is requesting. Expanding with additional studies focusing on Adult and Subadult system wide survival and movement would be beneficial to obtaining information that the CVPIA restoration plan can use to build a plan for Green Sturgeon. .

Informational Need #3 (Spawner Abundance Monitoring) is addressed by two studies aimed specifically at Green Sturgeon. One samples fish on the Feather River, which is thought to be used as spawning grounds during wetter years. The other study samples fish on the Upper Sacramento River using side-scan sonar technology. Expanding these studies to other suspected spawning locations, and broadening these studies to include other/additional monitoring techniques will more reliably fulfill this informational need.

The three focused efforts for addressing **Informational Need #4 "Estimate juvenile rearing and adult spawning habitat availability (system wide)"** all attempt to locate suitable spawning habitat and to establish where juvenile rearing is occurring. Researchers still do not know where juvenile Green Sturgeon drift to rear, and there is no evidence yet of juveniles moving into the Delta. One important question posed earlier (Part One, Section 5) is: once Green Sturgeon juveniles move down into the mainstem Sacramento River, where do they go? And is this a point of behavioral divergence between Green and White Sturgeon?

In the final analysis, and after many conversations with subject matter experts and a re-reading of the existing published and grey literatures, there is considerable need to bolster existing monitoring (data collection) efforts and independent research studies to address known knowledge gaps (as listed above). The traditional method of using Catch Per Unit Effort (CPUE) to inform management of sturgeon populations is useful for evaluating long-term trends in abundance over time but is not sufficient to understand what proximal causes of mortality or impairment really control current Sturgeon survival rates, nor does it help in identification of specific recovery actions that may be used to improve sturgeon survival, recruitment, and harvest-adequate population abundances. Even with the number of dedicated subject matter experts that are currently tasked with the job to improve, sustain, or protect sturgeon populations, there does not seem to be any coordinated, focused, or well-resourced State agency management program dedicated to long-term sturgeon conservation like there is for Chinook Salmon or Steelhead. The previously-listed and on-going studies will shed some light on these questions, but with a shifting climate and a highly altered river and Delta system, management needs to be flexible to adjust data collection efforts to match the stated analysis and management objectives. We need to act now to protect and conserve the current populations to ensure healthy sturgeon populations into the future.

In the next section, we provide recommendations to improve data collection and monitoring efforts for White and Green Sturgeon in the San Francisco Estuary, to inform and support management and recovery of the populations.



SECTION 3:

RECOMMENDATIONS

CDFW Photo: Courtesy of Jim Hobbs

This section is a list of recommendations assembled from and focused on the questions and concerns raised by the sturgeon experts that were interviewed (see Appendix A). Each interviewee was asked what they believe is a key area of concern that needs addressing through monitoring and analysis to give sturgeon the best chance of survival and potentially improve overall population numbers. This list includes many of the identified uncertainties posed in the published papers cited throughout this report. We highlight these questions, concerns, and uncertainties as priorities for management and future funding opportunities.

We note three key issues regarding effective understanding and management of sturgeon. The first is the lack of or insufficient data collection (as discussed in the sections above). The second is the lack of a committed and well-resourced plan of action for management and recovery of sturgeon in California. The third is regional climate change, which requires both evolving understanding and the need for increasing urgency when considering the recovery of these populations. Every opinion and imperative expressed below will be subject to the overall trajectory and pace of climate change, and how existing available sturgeon habitat is managed in response to our changing climate and ecosystem conditions.

RECOMMENDATION #1 IMPLEMENT A RECRUITMENT SAMPLING AND ANALYSIS PROGRAM

The Sacramento-San Joaquin White and Green Sturgeon are a long-lived species that are living in a highly altered system. The largest area of concern when it comes to these fish are understanding early life stages and recruitment into the standing population. Much of the sturgeon juvenile stage is unknown, and even more so about their survival rate.

Juveniles are at risk of being diverted or entrained by agricultural and other diversions and are subject to predation by both native and invasive predators. Tagging juveniles is a difficult process, because of their size and the available technology we have today. For Green Sturgeon, once juveniles leave the Bay-Delta and entire marine waters to migrate they become subadults, and once they spawn then they are considered adults. Some subadult Green Sturgeon leave the system for many years, identifying tagging methods that allow us to track fish over the long term is a challenge.

If successful, the data collected from a juvenile recruitment monitoring effort can be used to assess recruitment success in both historically wet and historically dry years. Relating the type of water year to recruitment rate will improve fishery management.

ADDITIONAL JUVENILE LIFE STAGE-RELATED QUESTIONS:

1) Do juveniles use the bypass or other parts of the Delta?
2) Is there existing potential unrealized juvenile sturgeon habitat in the San Joaquin River basin that would benefit from improvement?

RECOMMENDATION #2

ESTABLISH CRITICAL CAUSES OF ADULT MORTALITY AND MIGRATION IMPEDIMENTS

As the human population has expanded in the post-colonial and post-Reclamation era, and as the amount of high-quality Bay-Delta sturgeon-supporting habitat has been reduced to a fraction of what it once was, the remaining sturgeon are subject to many mechanisms contributing to general population declines. Understanding how each source of mortality affects White and Green Sturgeon can aid in identifying potential mitigation strategies.

Reducing bycatch related mortality is a potential key element for improving Bay-Delta Green Sturgeon abundance. For instance, a NMFS study[152] with the offshore California Halibut Bottom Trawl Fishery is focused on developing techniques and gear modifications to reduce the number of Green Sturgeon deaths that are attributed to bycatch from the fishery.

Removing adult sturgeon passage impediments may also contribute to augmenting sturgeon population levels. Many existing passage projects are tailored for salmon and may not work for sturgeon (ex: Sunset Weir can be a passage impediment at certain elevations), and the many diversion and storage dams on California rivers block sturgeon migrations to and from historical spawning grounds.[111]

Harvest is an important component of sturgeon mortality, and understanding the role of harvest rate in shaping sturgeon population structure and behavior will be an important component of successful sturgeon management. Improving the accuracy and reliability of harvest rate data and how this data is used in population assessments or modeling is critical. One recommendation is to establish conservative harvest limits until adequate information is collected to assess the effects of harvest rate on recruitment and the performance of the adult stocks over time.

In 2022, the San Francisco Estuary experienced a large and regional die-off associated with a harmful algal bloom event. Bay-Delta sturgeon fishery management needs to include a plan for responding to and mitigating the effects of similar events into the future. Furthermore, California sturgeon managers should consider the following questions: what would happen to sDPS Green Sturgeon if there was a mortality event (die off) when many of these fish are congregated off the coasts of Washington or British Columbia? What does this mean for management of the California coastal population?

RECOMMENDATION #3
IDENTIFY CURRENT AND FUTURE SPAWNING HABITAT

We know where some sturgeon spawn and researchers understand “ideal” spawning conditions and locations. However, individual fish don’t always choose to lay their eggs in areas suited for optimal egg survival.

There is a hypothesis that sturgeon choose to spawn in these less-than-ideal locations because that is where they have historically spawned. And while these areas are no longer of gravel and coarse material substrates, there is something that is leading sturgeon to spawn there. We also know and can document that spawning locations have been eliminated (or subjected to reduced access) for both Green and White Sturgeon. These factors increase the risk from egg predation, low flows, high sediment deposition, or other detrimental environmental effects that can reduce spawning success.

Management should weigh the cost-benefit ratio of creating new spawning habitat or mitigating for the destruction or alteration of existing spawning habitat. Sturgeon-based water management decisions and creating effective fish passage solutions should also be considered.

Photo: USGS Geology and Ecology of National Parks

RECOMMENDATION #4
ENLARGE THE ADULT STURGEON POPULATION STUDY

We feel a "re-boot" of the Adult Sturgeon Population Study (See Part Two: Section One and Two) effort is necessary to target more explicitly impacts from climate change on adult sturgeon populations (see Recommendation #5). This survey has been deployed from August to October four days a week in Suisun Bay, which is a small temporal sample frame compared to when we know sturgeon are moving through the system. White Sturgeon have been shown to leave the spawning grounds earlier than Green Sturgeon allowing overlap in sample collection coordination between the species given an enlarged temporal scope. Additionally, the survey and tagging effort would benefit from extending into sites in the South Bay which receive far less attention from programs monitoring migrating fish.

RECOMMENDATION #5
INCORPORATE CLIMATE CHANGE IMPACTS INTO POPULATION VIABILITY ASSESSMENTS

Understanding the climate change-related factors that contributed to recent fish kills in the San Francisco Estuary and on the coast of Washington is important because similar event are likely to occur again. Other climate-related events such as drought, warming water temperatures, and increased salinity place stress on sturgeon throughout their lifecycle. Incorporating these factors and their effects on population robustness or viability into estimates of future population trajectories are important, particularly for such a long-lived fish that accumulates these impacts over decades of environmental exposure.

ADDITIONAL QUESTIONS TO CONSIDER:

What future risks can we prepare for?
What is the likelihood that sturgeon populations will be exposed to harmful or stressful conditions region-wide again?

RECOMMENDATION #6
IMPROVE MONITORING AND MAPPING OF FLOODPLAIN HABITAT USE

Understanding sturgeon use of available floodplain habitat and the associated food availability from periodic activation of floodplains will enable a better understanding of life stage dynamics with respect to discovering and using alternate food sources and habitats.

The Sacramento-San Joaquin has changed significantly in a short amount of time (particularly from the perspective of a fish that has long generational times), and water management actions will continue to alter the watershed and its characteristics. These changing characteristics are cumulatively experienced by sturgeon over their long lifespans. Understanding how sturgeon interact with their environment and mapping critical use of floodplain areas is a vital component of conserving our sturgeon into the future.

Diving deeper into genetics can assist in answering some of the questions that are posed in this report, such as how long sturgeon can survive and why. Geneticists are already researching the spontaneous autopolyploidy (having more than two sets of chromosomes from the same species) making sturgeon triploid. There is also the question of "how much gene flows occurs between the nDPS and sDPS?", and what are the genetic differences between sturgeon who spawn in the Sacramento verses the San Joaquin Rivers? How much of their genetics play into their preferences?
UC Davis is conducting genomic studies (as listed previously in Part Two, Section 1) at this time. Sturgeon genetic research may inform a conservation plan to help them adjust to the effects of climate change.

RECOMMENDATION #7

IMPROVE UNDERSTANDING OF STURGEON GENETICS AND IMPLICATIONS FOR MANAGEMENT SCENARIOS

Many of the existing studies are localized in pockets of the Sacramento-San Joaquin River system, and datasets are hard to locate if you are not aware of what to specifically ask for. In addition, some studies only release information through reports or other publications. Agencies and other organizations should consider a more concerted effort into updating their datasets in a timely fashion so that current data is accessible to researchers and resource managers.

It is understandable that maintaining updated datasets takes time and resources and there may be lag time between when data is collected and when they are available in a database. Open communication between researchers and agencies should occur regularly to facilitate collaboration, avoid duplication of efforts, and ensure awareness of existing and future data collection to answer some of these sturgeon data gaps.

RECOMMENDATION #8

REQUIRE PUBLICATION OF DATASETS TO PUBLIC REPOSITORIES AND CREATION OF DEEP METADATA TO ACCOMPANY THESE DATASETS

SUMMARY

Green and White Sturgeon have survived for millions of years and were historically abundant in the San Francisco Estuary and Sacramento- San Joaquin Delta until about 150 years ago. Beamesderfer et al. (2004) states that by 1918 “Once extremely abundant in our larger streams and considered poor food, the sturgeon, now that it is the nearest extinct of all of our food fishes, is considered a delicacy and every attempt is being made to increase its numbers.”[33] While various management attempts have been made to increase abundance, additional actions are needed to improve overall sturgeon population resilience and trajectory. Unfortunately, a robust framework for monitoring and assessing sturgeon populations in the San Francisco Estuary and Sacramento-San Joaquin Delta has not yet been developed or implemented.

It is important that we make credible population abundance estimates to inform harvest rates and properly contextualize age-related mortalities. Age-structured data can be used to inform managers of the status of the reproducing population in the system, and to answer many of the age-specific questions outlined in this report. The San Francisco Estuary and Sacramento-San Joaquin Delta is a vital spawning and rearing location for both White and Green Sturgeon, and yet we know very little compared to similar systems in Oregon and Washington. These other states support monitoring programs that answer many of the questions posed in this report. A first step towards improving our understanding of California sturgeon populations is to learn from efforts in neighboring states that more successfully monitor and manage their native sturgeon populations.

A second step is to re-evaluate the White Sturgeon sports fishery regulations to establish appropriate harvest rates. Without adequate or reliable abundance estimates or properly focused data interpretation, take and/or harvest restrictions need to be updated and re-informed. This is particularly true when considering the catastrophic HAB-related mortality event that occurred in the Estuary in August 2022. Furthermore, the State needs to reassess its dependence on the angler/sport fishery’s contribution for monitoring fisheries catch. Since the 1980s, reported catches on CPFVs have declined, and in recent years only a third of the Sturgeon Fishing Report Cards are returned.

Sturgeon do not have many natural predators other than during early life stages, apart from sea lions. However, sturgeon face multiple anthropogenic threats that we believe are likely causing population declines. Ship strikes, fisheries catch, poaching, entrainment, loss of habitat, viruses, contaminants, harmful algal blooms, and invasive species are all adding to the assault sturgeon populations face in the San Francisco Estuary and Sacramento-San Joaquin Delta. Humans are also narrowing sturgeon spawning windows by changing river and stream outflows and associated aquatic environmental conditions over the year. Coastal development could potentially affect Green Sturgeon feeding on their migrations and watershed development results in reduced available spawning habitat. Simply put, the combined effects of climate change and other anthropogenic threats suggest we have a finite and diminishing timeline with which to conserve and improve the fate of these ancient fish in California.

The purpose of this report is not to say that all is lost, but rather to outline the areas that need to be improved in order to increase sturgeon numbers. By outlining key questions, concerns, and uncertainties, and existing or ongoing projects that target White and Green Sturgeon, we highlight priority needs and efforts to focus on so that we can succeed in the population restoration initiatives that were set decades ago.

FINAL REGULATION NOTE

The previous stated recommendations are still relevant to enact for the survival and continued monitoring of the Sacramento-San Joaquin Sturgeon, and should be considered going forward. However, as previously mentioned at the end of Part 3, Section 1, the proposed emergency regulations were finalized on November 16th, 2023.

- Report cards are still required and all existing regulations apply other than noted below (e.g. existing closures, gear restrictions, etc.).
- The slot limit will change to 42-48" FL (from 40-60" FL)
- The annual bag limit will be reduced to 1 fish (from 3)
    - For 2023 tag holders, if they have already tagged a fish, they are not permitted to harvest any more for the year. If they have not yet tagged a fish, they can tag one. Any remaining tags are invalid
    - 2024 cards will only come with one tag
- There is a maximum vessel harvest limit of two fish per boat per day. Anglers that have not harvested a fish may continue to fish catch and release when the vessel limit is reached.
- Anglers must stop fishing for sturgeon for the day after they tag a fish. They may continue to fish catch and release the rest of the year.
- Seasonal migration and spawning closures on the Sacramento and San Joaquin rivers/tributaries – upstream of the Hwy 50 bridge on the Sacramento River and I-5 bridge on the San Joaquin River:
    - Closed January 1 – May 31 to protect spawning
    - Catch and release June 1 – December 31

No harvest-based sturgeon derbies are permitted going forward, but catch-and-release are fine. This is not included in the emergency regulation, because CDFW already has the authority to manage derbies under other regulations and statutes.

The emergency regulations are expected to last through 2024, though CDFW will have to formally request some extensions with the FGC. The goal is to have new long-term regulations proposed to the FGC in time to start 2025. Those regulations will cap exploitation at 4% of the legal abundance estimate and will include adjustments to slot limit, season/geography, etc.

APPENDIX 1

DATA GAP CHARTS

Table 3
Priority (check marks) and secondary (asterisks) research needs for White Sturgeon throughout the species geographic distribution

	Research needs by river section										
		Columbia River			Snake River			Fraser River			
Research need	Sacramento San Joaquin Bay Delta	Lower	Mid	Upper	Lower	Mid	Kootenai River	Lower	Mid	Upper	Nechako
Spawning and early life											
Identify critical habitats used by early life stage and effects of environmental variables on year-class strength	√	*	√	√	√	√	√	√	√	√	√
Contaminant effects on reproduction	√	√	*	√	√	√	*				
Spawning periodicity	√		*	*	*			*		*	*
Population characteristics											
Validate length-at-age relationships	√				√	√					
Characterize population dynamics and carrying capacity	√	√	√	√	√	√	√	√	√	*	*
Population viability analysis model										√	
Stock composition of coastal and marine population segments	*							*			
Genetic characteristics of population segments	*	√	√	*	√	√		*			
Understand movements, behaviour, and habitat use by juvenile and adult life stages	√		√		*	*	√	√	√	√	√
Ecological interactions											
Pinniped predation	*	√									
Influence of invasive species	*	*	*	*				*			*
Climate change effects on pop. productivity	*			*		*	*			√	*
Nutritional value of the prey base	*	*		*	*	*	*	√	√	√	*
Management											
Quantify anthropogenic mortality	*		*	√		√	*	√	√		√
Long-term population trend data	*	√		*	√	√		*	*		√
Conservation aquaculture programs		*	√	√		√	√				√
Passage studies	*		*	*							

Chart: Hildebrand et al., 2016

Table ES-4. Sturgeon Information Priorities.

The information needs for green and white sturgeon represent short and long-term priorities for improving the sturgeon DSMs and the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.

Sturgeon Information Needs	Duration
Info Need 1: Early juvenile survival and growth of wild fish (larvae to age-1).	>5 years
Info Need 2: Adult and subadult survival and movement (system wide).	>5 years
Info Need 3: Spawner abundance monitoring.	>5 years
Info Need 4: Estimate juvenile rearing and adult spawning habitat availability (system wide).	2–3 years
Info Need 5: White sturgeon spawning distribution.	2–3 years

Table: From the Central Valley Project Improvement Act (CVPIA) Near Term Restoration Strategy

APPENDIX 2

QUESTIONS TO ADDRESS

PART ONE: SECTION ONE

- How do we manage tribal harvest for Green Sturgeon and fishery harvest for White Sturgeon to maintain what is equitable, sustainable, and thoughtful?
- How do we equitably include all diverse parties' mission statements and visions, while having holistic ideas about managing and harvesting sturgeon and keep an open dialog about the challenges that are being faced?

PART ONE: SECTION TWO [DIET]

1. Is there a high food availability in wet years that causes higher recruitment seen in sturgeon?
2. Are green sturgeon feeding on their upriver migrations; and if so, what are they feeding on?
3. Are spawning adults eating during their "recovery" time in the river after spawning? If so, what are they eating?
4. Does either sturgeon consume anything that is endemic to the Delta?
5. Are larval sturgeon influenced to migrate in and out of salinity gradients by food availability or salinity tolerance? (This can especially be asked about green sturgeon)
6. If so, what are they eating in the marine environment in their early life stages?
7. Diversity in the diet promotes growth from exposure to diverse prey. How many sturgeon (or what percentage of sturgeon) migrate upriver to spawn verses feed in different habitats?
8. How does food availability or the quality of spawning habitat affect upriver migration?
9. Management Question: Diet plays a vital role in long-term success, and fewer nutrient dense prey available affects not just sturgeon, but the entire ecosystem as a whole. What resources are needed to conduct diet analyses in the Sacramento-San Joaquin (SSJ) Delta?

PART ONE: SECTION THREE [MORTALITY]

1. What is the age of natural mortality?
2. Are there other sources of mortality that are not listed above?
3. Due to the HAB event that occurred there are cysts of H. akashiwo present in the system now. What does this mean for the sturgeon population in future years? Are we to expect another mass mortality event for sturgeon?
4. What can be done about the contaminants that are affecting recruitment levels?
5. Children, women of child-bearing age, and pre-menopausal women are cautioned against eating White Sturgeon from the San Francisco Estuary.[1] [2] How safe is it for anyone (not just these groups mentioned above) to be consuming sturgeon with these toxins present in their system?
6. Are sturgeon suffering from any diseases in the wild?
7. How can we protect green sturgeon from bycatch in fisheries, such as the California Halibut fishery?
8. Just as we saw a large sturgeon mortality event in the San Francisco Estuary in 2022, Washington state experienced sturgeon mortality event in the early 2000s. The cause is still not fully understood, but how can we prepare for future sturgeon mortality events? What is the likelihood that these events will occur again?
9. What threats are sturgeon being exposed to in the ocean and how can management reduce bycatch in fisheries, and the exposure to low dissolved oxygen, naval exercises, and wind farms?

PART ONE: SECTION FOUR [SPAWNING]

1. What is the male to female ratio?
2. What are the adults doing in the rivers during their migration?
3. What is keeping them in the rivers besides recovering from migrating and spawning? Is it a food source or something else?
4. Age at maturity for sturgeon is still unclear. Why is the range so large?
5. Do sturgeon spawn throughout their life once they have matured or do they cease reproducing at a certain age?
6. How greatly does sedimentation affect Green Sturgeon eggs or where they spawn? Does this keep them from spawning in locations or does it just hinder recruitment?
7. Where are White Sturgeon spawning in the Sacramento-San Joaquin system?
8. What is critical spawning habitat for White and Green Sturgeon?
9. Are they resorting to spawn in unsuitable habitat because that is where they have historically spawned?
10. Is spawning taking place in the water column? Some resources state that they need fast flowing water and deep pools and towards the bottom,[1] but do they spawn close to the floor or more pelagic?
11. Is temperature a factor in triggering spawning?
12. Does streamflow have any impact on sturgeon spawning and movement? Does it affect sturgeon in various systems differently?
13. Some tributaries where eggs have been found have low flow (e.g., the Feather and San Joaquin). Is flow a true indicator for spawning success?
14. Defining the riverine flow regime—How does velocity, flow rate, frequency, duration, seasonality, and rate of change in freshwater discharge over time affect sturgeon?
15. What is the sufficient flow rate to keep eggs from suffocating, keep sturgeon spawning, and maintain optimal temperatures?
16. How will flow and sediment discharge affect migrations?

PART ONE: SECTION FIVE [AGE SPCIFIC INFO]

EGG

- What level of recruitment is being seen?
- Where are sturgeon eggs typically found (habitat qualities)?
- How do sturgeon eggs affect the Delta ecosystem? How influential are they as a food source?

LARVAL

- What level of recruitment is occurring annually?
- Where are sturgeon larvae occurring?
- What habitats are preferred for rearing larvae and by YOY White Sturgeon?
- What behavior do sturgeon larvae exhibit in different habitats?
- How do sturgeon larvae affect the Delta ecosystem? How influential are they as a food source?
- Where do larvae go after they hatch? Do they stay in the river? Flow downstream?
- What food resources are available, and which do they prefer or feed on?
- Are larvae being pushed into an appropriate rearing area? If so, what is special about the habitats that they reside in?
- What predators' prey in sturgeon larvae? What is the level of predation pressure and what factors affect predation pressure?

JUVENILE

- Why are more year classes being represented over others? What is the key factor to recruitment success? What is making others vulnerable?
- What is occurring during these bottleneck events in sturgeon? What is causing that population to survive?
- How does sediment affect them? Especially during high wet and dry years?
- How are they affected to the variation in habitats?
- What is special about the habitats that they reside in?
- There's no evidence of juvenile Green Sturgeon moving into the Delta—which might be another divergence of the species—but they are in the Sacramento River but after 6-9 months where do they migrate to after that?
- What food resources are they capitalizing on?
- Are they following a food resource? (i.e., Herring or shrimp)
- What are the predator constraints in this life stage?
- How do the passage of dams affect them?
- What do they suffer from these hydrological locations? What is the mortality rate for early life stages from entrainment?

SUB-ADULT AND ADULT

- How long can sturgeon live? What is their natural age of mortality?
- What age do they stop spawning?
- What are the key differences that alter the age of maturity in the wild versus the lab?
- Why is the range in age of maturity so large?
- What is the San Francisco Estuary and Sacramento-San Joaquin population size of Green and White Sturgeon?
- What harvest rate can the population sustain?
- How does sediment affect them? Especially during high wet and dry years?
- How many strong cohorts are there over the years?
- Certain systems know where their White Sturgeon are overwintering. Where are the White Sturgeon overwintering in the Sacramento-San Joaquin system?
- What percentage of the Green Sturgeon and White Sturgeon populations go into the Sacramento-San Joaquin system and how long do they stay?
- How are sturgeon affected by invasive species? How is their abundance affected?
- 10 years is a small piece of this long-lived fish's life—how are they affected by these constant alterations to their habitat?
- How do we improve spawning and migrating habitat for them?
- What method is used for aging sturgeon with the most certainty?
- Why do Green Sturgeon make a northern (reverse migration) in the wintertime to non-natal estuaries? Is that for food resource? Better colder waters to get away from predators? Do they save energy? Does it trigger a physiological response? What is the big pay off? Why do some of them not migrate?
- MANAGEMENT QUESTION: What fisheries management measures have been established for Green Sturgeon within this migration route?
- How does low dissolved oxygen events in the coastal ocean affect them?
- What is the ocean distribution on a finer scale?

PART THREE: SECTION THREE [RECOMMENDATIONS]

REC. 1 ADDITIONAL JUVENILE LIFE STAGE-RELATED QUESTIONS:

- Do juveniles use the bypass or other parts of the Delta?
- Is there existing potential unrealized juvenile sturgeon habitat in the San Joaquin River basin that would benefit from improvement?

REC. 5 ADDITIONAL QUESTIONS TO CONSIDER:

- What future risks can we prepare for?
- What is the likelihood that sturgeon populations will be exposed to harmful or stressful conditions region-wide again?

REC. 7 ADDITIONAL QUESTIONS TO CONSIDER:

- How much gene flows occurs between the nDPS and sDPS?
- What are the genetic differences between sturgeon who spawn in the Sacramento verses the San Joaquin Rivers?
- How much of their genetics play into their preferences?

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