Green Sturgeon (Acipenser medirostris): 2014-2020

Bibliography

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Background & Scope

This bibliography focuses on the ESA-listed Southern Distinct Population Segment (sDPS) of the green sturgeon *Acipenser medirostris*. It is intended as a reference resource for ESA staff of the NOAA Fisheries Office of Protected Resources when compiling and summarizing new (i.e. 2014 to present) information on this endangered population. The literature in this bibliography is from 2014 to the present, and includes: peer-reviewed academic work; technical reports and memoranda from local and federal government; biological opinions; fishing season reports and field summaries; and some local news articles relating to this specific sturgeon population. It is organized into four sections: Biology and Life History; Ecology and Habitat Use; Population Abundance and Trends; and Threats.

Section I – Biology and Life History

Section one is intended to provide an overview of the life history of the green sturgeon sDPS. The research in this section includes: its diet; lifespan; morphology; evolution; bioenergetics; DNA and genomics; growth and development; and swimming performance. This section also includes literature on its more general life history and biology.

Section II – Ecology and Habitat Use

Section two is intended to provide an overview of how the green sturgeon interacts with its environment. The research in this area includes information on where the sDPS is located; its migration and movement patterns; fish passage research; habitat selection; and feeding behavior.

Section III – Population Abundance and Trends

Section three is intended to provide an overview of the latest population estimates and trends for the green sturgeon, specifically in the sDPS in California. This literature includes fishing season report cards; field season summaries; observation reports of sturgeon at specific sites; and some information relating to managing the existing population.

Section IV – Threats

A threat is defined as any factor that could represent an impediment to a species' recovery. Thus, section four is intended to provide an overview of any new and/or existing threats to the sDPS of the green sturgeon. These threats include climate change, drought, dams, and various kinds of anthropogenic activity including maritime and riverine construction, poaching, and vessel strikes.

Sources Reviewed

The following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded and Social Science Index; Science.gov; ProQuest's Science and Technology including Aquatic Science Fisheries Abstracts; Elsevier's Science Direct; JSTOR; EBSCO's Academic Search Complete and Environment Complete; NOAA's Institutional Repository; BioOneComplete; and Google Scholar.

Section I: Biology and Life History

Borin, J. M., Moser, M. L., Hansen, A. G., Beauchamp, D. A., Corbett, S. C., Dumbauld, B. R., . . . Donoghue, C. (2017). Energetic Requirements of Green Sturgeon (Acipenser medirostris) Feeding on Burrowing Shrimp (Neotrypaea californiensis) in Estuaries: Importance of Temperature, Reproductive Investment, and Residence Time. *Environmental Biology of Fishes,* 100(12), 1561-1573. https://doi.org/10.1007/s10641-017-0665-3

Habitat use can be complex, as tradeoffs among physiology, resource abundance, and predator avoidance affect the suitability of different environments for different species. Green sturgeon (Acipenser medirostris), an imperiled species along the west coast of North America, undertake extensive coastal migrations and occupy estuaries during the summer and early fall. Warm water and abundant prey in estuaries may afford a growth opportunity. We applied a bioenergetics model to investigate how variation in estuarine temperature, spawning frequency, and duration of estuarine residence affect consumption and growth potential for individual green sturgeon. We assumed that green sturgeon achieve observed annual growth by feeding solely in conditions represented by Willapa Bay, Washington, an estuary annually frequented by green sturgeon and containing extensive tidal flats that harbor a major prey source (burrowing shrimp, Neotrypaea californiensis). Modeled consumption rates increased little with reproductive investment (< 0.4%), but responded strongly (10-50%) to water temperature and duration of residence, as higher temperatures and longer residence required greater consumption to achieve equivalent growth. Accordingly, although green sturgeon occupy Willapa Bay from May through September, acoustically-tagged individuals are observed over much shorter durations (34 d + 41 d SD, N = 89). Simulations of < 34 d estuarine residence required unrealistically high consumption rates to achieve observed growth, whereas longer durations required sustained feeding, and therefore higher total intake, to compensate for prolonged exposure to warm temperatures. Model results provide a range of per capita consumption rates by green sturgeon feeding in estuaries to inform management decisions regarding resource and habitat protection for this protected species.

Chalupnicki, M. A., & Dittman, D. E. (2016). North American Sturgeon Otolith Morphology. *Copeia,* 104(1), 260-266. Retrieved from https://www.jstor.org/stable/44972622

Accurate expedient species identification of deceased sturgeon (Acipenseridae) when external physical characteristic analysis is inconclusive has become a high priority due to the endangered or threatened status of sturgeon species around the world. Examination of otoliths has provided useful information to aid in population management, age and size-class analysis, understanding predator-prey interactions, and archeological research in other fish species. The relationship between otolith characteristics and sturgeon species has remained unknown. Therefore, we analyzed the shape of otoliths from the eight species of sturgeon found in North America to test the utility of otolith characteristic morphology in species identification. There were distinct differences in the size and shape of the otoliths between species of sturgeon with little shape variation among individuals of the same species. The relationship between otolith length axes was linear, and most of the variability was explained by a Log (axis - 1) transformation of the x and y axes (r^2 - 0.8983) using the equation y = 0.73x + 0.0612. Images of otoliths from all eight North American species are presented to assist in the identification process.

Corbett, S. C., Moser, M. L., Johnson, R. B., & Parker, E. L. (2018). A Feeding Experiment Using Captive Green Sturgeon (Acipenser medirostris Ayres, 1854): Testing Non-Invasive Methods to Assess Condition and Growth. *Journal of Applied Ichthyology,* 34(2), 412-418. https://doi.org/10.1111/jai.13567

Non-invasive methods to determine sturgeon condition are needed for both aquaculture and sturgeon conservation. Such information could help optimize feed choice or holding conditions in aquaculture, and/or allow identification of habitats that are important for sturgeon feeding in the wild. The aim was to determine whether lipid levels (measured by a Distell fish fatmeter) could be used to assess changes in green sturgeon (Acipenser medirostris) condition relative to lethal methods (proximate analysis). Thirty non-reproductive and uniquely marked sturgeon (age 9-11, total length 75.1-114 cm, weight 1.9-7.4 kg) were held at the Conte Anadromous Fish Research Center, Turners Fall, Massachusetts, USA, in Connecticut River water at 14 degrees C, and under five different rations: 0.1%, 0.25%, 0.5%, 1.0%, and 1.5% body weight/day. Fatmeter readings and conducted proximate composition analysis were taken on muscle tissue of sacrificed animals after 167 days. Five fatmeter measurements were taken at each of three different sites along the dorsal flank above the lateral line. Muscle fat content was determined at the same locations via supercritical fluid extraction (SFE) using carbon dioxide and an ethanol modifier. Fish fed at >0.1% body weight/day gained weight (mean 0.53 +/- 0.69-0.74 +/- 0.34 kg) and their condition increased by 2%-9% in <6 months. The hepatosomatic index (liver weight/body weight x 100) increased with the ration from 1.12 +/- 0.180 (lowest ration) to 1.96 +/- 0.357 for fish fed at 0.5% body weight/day. Muscle protein content was positively correlated with the ration and inversely correlated with muscle moisture content. In spite of a wide range of final individual muscle lipid levels determined by proximate analysis (0.5%-3.4%), there was no statistical relationship between the two measures of lipid content, regardless of the position of where they were taken on the sturgeon body. Further refinement of this technology, including species-specific calibration, is needed if it is to be used on sturgeon either in aquaculture settings or in the wild.

Cuanang, A. (2014, Jan 2014). Shallow-Water Dinosaurs: California Sturgeon. *Salt Water Sportsman, 75,* 44-48. Retrieved from https://www.saltwatersportsman.com/species/california-sturgeon-shallow-water-dinosaurs/

The day is sunny, and the shallow expanse of San Pablo Bay is glass calm. The outgoing tide kicks in, and like nesting hens, the four of us guard our rod tips. My brother Angelo and I stand amidships, while our friends Dave Scott and Pat Curran watch the stern lines. I don't know how much time has elapsed, but without warning, Curran's rod tip begins to dip.

Curran times the bite perfectly and sets the hook. His spinning rod loads up, and before we know it, a white sturgeon in the 60-pound range dances across the surface. The jump ends with a loud plop, but the moment the fish touches down, it charges down-current on a blistering run. Curran is breathless as he maintains line tension. Eventually the battle ends as Scott makes a deep scoop with the net. Clearing it from the mesh, quick pose shots are taken before Curran releases his finned dinosaur back into the bay.

De Riu, N., Lee, J.-W., Huang, S. S. Y., Moniello, G., & Hung, S. S. O. (2014). Effect of Dietary Selenomethionine on Growth Performance, Tissue Burden, and Histopathology in Green and White Sturgeon. *Aquatic Toxicology,* 148, 65-73. https://doi.org/10.1016/j.aquatox.2013.12.030

A comparative examination of potential differences in selenium (Se) sensitivity was conducted on two sturgeon species indigenous to the San Francisco Bay-Delta. Juvenile green (Acipenser medirostris), recently given a federally threatened status, and white sturgeon (Acipenser transmontanus) were exposed to one of four nominal concentrations of dietary l-selenomethionine (SeMet) (0 (control), 50, 100, or 200mgSeMet/kg diet) for 8 weeks. Mortality, growth performance, whole body composition, histopathology, and Se burdens of the whole body, liver, kidneys, gills, heart, and white muscle were determined every 2 to 4 weeks. Significant ($p<0.05$) mortality was observed in green sturgeon fed the highest SeMet diet after 2 weeks, whereas no mortality was observed in white sturgeon. Growth rates were significantly reduced in both species; however, green sturgeon was more adversely affected by the treatment. Dietary SeMet significantly affected whole body composition and most noticeably, in the decline of lipid contents in green sturgeon. Selenium accumulated significantly in all tissues relative to the control groups. After 4 and 8 weeks of exposure, marked abnormalities were observed in the kidneys and liver of both sturgeon species; however, green sturgeon was more susceptible to SeMet than white sturgeon at all dietary SeMet levels. Our results showed that a dietary Se concentration at 19.7±0.6mgSe/kg, which is in range with the reported Se concentrations of the benthic macro-vertebrate community of the San Francisco Bay, had adverse effects on both sturgeon species. However, the exposure had a more severe pathological effect on green sturgeon, suggesting that when implementing conservation measures, this federally listed threatened species should be monitored and managed independently from white sturgeon.

Dillman, C. B., & Hilton, E. J. (2015). Anatomy and Early Development of the Pectoral Girdle, Fin, and Fin Spine of Sturgeons (Actinopterygii: Acipenseridae). *Journal of Morphology (1931),* 276(3), 241-260. https://doi.org/10.1002/jmor.20328

Acipenseriformes hold an important place in the evolutionary history of bony fishes. Given their phylogenetic position as extant basal Actinopterygii, it is generally held that a thorough understanding of their morphology will greatly contribute to the knowledge of the evolutionary history and the origin of diversity for the major osteichthyan clades. To this end, we examined comparative developmental series from the pectoral girdle in Acipenser fulvescens, A. medirostris, A. transmontanus, and Scaphirhynchus albus to document, describe, and compare ontogenetic and allometric differences in the pectoral girdle. We find, not surprisingly, broad congruence between taxa in the basic pattern of development of the dermal and chondral elements of the pectoral girdle. However, we also find clear differences in the details of structure and development among the species examined in the dermal elements, including the clavicle, cleithrum, supracleithrum, posttemporal, and pectoral-fin spine. We also find differences in the internal fin elements such as the distal radials as well as in the number of fin rays and their association with the propterygium. Further, there are clear ontogenetic differences during development of the dermal and chondral elements in these species and allometric variation in the pectoral-fin spine. The characters highlighted provide a suite of elements for further examination in studies of the phylogeny of sturgeons. Determining the distribution of these characters in other sturgeons may aid in further resolution of phylogenetic relationships, and these data highlight the role that ontogenetic and comparative developmental studies provide in systematics.

Haller, L. Y., Hung, S. S. O., Lee, S., Fadel, J. G., Lee, J.-H., McEnroe, M., & Fangue, N. A. (2015). Effect of Nutritional Status on the Osmoregulation of Green Sturgeon (Acipenser medirostris). *Physiological and Biochemical Zoology,* 88(1), 22-42. https://doi.org/10.1086/679519

Anthropogenic climate change is linked to food web and salinity fluctuations in estuarine environments. Both decreased nutritional status and environmental salinity influence the physiological tolerance and health of fish populations; however, limited information on the interaction of these two factors and their physiological consequences is available. The green sturgeon (Acipenser medirostris) is a species of special concern in California, and the southern distinct population segment is listed as threatened. To test the hypothesis that poor nutrition negatively affects osmoregulation, juvenile green sturgeon (222 d posthatch) were randomly assigned to four feed restriction groups (12.5%, 25%, 50%, and 100% of the optimal feeding rate for 4 wk). Fish were then acutely exposed to 0-, 8-, 16-, or 32-ppt salinities and sampled at three time points (12, 72, or 120 h). Feed restriction significantly ($P < 0.05$) decreased specific growth rate, feed efficiency, condition factor, whole-body lipids, and protein content as well as plasma glucose, triglycerides, and proteins. Furthermore, feed restriction, salinity concentration, and salinity exposure time had significant effects on hematological indexes (hematocrit, hemoglobin), plasma values (osmolality, Na+, K+, Cl?, glucose, lactate, cortisol), enzymatic activity (gill and pyloric ceca Na+/K+ ATPase), and morphology of gill mitochondria-rich cells. The largest disturbances were observed at the highest salinity treatments across all feeding regimes. In addition, the interaction between feed restriction and acute salinity exposure at the highest salinity treatment resulted in high mortality rates during the first 72 h of salinity exposure. Evaluating the interactions of these environmental stressors and their implications on green sturgeon physiological tolerance will inform restoration and management efforts in rapidly changing estuarine environments.

Heublein, J. C., Bellmer, R. J., Chase, R. D., Doukakis, P., Gingras, M., Hampton, D., . . . Stuart, J. S. (2017). Life History and Current Monitoring Inventory of San Francisco Estuary Sturgeon. https://doi.org/10.7289/V5/TM-SWFSC-589

This document describes life history and current monitoring of the two endemic sturgeon species of the San Francisco Estuary watershed: the southern Distinct Population Segment (sDPS) of North American green sturgeon green sturgeon and the Sacramento-San Joaquin River white sturgeon. It serves as background information used in the development of the conceptual models in Heublein et al. (2017). This document as well as Heublein et al. (2017) are fundamental in identifying existing and expanded monitoring needs necessary to track the status, trend, and viability of sDPS green sturgeon identified in National Marine Fisheries Service recovery planning efforts. Finally, this synthesized information is relevant in the development of future quantitative life cycle models for both sturgeon species. A comparative life history and a monitoring inventory are summarized below to relate areas where management actions and monitoring opportunities overlap for the two species and identify factors that may be unique to each species. More detailed life history descriptions and monitoring inventories follow; these are organized by species life stage.

Johnston, M. E., Kelly, J. T., Lindvall, M. E., McElreath, R., & Klimley, A. P. (2017). Experimental Evaluation of the Use of Vision and Barbels as References for Rheotaxis in Green Sturgeon. *Journal of Experimental Marine Biology and Ecology,* 496, 9-15. https://doi.org/10.1016/j.jembe.2017.04.002

Rheotropism (the ability to detect and respond to a current) and rheotaxis (deliberate orientation relative to a current) are widespread in fishes and aquatic organisms, but the relative importance of different sensory modalities as references for the rheotaxis response in fishes is largely unknown. While mechanical stimuli (including water flows) have been used to evaluate rheotaxis behavior in fishes, comparison between sensory modalities is rare, and there has been little or no investigation into the mechanosensory role of barbels in rheotaxis for bottom-oriented fish. We conducted two experiments to evaluate the role of visual stimuli (in the form of an optomotor belt) and barbels in juvenile green sturgeon rheotaxis behavior. The green sturgeon did not exhibit a clear optomotor response, and spent a higher proportion of time positively oriented toward a flowing current than they did toward a moving background in the absence of flow. Removal of barbels increased the average individual tendency to orient positively in the presence of flow. While visual cues almost certainly play a role in rheotaxis behavior at large, individuals vary greatly in their degree of responsiveness to stimuli, and the optomotor stimuli used in our experiments were not as effective as the mechanosensory stimuli in provoking positive rheotaxis. Further, the barbels of green sturgeon do not appear to influence their ability to display positive rheotaxis in the presence of water current.

Katopodis, C., Cai, L., & Johnson, D. (2019). Sturgeon Survival: The Role of Swimming Performance and Fish Passage Research. *Fisheries Research,* 212, 162-171. https://doi.org/10.1016/j.fishres.2018.12.027

The rapid decline in sturgeon populations is largely a result of human activities, especially the proliferation of hydraulic structures and lack of fish passage systems effective for sturgeon. This review highlights: (1) the importance of sturgeon conservation; (2) the need for data on swimming performance, including capability, metabolism and kinematics; (3) the relevance and limitations of swimming performance data in designing fish passage systems; (4) the need for experiments to develop sturgeon fishways that better reflect natural conditions. A proper understanding of swimming performance is crucial for designing effective fish passage systems. Although swimming performance and fish passage have been investigated for decades, knowledge and results have been limited by biological, methodological and analytical restrictions. To continue advancing passage effectiveness, continued research is necessary on sturgeon swimming performance and its interface with complex fishway hydraulics.

Kornienko, I. V., Chebotarev, D. A., Makhotkin, M. A., Grigoriev, V. A., Ponomareva, E. N., & Matishov, G. G. (2019). Termination of Replication and Mechanisms of Heteroplasmy in Sturgeon Mitochondrial DNA. *Molecular Biology,* 53(1), 107-117. https://doi.org/10.1134/s0026893319010060

The control region of mitochondrial DNA (mtDNA) in sturgeon contains one to seven tandem nucleotide repeats 7883 bp in size. Some sturgeon species are homoplasmic by the D-loop size (Acipenser nudiventris, A. oxyrinchus, A. sturio), some are mildly heteroplasmic (A. fulvescens, Huso huso) and

some are markedly heteroplasmic (A. brevirostrum, A. medirostris, A. mikadoi, A. naccarii, and A. transmontanus). This work presents a comparison of the D-loop sequences associated with the termination of mtDNA replication in fish and the conservative sequences determining the termination of replication (TAS) in these organisms. It is proposed that the D-loop heteroplasmy in sturgeon may be associated with variation in the number of tandem repeat sequences, which can form stable spatial structures during mtDNA replication. In most sturgeon species with pronounced heteroplasmy, the energy levels required for the folding of tandem repeats containing variable number of repeated units differ minimally.

Lee, S., Hung, S. S. O., Fangue, N. A., Haller, L., Verhille, C. E., Zhao, J., & Todgham, A. E. (2016). Effects of Feed Restriction on the Upper Temperature Tolerance and Heat Shock Response in Juvenile Green and White Sturgeon. *Comparative Biochemistry and Physiology A-Molecular & Integrative Physiology,* 198, 87-95. https://doi.org/10.1016/j.cbpa.2016.04.016

The objective of the current study was to investigate the effects of feed restriction on whole-organism upper thermal tolerance and the heat shock response of green and white sturgeon to determine how changes in food amount might influence physiological performance of each species when faced with temperature stress. Two parallel feed restriction trials were carried out for juvenile green (202 g; 222-day post hatch: dph) and white sturgeon (205 g; 197-dph) to manipulate nutritional status at 12.5%, 25%, 50%, or 100% of optimum feeding rate (100% OFR were 1.6% and 1.8% body weight/day, respectively) for four weeks. Following the trials, the critical thermal maximum (CTMax, 0.3 degrees C/min) of sturgeon (N = 12/treatment/species) was assessed as an indicator of whole-organism upper thermal tolerance. To assess temperature sensitivity, sturgeon (N = 9/treatment/species) were acutely transferred to two temperature treatments (28 degrees C and 18 degrees C as a handling control) for 2 h followed by 2 h of recovery at 18 degrees C before being sacrificed, and gill, brain, and mucus sampled for measurements of 70-kDa heat shock protein levels (Hsc/Hsp70). Feeding rate had species-specific effects on CTMax in green and white sturgeon such that CTMax of green sturgeon decreased as the magnitude of feed restriction increased; whereas, CTMax of white sturgeon did not change with feed restriction. Elevated temperature (28 degrees C) and feed restriction increased Hsc/Hsp70 levels in the gill tissue of green sturgeon, while heat shock increased Hsc/Hsp70 levels in the mucus of white sturgeon. Our results suggest that green sturgeon may be more susceptible to temperature stress under food-limited conditions.

Lin, C. Y., Huang, L. H., Deng, D. F., Lee, S. H., Liang, H. J., & Hung, S. S. O. (2019). Metabolic Adaptation to Feed Restriction on the Green Sturgeon (Acipenser medirostris) Fingerlings. *Science of the Total Environment,* 684, 78-88. https://doi.org/10.1016/j.scitotenv.2019.05.044

Food restriction may cause severe biological effects on wildlife and lead to population decline and extinction. The objective of the current study was to examine the metabolic effects on green sturgeon in response to feed restriction. Green sturgeon fingerlings were fed for two weeks at 12.5. 25. 50 and 100% of the optimum feeding rate (OFR), which corresponded to 0.25. 0.50, 1.00, and 2.00% body weight per day. We characterized the changes in hydrophilic and hydrophobic metabolites from extracts of muscle, liver, and kidney using nuclear magnetic resonance spectroscopy followed by multivariate statistical analysis. The results of principal component analysis (PCA) score plots from the analyses of

hydrophilic metabolites showed that they exhibited a greater response to feed restriction than hydrophobic metabolites. In general, the hydrophilic metabolites in tissues from fish fed 05% of the OFR were separated from those fed 100% of the OFR in the PCA score plots. Among the three types of tissues examined, the overall metabolite changes showed a greater response to feed restriction in kidney tissue than in liver or muscle tissues. Numerous glucogenic amino acids in muscle and most amino acids in the kidney were decreased under feed restriction conditions. A significant decrease in ketone bodies (3-hydroxyisobutyrate) was observed in the muscle. Most fatty acids except for glycerol, phospholipid and cholesterol in the liver and kidney tissues were decreased under feed restriction conditions. Creatine phosphate, taurine and glycine were also significantly increased in tissues under feed restriction conditions. In conclusion, this study suggests that the manipulation of feed restriction under the current conditions perturbed metabolites related to energy metabolism, osmolality regulation, and antioxidation capacity in the sturgeon.

Miller, E. A., Froehlich, H. E., Cocherell, D. E., Thomas, M. J., Cech, J. J., Klimley, A. P., & Fangue, N. A. (2014). Effects of Acoustic Tagging on Juvenile Green Sturgeon Incision Healing, Swimming Performance, and Growth. *Environmental Biology of Fishes,* 97(6), 647-658. https://doi.org/10.1007/s10641-013-0167-x

Ultrasonic telemetry is a preferred method for fish-movement studies. Despite surgical tag implantation being the most common method for affixing tags, many studies lack tests addressing the assumption that tagging has no effect on fish performance or survival. The threatened, anadromous green sturgeon, Acipenser medirostris, has little documentation concerning its movements. We evaluated the effects of surgery and tag implantation in juveniles. We compared three groups: tagged fish with dummy transmitters implanted in the peritoneal cavity, sham fish that underwent surgery without tag implantation, and control fish that were handled and anesthetized but did not undergo surgery. We found no differences in growth or critical swimming velocity among groups. Photos of incisions were taken towards the beginning and at the end of the study to assess inflammation and to score each incision for closure and suture retention. Inflammation declined similarly for tagged and sham fish during the study. U^sub crit^ was not related to the extent of inflammation or to post-surgery time. All fish showed healing during the study (ca. 140 day duration) and 10 % of tagged and sham fish showed signs of inflammation by the study end. These results suggest that current ultrasonic surgical tagging methods do not significantly affect the short-term growth or swimming performance of juvenile green sturgeon. Additionally, effects of surgery can be mitigated by minimizing the number of suture entry points and by using rapid-absorbing sutures.

Moser, M. L., Corbett, S. C., Burke, B. J., & Langness, O. P. (2018). Potential for Use of Accelerometers to Monitor Green Sturgeon Acipenser medirostris (Ayres, 1854) Behavior after Handling. *Journal of Applied Ichthyology,* 34(2), 405-411. https://doi.org/10.1111/jai.13571

A pilot study was conducted to test the use of accelerometer tags (coded acoustic transmitters equipped with inertial sensors) to detect changes in green sturgeon activity following gillnet capture and release. Green sturgeon Acipenser medirostris (Ayres, 1854) is listed as threatened under the Endangered Species Act, but is captured as bycatch in both estuarine and coastal gillnet and trawl fisheries. Measured were tailbeat activity and swimming depth of sturgeon (145-167 cm fork length) caught with

gillnets in Willapa Bay, Washington during late July 2011. These data were transmitted acoustically over a period of up to 55 d to an array of 16 receivers positioned in the bay. Transmitters were either surgically implanted (n = 2) or attached externally to the dorsal scutes (n = 2). In spite of the small number of fish tagged, over 4,800 data transmissions were obtained, with three fish detected over more than 46 d and in estuaries up to 55 km from the release site. Breakpoint regression analysis indicated that the accelerometers could be used to document discrete changes in activity of the fish after handling. Use of this technology could therefore allow the identification of fishing methods that are most harmful to protected species.

Moser, M. L., Israel, J. A., Neuman, M., Lindley, S. T., Erickson, D. L., McCovey, B. W., & Klimley, A. P. (2016). Biology and Life History of Green Sturgeon (Acipenser medirostris Ayres, 1854): State of the Science. *Journal of Applied Ichthyology,* 32, 67-86. https://doi.org/10.1111/jai.13238

Green Sturgeon (GRS) Acipenser medirostris is one of the most marine-oriented of all sturgeons. It primarily spawns in the Sacramento, Klamath, and Rogue Rivers, yet lives most of its life in estuarine and coastal waters along the West Coast of North America. Spawning is only known to occur in the Rogue, Klamath and Sacramento rivers and optimal temperatures for egg incubation and larval growth are not always maintained in these dammed and highlyregulated systems. Genetic analysis and acoustic telemetry have confirmed the presence of two genetically distinct populations; the southern population is listed as "threatened" under the ESA. Adults only enter natal rivers to spawn every 1-4 years. They make extensive coastal migrations in depths <80 m and move between estuaries where they aggregate in summer. The long marine occupancy of GRS potentially exposes them to mortality from various marine activities such as bottom trawl fishing, dredging, and ocean energy projects, but also provides a theoretical reservoir of fish to support viable populations. Critically-needed information for protection of this species includes: accurate annual population size estimates, data on distribution and habitat requirements for larvae and juveniles, and assessment of mortality due to bycatch, poaching and marine mammal predation.

Poletto, J. B., Cocherell, D. E., Ho, N., Cech, J. J., Klimley, A. P., & Fangue, N. A. (2018). The Effect of Size on Juvenile Green Sturgeon (Acipenser medirostris) Behavior near Water-Diversion Fish Screens. *Environmental Biology of Fishes,* 101(1), 67-77. https://doi.org/10.1007/s10641-017-0681-3

Anthropogenic water management projects and facilities that alter the local and regional hydrology of riverine environments greatly influence the behavior, physiology, and survival of native fishes. To mitigate for losses of native fishes at these structures, many are outfitted with fish-exclusion screens to reduce entrainment. The effect of fish size and age on behavior near fish screens, however, is largely unknown. Therefore, we tested two size classes of juvenile green sturgeon (Acipenser medirostris; small, early juveniles: 9.2 +/- 0.2 cm fork length [FL], 6.9 +/- 0.3 g; intermediate juveniles: 18.8 +/- 0.2 cm FL, 36.9 +/- 0.8 g) near fish-exclusion screens in a laboratory swimming flume. Although size was a significant factor influencing the way in which fish contacted the screens (i.e., proportion of body contacts, p = 2.5 x 10(-9)), it did not significantly influence the number of times fish contacted screens or the amount of time fish spent near screens. We also compared the performance of these two size classes to that of older and larger sturgeon that were tested previously (29.6 +/- 0.2 cm FL, 147.1 +/- 3.1 g), and documented a clear difference in the behavior of the fish that resulted in disparities in how the

large fish contacted screens relative to small- or intermediate-sized juveniles (p = 0.005, 5.4 x 10(-4), respectively). Our results further our understanding of how ontogeny affects fish behavior near anthropogenic devices, and are informative for managers seeking to identify the most susceptible size and age class of juvenile green sturgeon to water-diversion structures to potentially develop size-specific conservation strategies.

Recovery Plan for the Southern Distinct Population Segment of North American Green Sturgeon (Acipenser medirostris). (2018). Sacramento, CA Retrieved from https://www.fisheries.noaa.gov/action/recovery-plan-southern-distinct-population-segment-north-american-green-sturgeon-acipenser

The goal of this recovery plan is to recover sDPS green sturgeon and consequently remove it from the Federal List of Endangered and Threatened Wildlife. Achieving this goal will have a number of economic, societal, and ecosystem benefits. Delisting of the sDPS may result in opening fisheries that were closed due to direct or incidental sDPS mortality, resulting in economic and recreational benefits. The ESA regulatory burden will also be eased for fisheries, water resource, industrial, and commercial activities. Accomplishing the habitat restoration measures will also result in more functional ecosystems that support other economic activities and contribute to the conservation and recovery of other species.

Shedko, S. V. (2017). The Low Level of Differences between Mitogenomes of the Sakhalin Sturgeon Acipenser Mikadoi Hilgendorf, 1892 and the Green Sturgeon A. Medirostris Ayeres, 1854 (Acipenseridae) Indicates Their Recent Divergence. *Russian Journal of Marine Biology,* 43(2), 176-179. https://doi.org/10.1134/s1063074017020080

The complete mitochondrial genome of the Sakhalin sturgeon Acipenser mikadoi and two mitogenomes of the Amur sturgeon A. schrenckii were sequenced using Roche 454 technology. The mitogenomes of the green sturgeon A. medirostris (obtained from GenBank) and the Sakhalin sturgeon differ as much as the mitogenomes of two mtDNA haplogroups (SM and BG) found in the same population of the Amur sturgeon: 0.0042 +/- 0.0006 and 0.0036 +/- 0.0005 substitutions per site (Tamura-Nei distance, TrN), respectively. The differences of these mitogenome pairs from mitogenomes of sister species (kaluga A. dauricus and white sturgeon A. transmontanus) are 3-6 times larger: 0.0260 +/- 0.0015 and 0.0102 +/- 0.0008, respectively. Thus, the differences between the mitogenomes of the Sakhalin and green sturgeons can be attributed to the variability at the intraspecific level. The time that has passed since the divergence of the Sakhalin and green sturgeons is considered to be much shorter than was previously believed: approximately 0.16 rather than 9.60 million years.

Southern Distinct Population Segment of the North American Green Sturgeon (Acipenser medirostris) 5-Year Review: Summary and Evaluation. (2015). Long Beach, CA: National Marine Fisheries Service, West Coast Region Retrieved from https://repository.library.noaa.gov/view/noaa/17034

The 5-year review was conducted by a contractor in collaboration with personnel at the NOAA NMFS West Coast Region (Long Beach office). The review process included collecting information through the following: 1) a literature search for information published since the last review (2006); 2) publication of a Federal Register (FR) notice soliciting new information about North American green sturgeon (77 FR 64595; October 24, 2012); and 3) email and phone contact with knowledgeable individuals at universities, tribal agencies, and state and federal government agencies (Appendix A). Eleven (11) responses to the FR notice were received from 11 different agencies or individuals and included information on population abundance, reviews of recent literature, lists of agency reports summarizing fieldwork, fisheries data, salvage, and academic scientific studies. A draft version of this report was reviewed by West Coast Region and NMFS Northwest Fisheries Science Center personnel in addition to those listed in Appendix B. This report describes the most relevant of the new information about North American green sturgeon and how it relates to the status of the Southern Distinct Population Segment (DPS) of green sturgeon (Acipenser medirostris). Some information on the Northern DPS is also included where relevant. Since the Northern DPS is not listed under the Endangered Species Act, a full review of its status is not included here, but a review has been conducted, added to our file and made publically available.

Vaz, P. G., Kebreab, E., Hung, S. S. O., Fadel, J. G., Lee, S., & Fangue, N. A. (2015). Impact of Nutrition and Salinity Changes on Biological Performances of Green and White Sturgeon. *Plos One,* 10(4). https://doi.org/10.1371/journal.pone.0122029

Green and white sturgeon are species of high conservational and economic interest, particularly in the San Francisco Bay Delta (SFBD) for which significant climate change-derived alterations in salinity and nutritional patterns are forecasted. Although there is paucity of information, it is critical to test the network of biological responses underlying the capacity of animals to tolerate current environmental changes. Through nutrition and salinity challenges, climate change will likely have more physiological effect on young sturgeon stages, which in turn may affect growth performance. In this study, the two species were challenged in a multiple-factor experimental setting, first to levels of feeding rate, and then to salinity levels for different time periods. Data analysis included generalized additive models to select predictors of growth performance (measured by condition factor) among the environmental stressors considered and a suite of physiological variables. Using structural equation modeling, a path diagram is proposed to quantify the main linkages among nutrition status, salinity, osmoregulation variables, and growth performances. Three major trends were anticipated for the growth performance of green and white sturgeon in the juvenile stage in the SFBD: (i) a decrease in prey abundance will be highly detrimental for the growth of both species; (ii) an acute increase in salinity within the limits studied can be tolerated by both species but possibly the energy spent in osmoregulation may affect green sturgeon growth within the time window assessed; (iii) the mechanism of synergistic effects of nutrition and salinity changes will be more complex in green sturgeon, with condition factor responding nonlinearly to interactions of salinity and nutrition status or time of salinity exposure. Green sturgeon merits special scientific attention and conservation effort to offset the effects of feed restriction and salinity as key environmental stressors in the SFBD.

Verhille, C. E., Lee, S., Todgham, A. E., Cocherell, D. E., Hung, S. S. O., & Fangue, N. A. (2016). Effects of Nutritional Deprivation on Juvenile Green Sturgeon Growth and Thermal Tolerance. *Environmental Biology of Fishes,* 99(1), 145-159. https://doi.org/10.1007/s10641-015-0463-8

In the San Francisco Estuary (SFE), declines in the abundance of native fish species have been linked to altered food webs and reduced food availability (Moyle 2002; Feyrer et al. 2003; Kimmerer 2004). This is particularly concerning for protected green sturgeon (Acipenser medirostris Ayres, 1854) populations restricted to the SFE during early life stages. Green sturgeon are composed of at least two genetically distinct and protected populations (Israel et al. 2009): the Northern and Southern Distinct Population Segments (DPS), and spawn only in Oregon and California, USA. Details of the current distribution and spawning locations of these fish can be found in Beamesderfer et al. (2007). Briefly, anadromous adult green sturgeon spend most of their lives in the marine environment, with seasonal migrations between natal freshwater spawning grounds and the ocean. Adults of the Northern DPS, which is classified as a species of concern by the National Oceanic and Atmospheric Administration (NOAA) of the USA, spawn in rivers north of the Eel River of northwest California (Adams et al. 2007). The Southern DPS is classified as threatened under the Endangered Species Act, and all suspected and confirmed spawning locations are within the watershed of the Sacramento and San Joaquin rivers (Adams et al. 2007). As juvenile green sturgeon are intolerant of full strength seawater until they are 0.5 to 1.5 years old (Allen and Cech 2007; Allen et al. 2009, 2011), habitat is restricted to the fresh to brackish water sections of the SFE for early life stages.

Verhille, C. E., Poletto, J. B., Cocherell, D. E., DeCourten, B., Baird, S., Cech, J. J., Jr., & Fangue, N. A. (2014). Larval Green and White Sturgeon Swimming Performance in Relation to Water-Diversion Flows. *Conservation Physiology,* 2(1). https://doi.org/10.1093/conphys/cou031

Little is known of the swimming capacities of larval sturgeons, despite global population declines in many species due in part to fragmentation of their spawning and rearing habitats by man-made water-diversion structures. Larval green (Acipenser medirostris) and white sturgeon (Acipenser transmontanus) inhabit the highly altered Sacramento–San Joaquin watershed, making them logical species to examine vulnerability to entrainment by altered water flows. The risk of larval sturgeon entrainment is influenced by the ontogeny of swimming capacity and dispersal timing and their interactions with water-diversion structure operations. Therefore, the aim of this study was to describe and compare the ontogeny and allometry of larval green and white sturgeon swimming capacities until completion of metamorphosis into juveniles. Despite the faster growth rates and eventual larger size of larval white sturgeon, green sturgeon critical swimming velocities remained consistently, though modestly, greater than those of white sturgeon throughout the larval life stage. Although behavioural interactions with water-diversion structures are also important considerations, regarding swimming capacity, Sacramento–San Joaquin sturgeons are most vulnerable to entrainment in February–May, when white sturgeon early larvae are in the middle Sacramento River, and April–May, when green sturgeon early larvae are in the upper river. Green sturgeon migrating downstream to the estuary and bays in October–November are also susceptible to entrainment due to their movements combined with seasonal declines in their swimming capacity. An additional inter-species comparison of the allometric relationship between critical swimming velocities and total length with several sturgeon species found throughout the world suggests a similar ontogeny of swimming capacity with growth. Therefore, although dispersal and behaviour differ among river systems and sturgeon species, similar

recommendations are applicable for managers seeking to balance water demands with restoration and conservation of sturgeons worldwide.

Willmes, M., Glessner, J. J. G., Carleton, S. A., Gerrity, P. C., & Hobbs, J. A. (2016). Sr-87/Sr-86 Isotope Ratio Analysis by Laser Ablation MC-ICP-MS in Scales, Spines, and Fin Rays as a Nonlethal Alternative to Otoliths for Reconstructing Fish Life History. *Canadian Journal of Fisheries and Aquatic Sciences,* 73(12), 1852-1860. https://doi.org/10.1139/cjfas-2016-0103

Strontium isotope ratios (Sr-87/Sr-86) in otoliths are a well-established tool to determine origins and movement patterns of fish. However, otolith extraction requires sacrificing fish, and when working with protected or endangered species, the use of nonlethal samples such as scales, spines, and fin rays is preferred. Unlike otoliths that are predominantly aragonite, these tissues are composed of biological apatite. Laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICP-MS) analysis of biological apatite can induce significant interference on mass 87, causing inaccurate Sr-87/Sr-86 measurements. To quantify this interference, we applied LA-MC-ICP-MS to three marine samples (white seabass (Atractoscion nobilis) otolith; green sturgeon (Acipenser medirostris) pectoral fin ray; salmon shark (Lamna ditropis) tooth), and freshwater walleye (Sander vitreus) otoliths, scales, and spines). Instrument conditions that maximize signal intensity resulted in elevated Sr-87/Sr-86 isotope ratios in the bioapatite samples, related to a polyatomic interference ((CaPO)-Ca-40-P-31-O-16, (ArPO)-Ar-40-P-31-O-16). Retuning instrument conditions to reduce oxide levels removed this interference, resulting in accurate Sr-87/Sr-86 ratios across all tissue samples. This method provides a novel, nonlethal alternative to otolith analysis to reconstruct fish life histories.

Zheng, K., Wang, W., Hung, S. S. O., & Deng, D.-F. (2015). Feeding Rates Affect Expression of Heat-Shock Protein 70 in Green Sturgeon Fry. *North American Journal of Aquaculture,* 77(2), 206-210. https://doi.org/10.1080/15222055.2014.987931

Two growth trials were conducted to determine the effect of feeding rate on the responses of a heat-shock protein (hsp70) in the fry of Green Sturgeon Acipenser medirostris. Four tanks were randomly assigned to each feeding treatment: 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0% of body weight/d in trial I and 2.0, 3.0, 4.0, 5.0, 6.0 and 7.0% of body weight/d for trial II. The fry were raised indoor at 18°C and fed a commercial salmonid soft-moist diet. Densities were 50 fry/tank in trial I fed for 49 d posthatch (dph) and 30 fry/tank in trial II fed for 70 dph. At the end of 1 week of feeding, five fish from each tank were subjected to heat shock by increasing the water temperature from 18°C to 28°C at a rate of 4°C/h and then holding at 28°C thereafter for 4 h before tissue samples were collected. Heat shock induced significant changes in the levels of hsp70 in the liver and white muscle of fish in all feeding treatments. However, feeding rate treatments had no significant effect on the basal and heat-shocked levels of hsp70 in the liver of these fish. The lowest feeding rate significantly depressed the induced level of hsp70 in the muscle of Green Sturgeon. A feeding rate of 10.0% of body weight/d is suggested for Green Sturgeon at 49 dph and 6.0% at 70 dph, based on their maximum responses of hsp70 in white muscle tissue. This study indicates that the response of hsp70 in the liver and muscle of Green Sturgeon is sensitive to heat-shock stress. The effect of different feeding rates on the response of hsp70 is also tissue-dependent. This variation should be considered when hsp70 is used as a biomarker to evaluate heat-shock response.

Zheng, K. K., Deng, D. F., De Riu, N., Moniello, G., & Hung, S. S. O. (2015). The Effect of Feeding Rate on the Growth Performance of Green Sturgeon (Acipenser medirostris) Fry. *Aquaculture Nutrition,* 21(4), 489-495. https://doi.org/10.1111/anu.12179

Four one-week growth trials were conducted on green sturgeon fry to determine the effect of feeding rate on their growth performance at 18 °C when they were fed a salmonid soft moist feeds containing 445–457 g kg^{-1} of crude protein and 201–207 g kg^{-1} of lipid. The fry used in Trials I-IV were 5–8 weeks after their initiation of exogenous feeding. Their average initial body weights were 1.63 ± 0.01, 2.63 ± 0.03, 5.08 ± 0.08 and 7.49 ± 0.05 g, respectively. Six feeding rates used were as follows: 2.5–15.0% body weight per day (% BW day^{-1}) with a 2.5% increment in Trial I; 1.25–7.50% BW day^{-1} with a 1.25% increment in Trial II; and 2.0–7.0% BW day−1 with a 1.0% increment in T rials III and IV . Four replicates with 50 fry per tank in Trials I-III and 30 fry per tank in Trial IV were assigned randomly to each feeding rates. The final body weight, specific growth rate, feed efficiency, protein retention, and whole-body moisture, lipid, and energy contents were significantly ($P<0.05$) affected by the feeding rates. The optimum feeding rates determined by the broken-line model were 7.1, 5.7 and 5.3% BW day^{-1} for Trials I, II and IV, when the fry were 5, 6 and 8 weeks after their initiation of exogenous feeding, respectively.

Section II: Ecology and Habitat Use

Bergman, P. S., Schumer, G., Blankenship, S., & Campbell, E. (2016). Detection of Adult Green Sturgeon Using Environmental DNA Analysis. *Plos One,* 11(4). https://doi.org/10.1371/journal.pone.0153500

Environmental DNA (eDNA) is an emerging sampling method that has been used successfully for detection of rare aquatic species. The Identification of sampling tools that are less stressful for target organisms has become increasingly important for rare and endangered species. A decline in abundance of the Southern Distinct Population Segment (DPS) of North American Green Sturgeon located in California's Central Valley has led to its listing as Threatened under the Federal Endangered Species Act in 2006. While visual surveys of spawning Green Sturgeon in the Central Valley are effective at monitoring fish densities in concentrated pool habitats, results do not scale well to the watershed level, providing limited spatial and temporal context. Unlike most traditional survey methods, environmental DNA analysis provides a relatively quick, inexpensive tool that could efficiently monitor the presence and distribution of aquatic species. We positively identified Green Sturgeon DNA at two locations of known presence in the Sacramento River, proving that eDNA can be effective for monitoring the presence of adult sturgeon. While further study is needed to understand uncertainties of the sampling method, our study represents the first documented detection of Green Sturgeon eDNA, indicating that eDNA analysis could provide a new tool for monitoring Green Sturgeon distribution in the Central Valley, complimenting traditional on-going survey methods.

Cech, J. (2017). Saving California's Native Fishes: Physiological and Behavioural Approaches. *Conservation Physiology,* 5. https://doi.org/10.1093/conphys/cox044

Many of California's diverse, freshwater habitats have been modified, limiting the normal movements of many resident and migratory fishes. My students, colleagues and I used physiological and behavioural approaches to study the environmental requirements of native fishes that had low, or steeply declining, population sizes. Findings included swimming muscle 'remodelling' and decreases in sustained swimming performance in coho salmon as they developed towards their salt-water life-stage. These results, plus those on juvenile green sturgeon's decreases in swimming performance with saltwater readiness and this species' vulnerability to water diversions, should help natural resource managers set stream and river standards to ensure adequate flows for preserving our natural heritage of native fishes.

Cooke, S. J., Cech, J. J., Glassman, D. M., Simard, J., Louttit, S., Lennox, R. J., . . . O'Connor, C. M. (2020). Water Resource Development and Sturgeon (Acipenseridae): State of the Science and Research Gaps Related to Fish Passage, Entrainment, Impingement and Behavioural Guidance. *Reviews in Fish Biology and Fisheries,* 30(2), 219-244. https://doi.org/10.1007/s11160-020-09596-x

Acipenserids (sturgeons) live in large rivers and lakes in North America and Eurasia, where many species and populations are considered imperiled. One of the most pervasive threats across the global range of sturgeon is water resource development (e.g., hydropower dams, water intakes for irrigation, industrial use, or human consumption). We report on the outcome of a literature review focused on interactions

between sturgeon and water resource development. We focused on the persistent issue of dam passage (both upstream and downstream), impingement, and entrainment, which are all relevant issues for both existing and planned facilities. We discuss aspects of sturgeon sensory physiology, and how knowledge of sensory physiology can be used for behavioural guidance. We also consider how the swimming ability and style of sturgeon is relevant for passage. Most of the literature emanated from research on just a few species (especially lake sturgeon, white sturgeon, green sturgeon, and shortnose sturgeon). Although there are several examples of apparent "success stories" (e.g., successful upstream fish passage, efforts to reduce impingement and entrainment), there are also many failures, and such examples are likely under-reported. Without significant investments in solutions-oriented research related to sturgeon-water resource development interactions, we submit that fish passage, entrainment and impingement problems for acipenserids will remain. There is a need for research that spans life-stages, compares different species, and considers how passage, entrainment, and impingement influence demography. Further, there is a need for investment into evidence-based implementation of mitigation infrastructure and management strategies to ensure conservation needs of sturgeons are adequately considered.

Corline, N. J., Sommer, T., Jeffres, C. A., & Katz, J. (2017). Zooplankton Ecology and Trophic Resources for Rearing Native Fish on an Agricultural Floodplain in the Yolo Bypass California, USA. *Wetlands Ecology and Management,* 25(5), 533-545. https://doi.org/10.1007/s11273-017-9534-2

Out-migrating juvenile Chinook Salmon Oncorhynchus tshawytscha in California's Central Valley lack frequent access to historical off-channel habitats such as floodplains. However, many regions have agricultural floodplains that may provide habitat value to young salmon. To determine the suitability of agricultural floodplain, this study tested whether winter-inundated rice fields in a historic flood basin in California's Central Valley could provide adequate food resources for rearing juvenile Chinook Salmon. We examined the suitability of flooded rice fields for three post-harvest habitat types: stubble, fallow, and disced. Soil emergent and pelagic zooplankton communities were compared to determine colonization sources. Winter-inundated rice fields had high densities of zooplankton, which increased over the course of the study. Daphnia pulex, a large-bodied cladoceran and an excellent forage species of juvenile Chinook Salmon, was abundant in our study. Cladocerans colonized via source water while ostracods likely colonized from a soil egg bank. Overall, there was no discernable effect of habitat type on zooplankton community structure or density, except for D. pulex. Our results suggest that flooded agricultural rearing habitat can support juvenile Chinook Salmon based on high densities of zooplankton and other suitable habitat conditions have the potential to support a robust aquatic food web.

Hamda, N. T., Martin, B., Poletto, J. B., Cocherell, D. E., Fangue, N. A., Van Eenennaam, J., . . . Danner, E. (2019). Applying a Simplified Energy-Budget Model to Explore the Effects of Temperature and Food Availability on the Life History of Green Sturgeon (Acipenser medirostris). *Ecological Modelling,* 395, 1-10. https://doi.org/10.1016/j.ecolmodel.2019.01.005

In highly regulated systems, like large dammed rivers, conservation legislation requires that systems are managed, in part, to avoid adverse impacts on endangered species. However, multiple endangered species can occur in the same system, and management actions that benefit one species may be detrimental to another species. The current water management strategies in the Sacramento River basin

are an example of this conflict. Cold-water releases from Shasta Reservoir during the summer and fall months are aimed at protecting Sacramento River winter-run Chinook (SRWRC) salmon by providing suitable incubation temperatures for their eggs. However, the effects of these regulated water temperature releases on another threatened species, green sturgeon, are less well understood. In this study, we applied a simplified dynamic energy budget (DEB) model (aka DEBkiss) to explore the effect of food limitation and water temperature on the growth rates of green sturgeon. This model captures these effects and able to predict the growth of green sturgeon at different food levels and temperature conditions. We then linked the DEB model with a physically-based water temperature model. We applied the DEB- water temperature linked model for green sturgeon along with a temperature-dependent egg to fry survival model for SRWRC salmon to quantify the consequences of managing water temperatures to improve salmon eggs survival on the growth rate of green sturgeon. We found that mean temperature-dependent egg-to-fry survival of salmon increased across a modeled environmental gradient from critically dry to wet water year types, while the fractional growth rate of juvenile green sturgeon showed the opposite trend, and decreased as water years transitioned from dry to wet conditions. We also found a non-linear negative correlation between temperature dependent mean growth rate of green sturgeon and mean temperature-dependent egg-to-fry survival of salmon, which indicated there is a river temperature related trade-off between early growth rate of green sturgeon and embryonic stage survival of salmon. However, the relatively small gains in the growth rate of green sturgeon achieved in years when temperature criteria for SRWRC salmon eggs were not met came at the cost of large reduction in temperature-dependent egg-to-fry survival of salmon. Thus, we concluded the current Sacramento River water-temperature management for the eggs of the endangered SRWRC salmon eggs have a relatively small impact on the growth rate of green sturgeon.

Klimley, A. P., Chapman, E. D., Cech, J. J., Jr., Cocherell, D. E., Fangue, N. A., Gingras, M., . . . Poletto, J. B. (2015). Sturgeon in the Sacramento-San Joaquin Watershed: New Insights to Support Conservation and Management. *San Francisco Estuary and Watershed Science,* 13(4), 1-19. https://doi.org/10.15447/sfews.2015v13iss4art1

The goal of a day-long symposium on March 3, 2015, Sturgeon in the Sacramento-San Joaquin Watershed: New Insights to Support Conservation and Management, was to present new information about the physiology, behavior, and ecology of the green (Acipenser medirostris) and white sturgeon (Acipenser transmontanus) to help guide enhanced management and conservation efforts within the Sacramento-San Joaquin watershed. This symposium identified current unknowns and highlighted new electronic tracking technologies and physiological techniques to address these knowledge gaps. A number of presentations, each reviewing ongoing research on the two species, was followed by a round-table discussion, in which each of the participants was asked to share recommendations for future research on sturgeon in the watershed. This article presents an in-depth review of the scientific information presented at the symposium with a summary of recommendations for future research.

Klimley, A. P., McDonald, R., Thomas, M. J., Chapman, E., & Hearn, A. (2020). Green Sturgeon Habitat Suitability Varies in Response to Drought Related Flow Regimes. *Environmental Biology of Fishes*. https://doi.org/10.1007/s10641-020-00946-z

A series of habitat suitability models were created based upon 2-dimensional tracking of Green Sturgeon and hydraulic simulations. This is an effort to better understand the relationship between the population decline, habitat suitability, and knowledge of the remaining post-dam era habitat available to Green Sturgeon. Records of the movements of Green Sturgeon were collected using a refined acoustic telemetry system (Vemco Ltd., Vemco Positioning System [VPS]) in three pools, the first at rkm 377.0 at the confluence with the Sacramento River of Antelope Creek, the second at rkm 407.5 at the confluence with Inks Creek, and the third at rkm 426.0 at the confluence with Paynes Creek near Red Bluff over a period of two years. The Flow and Sediment Transport with Morphologic Evolution of Channels (FaSTMECH) model was used to simulate depth and velocity. Previously developed habitat suitability curves for spawning Green Sturgeon within the study area were coupled to two-dimensional hydraulic simulations to estimate Weighted Usable Area (WUA), a metric of suitable habitat area within each of the studied reaches. The effect of changing river discharges on suitable spawning habitat for Green Sturgeon was examined over a six-year period, the first of which had normal rain conditions and the following years drought conditions. The peak amounts of spawning habitat in the pool on the Sacramento River at the rkm 377 was the same for all six years, roughly 8000 square meters. The constancy in the amount of WUA, in the face of decreasing rates of discharge may explain why these sites are occupied from year to year. The amount of spawning habitat in the pool at rkm 426, decreased during the four-year drought period, from 2012 to 2015. This may make it less favorable for occupation by Green Sturgeon.

Moser, M. L., Patten, K., Corbett, S. C., Feist, B. E., & Lindley, S. T. (2017). Abundance and Distribution of Sturgeon Feeding Pits in a Washington Estuary. *Environmental Biology of Fishes,* 100(5), 597-609. https://doi.org/10.1007/s10641-017-0589-y

Sturgeon diet and feeding habitats are notoriously difficult to document. We mapped the locations of feeding pits in Willapa Bay, Washington, to characterize estuarine habitats used by sub-adult and adult sturgeon for infaunal feeding. Monthly summer surveys of intertidal plots revealed that feeding pit density was highest in July and August, when sturgeon occupy Willapa Bay. The ephemeral nature of feeding pits and high daily densities (> 1000 pits/ha) indicated intensive sturgeon feeding over unvegetated littoral mud flats during high tide. Feeding pit density was lowest in subtidal areas, over sand (grain sizes primarily > 63 mu), and at sites with dense stands of non-indigenous seagrass, Zostera japonica. Sub-adult and adult sturgeon apparently used these habitats significantly less than would be predicted based on their availability. Feeding pit formation was negatively correlated with Z. japonica shoot dry weight and positively correlated with the abundance of thalassinid shrimp burrows. Experimental removal of Z. japonica resulted in increased sturgeon feeding, but experimental removal of burrowing shrimp did not significantly affect feeding pit formation. Aquaculture activities that harden substrate and proliferation of invasive seagrass both appear to produce estuarine substrates that are unsuitable for benthic feeding by sturgeon.

Poletto, J. B., Cocherell, D. E., Ho, N., Cech, J. J., Klimley, A., & Fangue, N. A. (2014). Juvenile Green Sturgeon (Acipenser medirostris) and White Sturgeon (Acipenser transmontanus) Behavior near Water-Diversion Fish Screens: Experiments in a Laboratory Swimming Flume. *Canadian Journal of Fisheries and Aquatic Sciences,* 71(7), 1030-1038. https://doi.org/10.1139/cjfas-2013-0556

Water diversions that extract fresh water for urban, industrial, and agricultural uses, as well as export to southern California, are prevalent throughout the Sacramento-San Joaquin watershed. Many water diversions are fitted with fish-exclusion screens designed to prevent fish from entrainment (i.e., being drawn in). The impact of fish screens on the behavior of migrating juvenile fishes remains largely unknown, especially for threatened species such as sturgeon. We placed individual juvenile green (Acipenser medirostris) or white (Acipenser transmontanus) sturgeon in a laboratory swimming flume in the presence of standard fish screens (2 mm bar spacing) at two field-relevant water velocities (20.4 plus or minus 0.1 and 37.3 plus or minus 0.3 cm.s super(-1)). Fish were tested at 18 degree C for 15 min during the day or night and in the presence of possible behavioral deterrents. Behavioral responses, including screen contacts, impingements, and time spent near screens were quantified. Green sturgeon contacted and impinged upon the screens twice as frequently as white sturgeon and also differed in how their behaviors were altered by water velocities and time of day. Our results are informative in developing effective management strategies to mitigate the impacts of water diversions on sturgeon populations and suggest that effective restoration strategies for both species should be considered separately.

Rodgers, E. M., Cocherell, D. E., Nguyen, T. X., Todgham, A. E., & Fangue, N. A. (2018). Plastic Responses to Diel Thermal Variation in Juvenile Green Sturgeon, Acipenser medirostris. *Journal of Thermal Biology,* 76, 147-155. https://doi.org/10.1016/j.jtherbio.2018.07.015

Human-induced thermal variability can disrupt energy balance and performance in ectotherms; however, phenotypic plasticity may play a pivotal protective role. Ectotherm performance can be maintained in thermally heterogeneous habitats by reducing the thermal sensitivity of physiological processes and concomitant performance. We examined the capacity of juvenile green sturgeon (Acipenser medirostris) to respond to daily thermal variation. Juveniles (47 days post-hatch) were exposed to either stable (15 +/- 0.5 degrees C) or variable (narrowly variable: 13-17 degrees C day(-1) or widely variable 11-21 degrees C day(-1)) thermoperiod treatments, with equivalent mean temperatures (15 +/- 0.5 degrees C), for 21 days. Growth (relative growth rate, % body mass gain), upper thermal tolerance (critical thermal maxima, CTMax) and the thermal sensitivity of swimming performance (critical swimming speed, U-crit) were assessed in fish from all treatments. Accelerated growth was observed in fish maintained under widely variable temperatures compared to narrowly variable and stable temperatures. No significant variation in CTMax was observed among thermoperiod treatments, suggesting all treatment groups acclimated to the mean temperature rather than daily maximums. The widely variable treatment induced a plastic response in swimming performance, where U-crit was insensitive to temperature and performance was maintained across a widened thermal breadth. Maximum U-crit attained was similar among thermoperiod treatments, but performance was maximised at different test temperatures (stable: 4.62 +/- 0.44 BL s(-1) at 15 degrees C; narrowly variable: 4.52 +/- 0.23 BL s(-1) at 21 degrees C; widely variable: 3.90 +/- 0.24 BL s(-1) at 11 degrees C, mean +/- s.e.m.). In combination, these findings suggest juvenile A. medirostris are resilient to daily fluctuations in temperature, within the temperature range tested here.

Rodgers, E. M., Poletto, J. B., Isaza, D. F. G., Van Eenennaam, J. P., Connon, R. E., Todgham, A. E., . . . Fangue, N. A. (2019). Integrating Physiological Data with the Conservation and Management of Fishes: A Meta-Analytical Review Using the Threatened Green Sturgeon (Acipenser medirostris). *Conservation Physiology,* 7. https://doi.org/10.1093/conphys/coz035

Reversing global declines in the abundance and diversity of fishes is dependent on science-based conservation solutions. A wealth of data exist on the ecophysiological constraints of many fishes, but much of this information is underutilized in recovery plans due to a lack of synthesis. Here, we used the imperiled green sturgeon (Acipenser medirostris) as an example of how a quantitative synthesis of physiological data can inform conservation plans, identify knowledge gaps and direct future research actions. We reviewed and extracted metadata from peer-reviewed papers on green sturgeon. A total of 105 publications were identified, spanning multiple disciplines, with the primary focus being conservation physiology (23.8%). A meta-analytical approach was chosen to summarize the mean effects of prominent stressors (elevated temperatures, salinity, low food availability and contaminants) on several physiological traits (growth, thermal tolerance, swimming performance and heat shock protein expression). All examined stressors significantly impaired green sturgeon growth, and additional stressor-specific costs were documented. These findings were then used to suggest several management actions, such as mitigating salt intrusion in nursery habitats and maintaining water temperatures within optimal ranges during peak spawning periods. Key data gaps were also identified; research efforts have been biased towards juvenile (38.1%) and adult (35.2%) life-history stages, and less data are available for early life-history stages (embryonic, 11.4%; yolk-sac larvae, 12.4%; and post yolk-sac larvae, 16.2%). Similarly, most data were collected from single-stressor studies (91.4%) and there is an urgent need to understand interactions among stressors as anthropogenic change is multi-variate and dynamic. Collectively, these findings provide an example of how meta-analytic reviews are a powerful tool to inform management actions, with the end goal of maximizing conservation gains from research efforts.

Schreier, A. D., & Stevens, P. (2020). Further Evidence for Lower Columbia River Green Sturgeon Spawning. *Environmental Biology of Fishes,* 103(2), 201-208. https://doi.org/10.1007/s10641-019-00945-9

The Green Sturgeon is a long-lived anadromous fish known to spawn in only three locations. Southern Distinct Population Segment (DPS) Green Sturgeon spawn only in the Sacramento drainage, while the Northern DPS spawns in the Klamath and Rogue rivers. In 2011, a young of year (YOY) Green Sturgeon was captured in the Columbia River below Bonneville Dam, providing preliminary evidence of a fourth spawning location. In 2017, four additional Green Sturgeon YOY of similar size were captured in the Columbia River below Bonneville Dam. Genetic analysis of all YOY samples indicates that they belong to the Northern DPS, confirming that the Northern DPS actually spawns in at least three locations. The detection of Green Sturgeon spawning in the Columbia River only in years with relatively high spring flow (2011, 2017), combined with confirmed correlations between flow and spawning for other White and Green Sturgeon populations, suggests that appropriate spawning conditions may only exist above a specific flow threshold. The Columbia River has the potential to play an important role in Green Sturgeon climate change adaptation due to its location at the northernmost end of the species' reproductive range. We recommend future research to better quantify Green Sturgeon recruitment magnitude, frequency and dynamics in the Columbia River.

Sturgeon Movements in the San Francisco Estuary: Summary of Current Telemetry Studies and Knowledge. (2015). Retrieved from https://www.sfei.org/sites/default/files/biblio_files/2015%20Summary%20of%20Sturgeon%20Telemetry%20Studies%20in%20SF%20Estuary.pdf

The RMP is currently involved in several studies of selenium concentrations in white sturgeon tissue collected in North San Francisco Bay. However, much is unknown about potential sources of selenium bioaccumulation in these fish over time. This document summarizes major studies on white and green sturgeon movements within the San Francisco Estuary that are either published or in progress that may provide information helpful to understanding the dynamics of sturgeon movement, behavior, and selenium accumulation over time. A number of key white and green sturgeon telemetry studies are currently in progress by researchers at UC Davis and the US Fish and Wildlife Service (USFWS), for which data are expected to be analyzed beginning this year. For background, the first section of the document is a short summary of known information about white sturgeon movements in the SF Bay.

Thomas, M. J., Peterson, M. L., Chapman, E. D., Fangue, N. A., & Klimley, A. P. (2019). Individual Habitat Use and Behavior of Acoustically-Tagged Juvenile Green Sturgeon in the Sacramento-San Joaquin Delta. *Environmental Biology of Fishes,* 102(8), 1025-1037. https://doi.org/10.1007/s10641-019-00888-1

Southern distinct population segment (sDPS) juvenile Green Sturgeon are thought to rear in the Sacramento-San Joaquin Delta for two to four years. The southern population segment has been listed as threatened under the Endangered Species Act. Habitat loss is cited as a significant driver in declines of the population. Specific to juvenile rearing, much of the historic floodplain habitat has been lost and replaced by leveed channelized waterways. In addition to geomorphic alterations, other direct and indirect activities such as water export, dredging, and the introduction of invasive species may have significant impacts to the viability of the species. The objective of this tracking study was to provide a first of its kind look at the movements and behaviors of wild caught juvenile Green Sturgeon within the putative nursery grounds of the Sacramento-San Joaquin Delta. We acoustically tagged and continuously tracked six yearling juvenile Green Sturgeon with mean total length (TL) of 50.6cm (SD=5.3) and mean mass of 563.3g (SD=151.7). We performed continuous mobile tracking for a period of up to five days per individual while recording GPS coordinates, depths, and water temperature at the sturgeon's location. We used first-passage times, defined as the amount of time spent within a given area, for which a radius was determined post hoc. First passage times were used as a metric for parsing bouts of localized movements from directed movements. Our results indicate that juvenile Green Sturgeon largely oriented at or near the bottom. Depths utilized by all sturgeon ranged from >3m to 20m across all tracks. Individuals exhibited fidelity to the San Joaquin River Channel with only one individual leaving the main channel. Juvenile green sturgeon were shown to exhibit both positive and negative rheotaxis during sustained directed movements under independent ebb tidal cycles. This study provides the first detailed examination into the early life movements and behaviors of a rare species within their putative nursery grounds.

Thomas, M. J., Peterson, M. L., Chapman, E. D., Hearn, A. R., Singer, G. P., Battleson, R. D., & Klimley, A. P. (2014). Behavior, Movements, and Habitat Use of Adult Green Sturgeon, Acipenser medirostris, in the Upper Sacramento River. *Environmental Biology of Fishes,* 97(2), 133-146. https://doi.org/10.1007/s10641-013-0132-8

We conducted the first continuous shipboard tracking of southern Distinct Population Segment green sturgeon, Acipenser medirostris, in the Sacramento River. Tracking of adult green sturgeon occurred between river kilometer (rkm) 434.8 and 511.6, a section of the putative spawning grounds located near Red Bluff, California. The recorded positions of acoustically tagged green sturgeon were analyzed using First Passage Time analysis to determine differences in habitat use between suitable and non-suitable habitats. Classification and Regression Tree modeling was used to determine explanatory inputs attributable to above average habitat use. Green sturgeon exhibited above average habitat use at five sites, identified as potential spawning aggregate sites. Three types of movements (holding, milling, and directed) could be categorized from tracks. Lastly, we show that green sturgeon while on the spawning grounds exhibit a high degree of mobility throughout the spawning grounds, often making large movements between specific habitat units. Our study illustrates how the application of shipboard tracking can be useful for describing movement, behavior and habitat utilization at a spatial scale not achieved by stationary acoustic monitors.

Wyman, M. T., Thomas, M. J., McDonald, R. R., Hearn, A. R., Battleson, R. D., Chapman, E. D., . . . Klimley, A. P. (2018). Fine-Scale Habitat Selection of Green Sturgeon (Acipenser medirostris) within Three Spawning Locations in the Sacramento River, California. *Canadian Journal of Fisheries and Aquatic Sciences,* 75(5), 779-791. https://doi.org/10.1139/cjfas-2017-0072

Vast sections of the Sacramento River have been listed as critical habitat by the National Marine Fisheries Service for green sturgeon spawning (Acipenser medirostris), yet spawning is known to occur at only a few specific locations. This study reveals the range of physical habitat variables selected by adult green sturgeon during their spawning period. We integrated fine-scale fish positions, physical habitat characteristics, discharge, bathymetry, and simulated velocity and depth using a two-dimensional hydraulic model (FaSTMECH). The objective was to create habitat suitability curves for depth, velocity, and substrate type within three known spawning locations over two years. An overall cumulative habitat suitability score was calculated that averaged the depth, velocity, and substrate scores over all fish, sites, and years. A weighted usable area index was calculated throughout the sampling periods for each of the three sites. Cumulative results indicate that the microhabitat characteristics most preferred by green sturgeon in these three spawning locations were velocities between 1.0 and 1.1 m/s, depths of 8-9m, and gravel and sand substrate. This study provides guidance for those who may in the future want to increase spawning habitat for green sturgeon within the Sacramento River.

Zarri, L. J., & Palkovacs, E. P. (2019). Temperature, Discharge and Development Shape the Larval Diets of Threatened Green Sturgeon in a Highly Managed Section of the Sacramento River. *Ecology of Freshwater Fish,* 28(2), 257-265. https://doi.org/10.1111/eff.12450

Feeding at early fish life stages is a key determinant of survival to recruitment. To understand the environmental and developmental determinants of early life stage feeding in ESA-threatened green

sturgeon (Acipenser medirostris), we performed a diet study in a highly managed section of California's Sacramento River, where temperature and discharge are controlled by dam releases. Utilising field collections from 2012 to 2016, we assessed the impacts of temperature, discharge and morphological development on the composition and number of prey items in larval green sturgeon diets. Results show that there are more empty stomachs at colder temperatures. Higher discharge conditions decreased prey taxon richness and counts, especially the abundance of cyclopoid copepods in diets. Fish smaller than 30 mm had teeth on the oral jaws and showed a strong reliance on zooplankton prey. The developmental loss of teeth in fish greater than 30 mm was associated with decreased zooplankton consumption and increased richness of benthic macroinvertebrates in diets. Our results show that river management through dam releases has the potential to impact the earliest life stage of green sturgeon by reducing the prevalence of favoured zooplankton prey in diets.

Section III: Population Abundance and Trends

Anderson, J. T., Schumer, G., Anders, P. J., Horvath, K., & Merz, J. E. (2018). Confirmed Observation: A North American Green Sturgeon Acipenser Medirostris Recorded in the Stanislaus River, California. *Journal of Fish and Wildlife Management,* 9(2), 624-630. https://doi.org/10.3996/012018-jfwm-006

Two sturgeon species are native to the San Francisco Estuary watershed in California: White Sturgeon Acipenser transmontanus and North American Green Sturgeon Acipenser medirostris. The San Francisco Estuary has two main tributaries, the Sacramento and San Joaquin rivers. Recent studies have shown that the San Joaquin River is used by Green and White Sturgeon and that at least a small number of White Sturgeon spawn there when environmental conditions allow. However, records of Green Sturgeon in the San Joaquin River and its tributaries are rare and limited to information from angler report cards. In 2006, the National Marine Fisheries Service listed the southern distinct population segment of North American Green Sturgeon as threatened under the Endangered Species Act. Federally designated critical habitat for the southern distinct population segment of Green Sturgeon does not extend upstream of the San Joaquin River's confluence with the Stanislaus River. We recently confirmed an adult Green Sturgeon holding in a deep pool near Knights Ferry, California in the Stanislaus River. We observed and recorded the fish using a GoPro (R) video camera and used environmental deoxyribonucleic acid sampling techniques to confirm species identification. This paper provides the first confirmed record of Green Sturgeon in any tributary of the San Joaquin River, which is beyond the designated critical habitat area. Future well-designed research focused on the San Joaquin River and its tributaries is expected to improve our understanding regarding the importance of these rivers for the various life stages of North American Green Sturgeon.

Chapman, E. D., Miller, E. A., Singer, G. P., Hearn, A. R., Thomas, M. J., Brostoff, W. N., . . . Klimley, A. P. (2019). Spatiotemporal Occurrence of Green Sturgeon at Dredging and Placement Sites in the San Francisco Estuary. *Environmental Biology of Fishes,* 102(1), 27-40. https://doi.org/10.1007/s10641-018-0837-9

We used acoustic telemetry to determine the spatial and temporal overlap between adult Green Sturgeon movements and areas affected by dredging within the San Francisco Estuary. Autonomous receivers were deployed for 3years within the lower Estuary at priority locations to assess the potential for adverse effects on Green Sturgeon. Green Sturgeon were present at the designated placement sites during all months of the year but more were detected during two time periods (February-March and June-September). Of the 134 tagged fish detected in the estuary, 109 (81%) were detected at one or more dredged or dredged material placement sites. The median duration of residence at dredged material placement sites was 72.5min near the Carquinez Strait, 141.1min in San Pablo Bay, and 37.1min near Alcatraz Island in San Francisco Bay. The median duration of residence at the dredged San Pablo Channel was 77.5min. Nine fish were detected with depth sensing transmitters. The majority of detections (95.2%) from these fish were at depths greater than five meters. Combined with information regarding the specific impacts of dredging on Green Sturgeon (e.g., suspended sediments, toxicity, entrainment, and behavior changes), these spatiotemporal data could be used to make recommendations for reassessing best management practices.

Danos, A., Kelly, J., Chalfin, J., & DuBois, J. (2020). *2019 Field Season Summary for the Sturgeon Population Study*. Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentId=175808

The California Department of Fish and Wildlife (CDFW) has conducted a sturgeon population study intermittently since 1967 and nearly annually since 2005. Part of the study is a "high-value reward" tagging program. Presented here is a summary of the 2019 sturgeon-tagging field season. For summaries of previous seasons, please see the Sturgeon Study Bibliography. This study is designed primarily to understand and monitor the White Sturgeon (Acipenser transmontanus) fishery, to assess White Sturgeon population dynamics, and to monitor aspects of the Green Sturgeon (A. medirostris) population. The tagging portion of the population study provides data on relative and absolute abundance, harvest rate, mortality rate, individual growth rates, and large-scale movement and migration patterns. Our primary objective during the 2019 field season was to capture, tag, measure, and release in good condition as many White Sturgeon as possible and to document previously tagged sturgeon. As part of an on-going collaboration, our staff also collected sturgeon tissue for the San Francisco Estuary Institute to monitor selenium concentrations in White Sturgeon.

DuBois, J., & Danos, A. (2017). *2016 Sturgeon Fishing Report Card: Preliminary Data Report*. Stockton, CA Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentId=141241

About 47,614 2016 Sturgeon Fishing Report Cards (Cards) were issued. This report was written 10-Mar2017 using information from the 15,008 Cards that had been received from anglers (11,036 via the Internet and 3,972 via mail) by that date. Most catch of sturgeon (both species) was in the Sacramento River from Rio Vista to Chipps Island and in Suisun Bay. Anglers reported the release of 220 Green Sturgeon, retention of 2,528 White Sturgeon, and release of 4,963 White Sturgeon. As has been the case since 2007, roughly 50% of the anglers who fished for sturgeon were not successful and successful anglers retained on average less than half the annual bag limit of three White Sturgeon. Anglers reported fork length measurements for 102 Green Sturgeon (range 18-71 inches, averaged 33 inches). Of the White Sturgeon retained, anglers reported fork length measurements for 2,516 fish (range 40-60 inches, average 48 inches). Of the White Sturgeon released, anglers reported a length measurement for 2,375 fish (range 12-108 inches, averaged 44 inches).

DuBois, J., & Danos, A. (2017). *2017 Field Season Summary for the Sturgeon Population Study*. Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentId=151049

A sturgeon population study conducted by the California Department of Fish and Wildlife (CDFW) has been ongoing intermittently since 1967 (annually since 2005). Part of the study is a "high-value reward" tagging program. Presented here is a summary of the 2017 sturgeon-tagging field season. For summaries from previous seasons, please click Bibliography. The population study is designed primarily to understand and monitor the fishery for and population dynamics of White Sturgeon (Acipenser transmontanus) is also used to monitor aspects of the Green Sturgeon (A. medirostris) population. The tagging portion of the population study provides data on relative and absolute abundance, harvest rate, mortality rate, individual growth rates, and large-scale movement/migration patterns. Our primary objective during the 2017 field season was to capture, tag, measure, and release in good condition as

many White Sturgeon as possible and to document previously-tagged sturgeon. As part of an on-going collaboration, our staff collected sturgeon tissue for San Francisco Estuary Institute to monitor Selenium concentrations in White Sturgeon.

DuBois, J., & Danos, A. (2018). *2017 Sturgeon Fishing Report Card: Preliminary Data Report*. Stockton, CA Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentId=156356

About 44,374 anglers were issued 2017 Sturgeon Fishing Report Cards (Cards). This report was written 05-Apr-2018 using information from the 14,578 Cards that had been received from anglers (11,223 via the Internet and 3,355 via mail) by that date. Most catch of White Sturgeon was in Suisun and San Pablo bays. Most catch of Green Sturgeon was in Suisun Bay and in the Sacramento River from Rio Vista to Chipps Island. Anglers reported the release of 230 Green Sturgeon, retention of 2,755 White Sturgeon, and release of 4,817 White Sturgeon. As has been the case since 2007, roughly 50% of the anglers who fished for sturgeon were not successful and successful anglers retained on average just less than half the annual bag limit of three White Sturgeon. Anglers reported fork length measurements for 117 Green Sturgeon (range 14-78 inches, averaged 33 inches). Of the White Sturgeon retained, anglers reported fork length measurements for 2,744 fish (range 40-60 inches, average 48 inches). Of the White Sturgeon released, anglers reported a length measurement for 2,522 fish (range 10-150 inches, averaged 44 inches).

Fonner, R., & Warlick, A. (2018). Marine Protected Resources on the U.S. West Coast: Current Management and Opportunities for Applying Economic Analysis. https://doi.org/10.25923/vprp-1507

The National Marine Fisheries Service (NMFS), also called NOAA Fisheries, manages both the listing and recovery of marine species under the Endangered Species Act (ESA) and the protection of marine mammals under the Marine Mammal Protection Act (MMPA). This report focuses on NOAA's West Coast Region, which includes marine resources in California, Oregon, Washington, and Idaho. The region is host to 46 ESA-listed species, or distinct population segments (DPSs),1 1 Under the U.S. Endangered Species Act, the listing unit for invertebrates is the taxonomic species; however, the listing unit for vertebrates includes species, subspecies, or distinct population segment. For Pacific salmon, the DPS equivalent is the evolutionarily significant unit, as described by Waples (1991). and over 30 species of marine mammals protected by the MMPA. Salmon and steelhead (salmonids, Oncorhynchus spp.) are at the forefront of marine protected resources (MPR) management in the West Coast Region, where 28 evolutionarily significant units (ESUs) of ESA-listed salmonids from six species are listed under the ESA. Other ESA-listed species in the region include killer whales (Orcinus orca), eulachon (Thaleichthys pacificus), yelloweye rockfish (Sebastes ruberrimus), bocaccio (Sebastes paucispinis), and green sturgeon (Acipenser medirostris).

Green Sturgeon Acoustic Monitoring. (2018). Retrieved from https://catalog.data.gov/dataset/green-sturgeon-acoustic-monitoring

This database is used to hold tracking data for green sturgeon tagged in Central California. The data collection began in late 2002 and is ongoing.

Heublein, J. C., Bellmer, R. J., Chase, R. D., Doukakis, P., Gingras, M., Hampton, D., . . . Sommer, T. (2017). Improved Fisheries Management through Life Stage Monitoring: The Case for the Southern Distinct Population Segment of North American Green Sturgeon and the Sacramento-San Joaquin River White Sturgeon. https://doi.org/10.7289/V5/TM-SWFSC-588

This conceptual model was compiled to support the development of monitoring studies and plans associated with management and recovery of sturgeon species in the San Francisco Estuary (SFE) watershed. Multiple life stages of the southern Distinct Population Segment (sDPS) of North American green sturgeon (Acipenser medirostris) and the Sacramento-San Joaquin River white sturgeon (A. transmontanus) are endemic to the SFE watershed. Potential increases in consecutive recruitment failures in SFE sturgeon raise concern about the resilience of sDPS green sturgeon and the sustainability of a harvestable white sturgeon stock. Fundamental sturgeon demographic measures are lacking in the existing monitoring and analytical framework. As a result, managers are unable to determine specific causes of poor recruitment, accurately track green sturgeon listing status under the Federal Endangered Species Act, or measure sturgeon population responses to management of water resources and/or harvest regulations. Here, we developed conceptual models for SFE sturgeon and identified 15 monitoring recommendations that would potentially test 41 hypotheses in 7 core areas of sturgeon management. Implementation of these monitoring recommendations would refine our understanding of the key factors influencing SFE sturgeon populations and improve outcomes for California's sturgeon through informed management.

Jaric, I., Gessner, J., & Lenhardt, M. (2015). A Life-Table Metamodel to Support the Management of Data Deficient Species, Exemplified in Sturgeons and Shads. *Environmental Biology of Fishes,* 98(12), 2337-2352. https://doi.org/10.1007/s10641-015-0439-8

Population models in fish represent one of the major scientific approaches to identify and bridge existing gaps in the understanding of the ecology and life history, as well as to support management. In general, the more complex the models get, the more they are restricted to a case-by-case basis for particular, well-studied species, because demographic data required for detailed models are unavailable for the majority of species. In the present study, we propose a simple life-table metamodel, which facilitates population and fishery assessments across entire groups of fish. The general approach is described and its application is demonstrated on two groups of fish, which reflect extremes in their life cycle: sturgeons (order Acipenseriformes) and shads (genus Alosa). The approach allows to determine fishing mortality thresholds across different life history types, and to analyze their general population elasticity. Its application is suggested for rapid assessments across large, species-rich groups of fish. The method also allows utilizing life history data from well-studied species to infer fishing mortality thresholds for other, poorly studied species within the same group. Comparisons of the model output with results from other population models indicated a good congruity.

Klimley, A. P., Agosta, T. V., Ammann, A. J., Battleson, R. D., Pagel, M. D., & Thomas, M. J. (2017). Real-Time Nodes Permit Adaptive Management of Endangered Species of Fishes. *Animal Biotelemetry,* 5(1), 22. https://doi.org/10.1186/s40317-017-0136-9

Currently acoustic tag-detecting autonomous receivers must be visited periodically to download the files of tag detections. Hence, the information about the whereabouts of tagged fishes is not available to make prompt regulatory decisions to reduce entrainment. In contrast, real-time receivers can detect the signal from a transmitter on a passing fish and immediately transmit its identity and time of detection to a website, where they can be viewed on either a computer or cellular telephone. Real-time nodes can aid regulatory biologists in making important decisions. This is a powerful new tool for resource managers and conservation biologists.

Mora, E. A., Battleson, R. D., Lindley, S. T., Thomas, M. J., Bellmer, R., Zarri, L. J., & Klimley, A. P. (2018). Estimating the Annual Spawning Run Size and Population Size of the Southern Distinct Population Segment of Green Sturgeon. *Transactions of the American Fisheries Society,* 147(1), 195-203. https://doi.org/10.1002/tafs.10009

The Southern Distinct Population Segment of Green Sturgeon Acipenser medirostris spawns in the Sacramento River, California, and is listed as a threatened species under the U.S. Endangered Species Act. We estimated the spawning run size and population size in 2010-2015 by using dual-frequency identification sonar (DIDSON) sampling, underwater video camera species identification, and acoustic tag detections. Spawning run size varied from 336 to 1,236 individuals. We estimated the total population size to be 17,548 individuals (95% confidence interval [CI]=12,614-22,482). The estimated number of adults was 2,106 (95% CI=1,246-2,966), the estimated number of juveniles was 4,387 (95% CI=2,595-6,179), and the estimated number of subadults was 11,055 (95% CI=6,540-15,571). This study provides the first estimate of Sacramento River Green Sturgeon run size and initiates a time series of abundance that can inform Endangered Species Act recovery processes. Furthermore, these absolute abundance estimates provide a context for evaluating the significance of impacts, such as bycatch in coastal fisheries or entrainment in water diversions, where the number of impacted individuals is known.

Mora, E. A., Lindley, S. T., Erickson, D. L., & Klimley, A. P. (2015). Estimating the Riverine Abundance of Green Sturgeon Using a Dual-Frequency Identification Sonar. *North American Journal of Fisheries Management,* 35(3), 557-566. https://doi.org/10.1080/02755947.2015.1017119

To determine the total number of Green Sturgeon Acipenser medirostris present in the Rogue River, Oregon, we compared plot sampling using a dual-frequency identification sonar (DIDSON), a density-based estimation technique combining the number of individuals detected and the area sampled, to a concurrent mark?recapture estimate. Using the DIDSON-based method, we estimated the total abundance of Green Sturgeon to be 223 (95% confidence interval = 180?266). The mark?recapture method resulted in an estimate of 236 individuals (150?424). The noninvasive DIDSON transect estimates resulted in tighter confidence intervals and required fewer technician hours to collect the data than did the mark?recapture method (37 h versus 232 h, respectively). Precise estimates of the abundance and distribution of Green Sturgeon are important components to species recovery and

management. Thus, this new technique has the potential to greatly improve population monitoring and is an excellent tool to identify occupied habitats.Received June 9, 2014; accepted January 28, 2015

Poytress, W. R., Gruber, J. J., Van Eenennaam, J. P., & Gard, M. (2015). Spatial and Temporal Distribution of Spawning Events and Habitat Characteristics of Sacramento River Green Sturgeon. *Transactions of the American Fisheries Society,* 144(6), 1129-1142. https://doi.org/10.1080/00028487.2015.1069213

Spawning of the Southern Distinct Population Segment of Green Sturgeon Acipenser medirostris occurs annually within the Sacramento River in California. Artificial substrate samplers were used to collect Green Sturgeon eggs between 2008 and 2012 and in a reach of the river 94 river kilometers (rkm) long (rkm 426?332). A total of 268 eggs and 5 posthatch larvae were sampled from seven identified spawning sites between April 2 and July 7, primarily from medium gravel substrates. At these sites the mean water column velocities were 0.8 m/s at depths ranging from 0.6 to 11.3 m (6.4 ± 2.3 m, mean ± SD). We noted an average discharge of 314 m3/s and a median turbidity value of 3.9 NTU during estimated spawning events. Spawning at all sites occurred when average water temperatures were 13.5 ± 1.0°C and during water year types ranging from critically dry to wet. Green Sturgeon eggs averaged 4.11 ± 0.20 mm in diameter (n = 207), were very adhesive, and were between developmental stages 2 (just fertilized) and 44 (posthatch larva). We estimated that eggs were collected from a minimum of 54 different spawning events, based on sample date and location, egg developmental stage at capture, and water temperatures. Green Sturgeon spawning data indicates there is spatial separation from sympatric White Sturgeon A. transmontanus, but some temporal overlap exists. The thermally and hydrologically managed Sacramento River with its numerous diversions and competing water demands appears to have an approximate reach of 120 rkm in the 405-km-long river that is favorable for Green Sturgeon spawning in most years. Management decisions need to assess and incorporate the spawning habitat requirements of Green Sturgeon and coordinate this information with that of endangered winter-run Chinook Salmon Oncorhynchus tshawytscha while attempting to meet the diverse demands of the limited Sacramento River water resources.Received April 20, 2015; accepted June 30, 2015

Schreier, A., Langness, O. P., Israel, J. A., & Van Dyke, E. (2016). Further Investigation of Green Sturgeon (Acipenser medirostris) Distinct Population Segment Composition in Non-Natal Estuaries and Preliminary Evidence of Columbia River Spawning. *Environmental Biology of Fishes,* 99(12), 1021-1032. https://doi.org/10.1007/s10641-016-0538-1

Green sturgeon (Acipenser medirostris) is a highly migratory, marine oriented species that congregates in non-natal estuaries during summer and early fall. Individuals from the threatened Southern Distinct Population Segment (SDPS) and non-listed Northern Distinct Population Segment (NDPS) regularly co-occur in non-natal estuaries including the Columbia River estuary, Willapa Bay, and Grays Harbor in relative proportions not explained by abundance or distance from natal river. We used genetic markers to assign green sturgeon sampled in these estuaries from 2010 to 2012 to distinct population segments (DPS). We then examined interannual differences in DPS composition among estuaries. Fork length distributions were compared between SDPS and NDPS green sturgeon to determine whether size varied within and among DPSs and estuaries. The majority of green sturgeon sampled in the Columbia River estuary and Willapa Bay were assigned to the SDPS, while we assigned nearly even DPS proportions to

our Grays Harbor samples. NDPS green sturgeon were significantly smaller than those originating from the SDPS within and among estuaries. We used these findings to develop several hypotheses about the mechanisms that may lead to specific patterns of non-natal estuary use. Genetic markers also assigned a single age-0 green sturgeon sampled in the Columbia River to the NDPS, although our analyses suggest that this individual's parents may not have originated from known NDPS spawning populations. Because the Columbia River may serve as alternative spawning habitat for green sturgeon as climate change occurs, we recommend monitoring the Columbia River more closely for further evidence of green sturgeon spawning.

Seesholtz, A. M., Manuel, M. J., & Van Eenennaam, J. P. (2015). First Documented Spawning and Associated Habitat Conditions for Green Sturgeon in the Feather River, California. *Environmental Biology of Fishes,* 98(3), 905-912. https://doi.org/10.1007/s10641-014-0325-9

California's Sacramento River mainstem was previously the only known spawning area for the Southern Distinct Population Segment of North American green sturgeon, Acipenser medirostris. Our study provides the first documentation of green sturgeon spawning in the Feather River, a major tributary of the Sacramento River. Egg mats were used to sample two lower Feather River sites from April 12 to July 7, 2011, and we collected 13 green sturgeon eggs at one of those sites. Developmental stages of the eggs ranged from early gastrulation (Stage 15) to post-neurulation (Stage 27), which led us to estimate that four independent spawning events occurred between June 12 and June 19. Spawning occurred after a flow increase while water temperatures were at an optimum (<17.5 °C) for eggs. Results suggest that the area near Thermalito Afterbay Outlet may be important green sturgeon spawning habitat and that the lower Feather River has the potential to provide a second production area of Southern Distinct Population Segment green sturgeon. It should be noted that 2011 was a wet water year and supplemental sampling is needed to understand if water-year type affects green sturgeon usage of the lower Feather River. Given this new information, future management decisions and water management strategies for the Feather River system should take green sturgeon life-history needs into consideration.

Stillwater Sciences, & Wiyot Tribe Natural Resources. (2017). *Status, Distribution, and Population of Origin of Green Sturgeon in the Eel River: Results of 2014–2016 Studies.* Office of Protected Resources, NOAA Fisheries. Retrieved from https://www.wiyot.us/DocumentCenter/View/126/Eel-River-Green-Sturgeon-Final-Report-PDF?bidId=

The Eel River, in Northern California, is one of the larger rivers in the state and historically had an apparently robust and important spawning run of green sturgeon, although inferences about population size are impossible because of the lack of historical data (Adams et al. 2002). Contemporary fisheries surveys from the Eel River would occasionally record some green sturgeon adults or juveniles. The general consensus was that green sturgeon in the Eel River had become exceedingly rare and it was uncertain if these sightings represented a few stray fish from other spawning rivers in the area, or signified an actual persistent and distinct spawning run (Adams et al. 2007). In the late 1960s, anadromous fish outmigration trapping studies conducted by the CDFW documented juvenile green sturgeon approximately 100 km upstream on the mainstem Eel River (Puckett 1976). Similarly, CDFW documented multiple adult green sturgeon during the summer in the mainstem Eel River in the same

general areas, a finding consistent with spawning run behavior. Also, sporadic sightings of adult green sturgeon by boaters and fishermen have occurred historically and in recent years, with observations of fish occurring in the lower mainstem as well as over 100 km upstream. In conceiving this project, we hypothesized that contemporary sightings of green sturgeon in the Eel River represented a persistent and distinct, albeit undocumented, spawning run and we predicted that a systematic, multi-year survey would demonstrate this.

Section IV: Threats

Amports Berth Rehabilitation Project. (2019). https://doi.org/10.25923/bn2z-ca92

NOAA's National Marine Fisheries Service (NMFS) prepared the biological opinion (BO) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 USC 1531 et seq.), and implementing regulations at 50 CFR 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

Because the proposed action would modify a stream or other body of water, NMFS also provides recommendations and comments for the purpose of conserving fish and wildlife resources, and enabling the Federal agency to give equal consideration with other project purposes, as required under the Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. 661 et seq.).

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). A complete record of this consultation is on file at NMFS California Central Valley Office.

Bacher, D. (2018). Winnemem Wintu Tribe and Water Sue to Stop Waste Discharge at Mt. Shasta Water Bottling Facility. *Daily Kos*. Retrieved from https://www.dailykos.com/stories/2018/4/28/1760680/-Winnemem-Wintu-Tribe-and-WATER-sue-to-stop-waste-discharge-at-Mt-Shasta-water-bottling-facility

The Winnemem Wintu, who are now leading a campaign to reintroduce winter-run Chinook now thriving in New Zealand back to their home on the McCloud River, and We Advocate Thorough Environmental Review (W.A.T.E.R.) have petitioned the Superior Court of Siskiyou County for a Writ of Mandate (Petition) against the City of Mt. Shasta.

The litigation challenges the city's March 26, 2018, split-vote approval of the Industrial Waste Discharge Permit for Crystal Geyser Water Company and the city's conclusion that the project was "adequately considered" in the Environmental Impact Report (EIR) prepared by Siskiyou County, in violation of the California Environmental Quality Act (CEQA).

Baird, S. E., Steel, A. E., Cocherell, D. E., Poletto, J. B., Follenfant, R., & Fangue, N. A. (2020). Experimental Assessment of Predation Risk for Juvenile Green Sturgeon, Acipenser medirostris, by Two Predatory Fishes. *Journal of Applied Ichthyology,* 36(1), 14-24. https://doi.org/10.1111/jai.13990

Predation is a common cause of early life stage mortality in fishes, with reduced risk as individuals grow and become too large to be consumed by gape-limited predatory fishes. Large-bodied species, such as sturgeon, may reach this size-refuge within the first year. However, there is limited understanding of what this size threshold is despite the value of this information for conservation management. We conducted laboratory-based predation experiments on juvenile green sturgeon, Acipenser medirostris,

to estimate vulnerability to predation during outmigration from their natal reaches in California to the Pacific Ocean. Two highly abundant and non-native predatory fish species (largemouth bass, Micropterus salmoides, and striped bass, Morone saxatilis) were captured in the wild to be tested with developing juvenile green sturgeon from the UC Davis Green Sturgeon Broodstock Program. Experimental tanks, each containing five predators, received thirty prey for 24-hr exposures. Between sturgeon prey trials, predators were exposed to alternative prey species to confirm predators were exhibiting normal feeding behaviors. In addition to green sturgeon mortality data, trials were video recorded and predatory behaviors were quantified. Overall, these predator species displayed much lower rates of predation on juvenile green sturgeon than alternate prey. Predation decreased with green sturgeon size, and predation risk diminished to zero once sturgeon reached a length threshold of roughly 20-22 cm total length, or between 38% and 58% of predator total length. Behavioral analyses showed low motivation to feed on green sturgeon, with both predators attempting predation less frequently as sturgeon grew. Results of this study imply that optimizing growth rates for larval and juvenile sturgeon would shorten the time in which they are vulnerable to predation. Future experiments should assess predation risk of juvenile green sturgeon by additional predator species common to the Sacramento-San Joaquin watershed.

Biological and Conference Opinion on U.S. Navy Northwest Training and Testing Activities and Associated Nmfs Regulations and Letters of Authorization. (2015). https://doi.org/10.7289/V5NG4NTZ

Section 7 (b)(3) of the ESA requires that at the conclusion of consultation, NMFS and/or USFWS provide an opinion stating how the Federal agencies' actions will affect ESA-listed species and their critical habitat under their jurisdiction. If an incidental take is expected, section 7 (b)(4) requires the consulting agency to provide an incidental take statement that specifies the impact of any incidental taking and includes reasonable and prudent measures to minimize such impacts.

For the actions described in this document, the action agencies are the United States Navy (Navy), which proposes to continue military training exercises and testing activities, and NMFS Office of Protected Resources -Permits and Conservation Division (Permits Division), which proposes to promulgate regulations pursuant to the Marine Mammal Protection Act of 1972, as amended (MMPA 16 U.S.C. 1361 et seq.), related to the Navy's activities in the Northwest Training and Testing (NWTT) Study Area that may affect several ESA-listed species. The regulations propose to authorize the issuance of two Letters of Authorization (LOAs) that will allow the Navy to "take" marine mammals incidental to its proposed action. The Federal action of issuing LOAs to the Navy is also considered in this biological opinion (Opinion). The consulting agency for these proposals is NMFS Office of Protected Resources - Endangered Species Act Interagency Cooperation Division.

Biological Opinion on Bureau of Land Management Vegetation Treatments Using Herbicides. (2015). https://doi.org/10.7289/V5BC3WMZ

The Bureau of Land Management has initiated formal consultation with the NMFS Office of Protected Resources on BLM's proposal to add three new active ingredients (aminopyralid, fluroxypyr, and rimsulfuron) to its list of approved active ingredients for use on BLM lands in 17 Western states.

Biological Opinion on Epa Multi-Sector General Permit for Industrial Stormwater Discharges Pursuant to the National Pollution Elimination System. (2015). https://doi.org/10.7289/V5D798G7

We evaluate whether the EPA's proposed action is likely to jeopardize endangered and threatened species or destroy or adversely modify designated critical habitat. The continued existence of a population is determined by the fate of the individuals within it and the continued existence of a species is determined by the fate of its populations. Populations grow or decline as its individuals live, die, grow, mature, migrate, and reproduce, or fail to do so. Critical habitat contains physical and biological features that are essential to the conservation of the species are physical and biological features including, but not limited to: (1) space for individual and population growth, and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and (5) habitats that are protected from disturbance or are representative of the historic geographic and ecological distributions of a species (ESA §3(5)(A)(i), 50 CFR §424.12(b)).

Biological Opinion on Long Term Operation of the Central Valley Project and the State Water Project. (2019). https://doi.org/10.25923/f6tw-rk19

This document represents NMFS' Opinion on the effects of the above actions on Sacramento River Winter-Run Chinook Salmon (Oncorhynchus tshawytscha), Central Valley Spring-Run Chinook Salmon (Oncorhynchus tshawytscha), California Central Valley Steelhead (Oncorhynchus mykiss), Southern distinct population segment (DPS) of North American Green Sturgeon (Acipenser medirostris), and Southern Resident DPS of Killer Whale (Orcinus orca).

The action agency for this consultation is the United States (U.S.) Department of Interior, Bureau of Reclamation (Reclamation), and the California Department of Water Resources (DWR) is considered an applicant. On August 2, 2016, Reclamation requested reinitiation of ESA section 7 consultation with the U.S. Fish and Wildlife Service (FWS) and NMFS on the coordinated Long-Term Operation (LTO) of the Central Valley Project (CVP) and State Water Project (SWP). Several factors resulted in Reclamation requesting reinitiation of consultation under the ESA, including new information on the status of listed species, new information related to recent multiple years of drought, and the evolution of best available science. The proposed action for this reinitiation of consultation (ROC) is the coordinated LTO of the CVP and SWP.

Biological Opinion on Reissuance of the Construction General Permit by the EPA. (2017). https://doi.org/10.7289/V5HX19SG

This document represents NMFS' opinion on the U.S. Environmental Protection Agency's (EPA) reissuance of its Construction General Permit (CGP) authorizing discharges of stormwater to waters of the U.S. and the implications of these discharges for threatened and endangered species and their designated critical habitat under NMFS' jurisdiction. The EPA uses general permits issued under section 402, the National Discharge Elimination System (NPDES) of the Clean Water Act (33 U.S.C. 1342 et seq.; CWA), to authorize routine discharges by multiple dischargers. Coverage for discharges under a general permit is granted to applicants after they submit a notice of intent to discharge (NOI1). Once the NOI is

submitted and any review period specified under the CGP has closed, the applicant is authorized to discharge under the terms of the general permit.

Biological Opinion on the Environmental Protection Agency's Registration of Pesticides Containing Chlorpyrifos, Diazinon, and Malathion. (2017). https://doi.org/10.7289/V5CJ8BQM

This Biological Opinion (Opinion) evaluated the effects of the Environmental Protection Agency's (EPA) registration of the pesticides chlorpyrifos, diazinon, and malathion on the Endangered Species Act (ESA)-listed species and designated critical habitats under the National Marine Fisheries Service (NMFS) jurisdiction. These three pesticides belong to the organophosphate class of insecticides and are highly toxic to mammals, fish, and aquatic invertebrates. Current product labels permit use on a variety of sites including agricultural, developed, and forested lands. Additionally, malathion and chlorpyrifos are registered for use as mosquitocides that can be applied to a wide array of land types nationwide. Current application rates and application methods are expected to produce aquatic concentrations of all three pesticides that are likely to harm aquatic species as well as contaminate their designated critical habitats. Species and their prey residing in shallow aquatic habitats proximal to pesticide use sites are expected to be the most at risk.

Boydstun, L. B., Stelle, W. W., Seger, J., Ames, R. T., & Waters, E. (2015). *Trawl Rationalization Trailing Actions: Season Date Change for Midwater Trawl Fishery (Whiting and Nonwhiting) : Environmental Assessment*. Retrieved from https://repository.library.noaa.gov/view/noaa/12613

This document provides background information analyses on modifications affecting regulations for the shorebased fishery using midwater gear to target Pacific whiting (whiting) as well as nonwhiting groundfish species that have been recommended by the Pacific Fishery Management Council (Council). The proposed action would require an amendment to the regulations implementing the Pacific Coast Groundfish Fishery Management Plan (FMP). The proposed action must conform to the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the principal legal basis for fishery management within the Exclusive Economic Zone (EEZ), which extends from the outer boundary of the territorial sea to a distance of 200 nautical miles from shore. In addition to addressing MSA mandates, this environmental assessment (EA) assesses the impacts of the Council's final preferred action alternative (PFMC 2012a) relative to the No Action Alternative, pursuant to the National Environmental Policy Act (NEPA) of 1969, as amended.

Coro, G., Magliozzi, C., Ellenbroek, A., Kaschner, K., & Pagano, P. (2016). Automatic Classification of Climate Change Effects on Marine Species Distributions in 2050 Using the Aquamaps Model. *Environmental and Ecological Statistics,* 23(1), 155-180. https://doi.org/10.1007/s10651-015-0333-8

Habitat modifications driven by human impact and climate change may influence species distribution, particularly in aquatic environments. Niche-based models are commonly used to evaluate the

availability and suitability of habitat and assess the consequences of future climate scenarios on a species range and shifting edges of its distribution. Together with knowledge on biology and ecology, niche models also allow evaluating the potential of species to react to expected changes. The availability of projections of future climate scenarios allows comparing current and future niche distributions, assessing a species' habitat suitability modification and shift, and consequently estimating potential species' reaction. In this study, differences between the distribution maps of 406 marine species, which were produced by the AquaMaps niche models on current and future (year 2050) scenarios, were estimated and evaluated. Discrepancy measurements were used to identify a discrete number of categories, which represent different responses to climate change. Clustering analysis was then used to automatically detect these categories, demonstrating their reliability compared to human supervised classification. Finally, the distribution of characteristics like extinction risk (based on IUCN categories), taxonomic groups, population trends and habitat suitability change over the clustering categories was evaluated. In this assessment, direct human impact was neglected, in order to focus only on the consequences of environmental changes. Furthermore, in the comparison between two climate snapshots, the intermediate phases were assumed to be implicitly included into the model of the 2050 climate scenario.

Demetras, N. J., Helwig, B. A., & McHuron, A. S. (2020). Reported Vessel Strike as a Source of Mortality of White Sturgeon in San Francisco Bay. *California Fish and Game,* 106(1), 59-65. Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=175917&inline

Ship strikes are a source of injury and mortality for many aquatic species worldwide (Holland 1986; Laist and Shaw 2006; Hazel et al. 2007). Over the past few years, the impact of vessel strikes involving large cetaceans has received significant attention (Laist et al. 2001; Peel et al. 2018). However, the impact of vessel strikes on large adult fishes has received considerably less attention worldwide. Currently, the knowledge base of vessel strikes and their potential impact on fishes in the scientific literature is limited to a few studies involving large, long-lived fishes such as sturgeon (Gutreuter et al. 2003; Simpson and Fox 2009; Brown and Murphy 2010; Balazik et al. 2012; Watanabe et al. 2013). Recently, both Simpson and Fox (2009) and Brown and Murphy (2010) reported vessel strike mortalities of the ESA listed Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) in the Delaware River estuary, while Balazik et al. (2012) reported vessel strike mortalities of Atlantic sturgeon in the tidal freshwater portion of the James River, Virginia. Using an-egg-per-recruit analysis, Brown and Murphy (2010) demonstrated that vessel strike mortalities could be detrimental to the population if more than 2.5% of the female Atlantic Sturgeon are killed annually in the Delaware Estuary.

Doukakis, P., Mora, E. A., Wang, S., Reilly, P., Bellmer, R., Lesyna, K., . . . Lindley, S. T. (2020). 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. *Fishery Bulletin,* 118, 63-73. https://doi.org/10.7755/FB.118.1.6

Understanding postrelease effects of incidental capture on fish species of conservation concern is critically needed. We collaborated with commercial fishermen to estimate postrelease survival of green sturgeon (Acipenser medirostris) captured and released from bottom trawls used to target California halibut (Paralichthys californicus). We developed a method for interpreting acceleration, depth, and

temperature data transmitted from pop-up satellite archival tags to classify the fate of individuals following capture and release in fishing operations. We first deployed SeaTag-MOD satellite tags on known living and dead sturgeon to develop a support vector machine that uses accelerometer readings to classify tagged fish as alive or dead. In 2015 and 2016, fishermen and West Coast Groundfish Observer Program observers tagged 76 green sturgeon (69–135 cm fork length) encountered as bycatch, yielding 51 useable data sets. Eleven sturgeon were classified as having died after release, 9 of which died within our designated 21-d (504 h) study period. Some green sturgeon entered the San Francisco Bay Delta after being tagged, indicating movement between ocean and estuary environments. Research is needed to understand how to minimize effects of handling time and trawl bycatch mortality.

Frew, J. A., Sadilek, M., & Grue, C. E. (2015). Assessing the Risk to Green Sturgeon from Application of Imidacloprid to Control Burrowing Shrimp in Willapa Bay, Washington—Part I: Exposure Characterization. *Environmental Toxicology and Chemistry,* 34(11), 2533-2541. https://doi.org/10.1002/etc.3089

Willapa Bay and Grays Harbor (WA, USA) comprise the largest region of commercial oyster cultivation on the Pacific Coast. The activities of 2 species of burrowing shrimp impair growth and survival of oysters reared on the intertidal mudflats. To maintain viable harvests, the oyster growers have proposed controlling the shrimp by applying the insecticide imidacloprid onto harvested beds. Green sturgeon (listed in the Endangered Species Act) forage on burrowing shrimp and could be exposed to imidacloprid in the sediment porewater and through consumed prey. Studies were conducted to evaluate the likelihood that green sturgeon would be exposed to imidacloprid and to characterize the subsequent environmental exposure. Comparisons between treated and untreated control beds following test application of the insecticide suggested that green sturgeon fed opportunistically on imidacloprid-impaired shrimp. The highest interpolated imidacloprid residue concentrations in field samples following chemical application were 27.8 μg kg^{-1} and 31.4 μg kg^{-1} in porewater and shrimp, respectively. Results from modeled branchial and dietary uptake, based on conservative assumptions, indicated that the porewater exposure route had the greatest contribution to systemic absorption of imidacloprid. The highest average daily uptake from porewater (177.9 μg kg^{-1} body wt) was 9.5-fold greater than total dietary uptake (18.8 μg kg^{-1} 1 body wt). Concentrations and durations of exposure would be lower than the levels expected to elicit direct acute or chronic toxic effects.

Kavet, R., Wyman, M. T., & Klimley, A. P. (2016). Modeling Magnetic Fields from a DC Power Cable Buried beneath San Francisco Bay Based on Empirical Measurements. *Plos One,* 11(2). https://doi.org/10.1371/journal.pone.0148543

The Trans Bay Cable (TBC) is a +/- 200-kilovolt (kV), 400 MW 85-km long High Voltage Direct Current (DC) buried transmission line linking Pittsburg, CA with San Francisco, CA (SF) beneath the San Francisco Estuary. The TBC runs parallel to the migratory route of various marine species, including green sturgeon, Chinook salmon, and steelhead trout. In July and August 2014, an extensive series of magnetic field measurements were taken using a pair of submerged Geometrics magnetometers towed behind a survey vessel in four locations in the San Francisco estuary along profiles that cross the cable's path; these included the San Francisco-Oakland Bay Bridge (BB), the Richmond-San Rafael Bridge (RSR), the Benicia-Martinez Bridge (Ben) and an area in San Pablo Bay (SP) in which a bridge is not present. In this

paper, we apply basic formulas that ideally describe the magnetic field from a DC cable summed vectorially with the background geomagnetic field (in the absence of other sources that would perturb the ambient field) to derive characteristics of the cable that are otherwise not immediately observable. Magnetic field profiles from measurements taken along 170 survey lines were inspected visually for evidence of a distinct pattern representing the presence of the cable. Many profiles were dominated by field distortions unrelated to the cable caused by bridge structures or other submerged objects, and the cable's contribution to the field was not detectable. BB, with 40 of the survey lines, did not yield usable data for these reasons. The unrelated anomalies could be up to 100 times greater than those from the cable. In total, discernible magnetic field profiles measured from 76 survey lines were regressed against the equations, representing eight days of measurement. The modeled field anomalies due to the cable (the difference between the maximum and minimum field along the survey line at the cable crossing) were virtually identical to the measured values. The modeling yielded a pooled cable depth below the bay floor of 2.06 m (+/- 1.46 std dev), and estimated the angle to the horizontal of the imaginary line connecting the cross-sectional center of the cable's two conductors (0.1143 m apart) as 178.9 degrees +/- 61.9 degrees (std dev) for Ben, 78.6 degrees +/- 37.0 degrees (std dev) for RSR, and 139.9 degrees +/- 27.4 degrees (std dev) for SP. The mean of the eight daily average currents derived from the regressions was 986 +/- 185 amperes (A) (std dev), as compared to 722 +/- 95 A (std dev) provided by Trans Bay Cable LLC. Overall, the regressions based on fundamental principles (Biot Savart law) and the vectorial summation of cable and geomagnetic fields provide estimates of cable characteristics consistent with plausible expectations.

Klimley, A. P., Wyman, M. T., & Kavet, R. (2017). Chinook Salmon and Green Sturgeon Migrate through San Francisco Estuary Despite Large Distortions in the Local Magnetic Field Produced by Bridges. *Plos One,* 12(6). https://doi.org/10.1371/journal.pone.0169031

Empirical evidence exists that some marine animals perceive and orient to local distortions in the earth's main static geomagnetic field. The magnetic fields produced by undersea electric power cables that carry electricity from hydrokinetic energy sources to shore-based power stations may produce similar local distortions in the earth's main field. Concerns exist that animals migrating along the continental shelves might orient to the magnetic field from the cables, and move either inshore or offshore away from their normal path. We have studied the effect of the Trans Bay Cable (TBC), an 85-km long, high voltage, direct current (DC) transmission line leading underwater from Pittsburg, CA to San Francisco, CA, on fishes migrating through the San Francisco Estuary. These included Chinook salmon smolts (Oncorhynchus tshawytscha) that migrate downstream through the San Francisco Estuary to the Pacific Ocean and adult green sturgeon (Acipenser medirostris), which migrate upstream from the ocean through the estuary to their spawning habitat in the upper Sacramento River and return to the ocean after spawning occurs. Based on a detailed gradiometer survey, we found that the distortions in the earth's main field produced by bridges across the estuary were much greater than those from the Trans Bay Cable. The former anomalies exceeded the latter by an order of magnitude or more. Significant numbers of tagged Chinook salmon smolts migrated past bridges, which produced strong magnetic anomalies, to the Golden Gate Bridge, where they were recorded by dual arrays of acoustic tag-detecting monitors moored in lines across the mouth of the bay. In addition, adult green sturgeon successfully swam upstream and downstream through the estuary on the way to and from their spawning grounds. Hence, the large anomalies produced by the bridges do not appear to present a strong barrier to the natural seasonal movement patterns of salmonid smolts and adult green sturgeon.

Mussen, T. D., Cocherell, D., Poletto, J. B., Reardon, J. S., Hockett, Z., Ercan, A., . . . Fangue, N. A. (2014). Unscreened Water-Diversion Pipes Pose an Entrainment Risk to the Threatened Green Sturgeon, *Acipenser medirostris*. *Plos One,* 9(1). https://doi.org/10.1371/journal.pone.0086321

Over 3,300 unscreened agricultural water diversion pipes line the levees and riverbanks of the Sacramento River (California) watershed, where the threatened Southern Distinct Population Segment of green sturgeon, Acipenser medirostris, spawn. The number of sturgeon drawn into (entrained) and killed by these pipes is greatly unknown. We examined avoidance behaviors and entrainment susceptibility of juvenile green sturgeon (35 plus or minus 0.6 cm mean fork length) to entrainment in a large (>500-kl) outdoor flume with a 0.46-m-diameter water-diversion pipe. Fish entrainment was generally high (range: 26-61%), likely due to a lack of avoidance behavior prior to entering inescapable inflow conditions. We estimated that up to 52% of green sturgeon could be entrained after passing within 1.5 m of an active water-diversion pipe three times. These data suggest that green sturgeon are vulnerable to unscreened water-diversion pipes, and that additional research is needed to determine the potential impacts of entrainment mortality on declining sturgeon populations. Data under various hydraulic conditions also suggest that entrainment-related mortality could be decreased by extracting water at lower diversion rates over longer periods of time, balancing agricultural needs with green sturgeon conservation.

Pess, G. R., Quinn, T. P., Gephard, S. R., & Saunders, R. (2014). Re-Colonization of Atlantic and Pacific Rivers by Anadromous Fishes: Linkages between Life History and the Benefits of Barrier Removal. *Reviews in Fish Biology and Fisheries,* 24(3), 881-900. https://doi.org/10.1007/s11160-013-9339-1

The last two decades have seen a rapid increase in barrier removals on rivers of the Northern Hemisphere, often for the explicit purpose of expanding the abundance, spatial distribution, and life history diversity of migratory fishes. However, differences in life history such as seasonal timing of migration and reproduction, iteroparity versus semelparity, and the extent of natal homing are likely to affect the capacity for expansion and re-colonization by taxa such as alosines, lamprey, and salmonids. We first review some basic life history traits that may affect re-colonization by migratory fishes, and then present selected examples from Atlantic and Pacific basins to illustrate these patterns and their implications for the success of barrier removal as a measure to advance the goal of fish conservation. We conclude that diadromous fishes have the capacity to rapidly re-colonize newly available habitats, though the life history patterns of each species, the proximity to source populations in the same or nearby river systems, and the diversity of habitats available may control the patterns and rates of re-colonization.

Poaching Suspected after Two Green Sturgeon Surface on Yuba River. (2018). *Appeal-Democrat*. Retrieved from https://www.appeal-democrat.com/news/poaching-suspected-after-two-green-sturgeon-surface-on-yuba-river/article_3566734e-97ad-11e8-9b77-b34a6831ac6d.html

Aug. 04--Poachers allegedly killed two adult green sturgeon in the Yuba River near Hallwood in recent weeks, prompting the California Department of Fish and Wildlife Law Enforcement Division to request the public's help in finding those responsible.

Poletto, J. B., Martin, B., Danner, E., Baird, S. E., Cocherell, D. E., Hamda, N., . . . Fangue, N. A. (2018). Assessment of Multiple Stressors on the Growth of Larval Green Sturgeon *Acipenser medirostris*: Implications for Recruitment of Early Life-History Stages. *Journal of Fish Biology,* 93(5), 952-960. https://doi.org/10.1111/jfb.13805

Early developmental stages of fishes are particularly sensitive to changes in environmental variables that affect physiological processes such as metabolism and growth. Both temperature and food availability have significant effects on the growth and survival of larval and juvenile fishes. As climate change and anthropogenic disturbances influence sensitive rearing environments of fishes it is unlikely that they will experience changes in temperature or food availability in isolation. Therefore, it is critical that we determine the effects of each of these potential stressors on larval growth and development, as well as understand the additive, synergistic or antagonistic effects of both. We reared threatened green sturgeon Acipenser medirostris (initial age ca. 32 days post hatch) at four temperatures (11, 13, 16 and 19 degrees C) and two food availability rates (100% and 40% of optimal) to assess the effects of these stressors and their interactions on larval growth. We compared the overall size (fork length, total length and mass), growth rates (cm day(-1) and g day(-1)) and relative condition factor of these larval and juvenile fish at 3 week intervals for up to 12 weeks. Our results indicated that temperature and food availability both had significant effects on growth and condition and that there was a significant interaction between the two. Fish reared with limited food availability exhibited similar patterns in growth rates to those reared with elevated food rates, but the effects of temperature were greatly attenuated when fish were food-limited. Also, the effects of temperature on condition were reversed when fish were reared with restricted food, such that fish reared at 19 degrees C exhibited the highest relative condition when fed optimally, but the lowest relative condition when food was limited. These data are critical for the development of relevant bioenergetics models, which are needed to link the survival of larval sturgeons with historic environmental regimes, pinpoint temperature ranges for optimal survival and help target future restoration sites that will be important for the recovery of sturgeon populations.

Power, M. E., Bouma-Gregson, K., Higgins, P., & Carlson, S. M. (2015). The Thirsty Eel: Summer and Winter Flow Thresholds That Tilt the Eel River of Northwestern California from Salmon-Supporting to Cyanobacterially Degraded States. *Copeia,* 103(1), 200-211. https://doi.org/10.1643/CE-14-086

Although it flows through regions of northwestern California that are thought to be relatively well watered, the Eel River is increasingly stressed by drought and water withdrawals. We discuss how critical threshold changes in summer discharge can potentially tilt the Eel from a recovering salmon-supporting ecosystem toward a cyanobacterially degraded one. To maintain food webs and habitats that support salmonids and suppress harmful cyanobacteria, summer discharge must be sufficient to connect mainstem pools hydrologically with gently moving, cool base flow. Rearing salmon and steelhead can survive even in pools that become isolated during summer low flows if hyporheic exchange is sufficient. But if the ground water discharge that sustains river flow during summer drought drops below critical levels, warm stagnant conditions will kill salmonids, and cyanobacteria will thrive. Challenges and opportunities for restoring the Eel and increasing its resilience to climate extremes, water diversions, and excessive loading of fine sediments point toward exploring how land use and terrestrial vegetation affect delivery from uplands of water, heat, sediments, solutes, organic matter, and organisms-in ways that either heal or damage rivers.

Programmatic Biological and Conference Opinion on the Towing of Inactive U.S. Navy Ships from Their Existing Berths to Dismantling Facilities or Other Inactive Ship Sites. (2017). https://doi.org/10.25923/sw62-zf21

The Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.) establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat they depend on. Section 7(a)(2) of the ESA requires Federal agencies to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Federal agencies must do so in consultation with National Marine Fisheries Service (NMFS) for threatened or endangered species (ESA-listed), or designated critical habitat that may be affected by the action that are under NMFS jurisdiction (50 C.F.R. §402.14(a)). If a Federal action agency determines that an action "may affect, but is not likely to adversely affect" endangered species, threatened species, or designated critical habitat and NMFS concurs with that determination for species under NMFS jurisdiction, consultation concludes informally (50 C.F.R. §402.14(b)).

Richerson, K., Jannot, J. E., McVeigh, J., Somers, K., Tuttle, V., & Wang, S. (2019). *Observed and Estimated Bycatch of Green Sturgeon in 2002-2017 Us West Coast Groundfish Fisheries*. Seattle, WA Retrieved from https://www.pcouncil.org/documents/2019/06/agenda-item-i-4-a-nmfs-report-3-observed-and-estimated-bycatch-of-green-sturgeon-in-2002-2017-us-west-coast-groundfish-fisheries-electronic-only.pdf/

This report presents observed and estimated bycatch of green sturgeon (Acipenser medirostris) in fishery sectors observed by the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP) from 2002-2017. Three federal groundfish fisheries observed by WCGOP and A-SHOP encountered green sturgeon between 2002 and 2017: the limited entry (LE) bottom trawl fishery (active 2002-2010), the individual fishing quota (IFQ) bottom trawl fishery (active 2011-2017), and the at-sea hake fishery (active 2002-2017).

Sacramento River Bank Protection Project, Phase II 80,000 Linear Feet, Programmatic. (2019). https://doi.org/10.25923/7t1n-9b83

The enclosed biological opinion (BO) analyzes the effects of the U.S. Army Corps of Engineer's (USACE) SRBPP PACR as a "Framework Programmatic" action. This is considered a Framework Programmatic BO because the biological assessment (BA) included general project details including design, possible locations, effects, and because subsequent bank protection actions are to be developed in the future. Any take of a listed species associated with implementation of SRBPP PACR would be covered under future ESA section 7 consultation (50 CFR Part 402.02) associated with each action. Therefore, an Incidental Take Statement is not included as part of this Framework Programmatic BO. Rather, USACE will request consultation on individual actions or suites of actions under the SRBPP PACR, including a description of the expected effects to species and critical habitat, and any avoidance or minimization measures, in order for NMFS to complete ESA consultation, including exempting incidental take as appropriate.

Sardella, B. A., & Kultz, D. (2014). The Physiological Responses of Green Sturgeon (Acipenser medirostris) to Potential Global Climate Change Stressors. *Physiological and Biochemical Zoology,* 87(3), 456-463. https://doi.org/10.1086/675494

The green sturgeon (Acipenser medirostris) is an anadromous species with a distinct population segment in the San Francisco Bay-Sacramento River Delta that is currently listed as threatened. Although this species is able to tolerate salinity challenges as soon as 6 mo posthatch, its ability to deal with unpredictable salinity fluctuations remains unknown. Global climate change is predicted to result in large freshwater (FW) flushes through the estuary during winter and greater tidal influence during the summer. We exposed green sturgeon acclimated to 15 (EST) or 24 (BAY) g/L salinity to a rapid EW influx, where salinity was reduced to 0 g/L in 3 h in order to simulate the effect of the "winter" scenario. Both groups survived, enduring a 10% plasma osmolality reduction after 3 h. BAY-acclimated sturgeon upregulated both Na+, K+-ATPase (NKA) activity and caspase 3/7 activity, but no changes were observed in the EST-acclimated fish. In addition, we exposed FW-acclimated sturgeon to a dual 12-h salinity fluctuation cycle (0-24-0 g/L) in order to simulate the effect of greater tidal influence. At 6 h, the sturgeon showed a significant increase in plasma osmolality, and branchial NKA and caspase 3/7 activities were increased, indicating an acclimation response. There was no acclimation at 18 h, and plasma osmolality was higher than the peak observed at 6 h. The second fluctuation elicited an upregulation of the stress proteins ubiquitin and heat shock 70-kDa protein (HSP 70). Sturgeon can acclimate to changes in salinity; however, salinity fluctuations resulted in substantial cellular stress.

Sebastiao, F. D., Loch, T. P., Marancik, D. P., Griffin, M. J., Maret, J., Richey, C., & Soto, E. (2019). Identification of Chryseobacterium Spp. Isolated from Clinically Affected Fish in California, USA. *Diseases of Aquatic Organisms,* 136(3), 227-234. https://doi.org/10.3354/dao03409

Chryseobacterium spp. (Family Flavobacteriaceae) are emergent fish pathogens in Europe, Asia and North America. In 2016-2017, 7 bacterial isolates were recovered from posterior kidney or spleen of cultured diseased rainbow trout Oncorhynchus mykiss (n = 1), green sturgeon Acipenser medirostris (n = 1), white sturgeon A. transmontanus (n = 2), blue ram cichlid Mikrogeophagus ramirezi (n = 1), and returning fall Chinook salmon O. tshawytscha (n = 2) from different freshwater systems. Bacterial colonies were visible after 24-48 h incubation at 20 degrees C on agar media. Isolates were Gram-negative, rod-shaped, catalase and oxidase positive. Amplification and partial sequence analysis of the 16S rRNA and gyrB genes allocated the microorganisms to the genus Chryseobacterium sharing 93.2-99.6% similarity to 6 described Chryseobacterium spp. at the 16S rRNA locus, and 87.8-99.1 % similarity at gyrB. Phylogenetic analyses in conjunction with percent sequence identity suggest some of the recovered isolates may represent novel Chryseobacterium subspecies or species. The pathogenicity of 5 isolates was evaluated experimentally in rainbow trout (n = 60), brown trout Salmo trutta (n = 60) and white sturgeon (n = 36) in flow-through freshwater at 18 degrees C. Approximately 10(7) CFU fish(-1) was injected in the epaxial musculature of anesthetized animals. Limited mortality was observed and no bacteria were recovered from dead or moribund fish post-challenge. Thirty days post-challenge, survivors were euthanized and multiple tissues were collected and fixed for histological analysis. No consistent histopathological changes were observed in challenged or control fish. While results suggest the recovered Chryseobacterium spp. may be opportunistic pathogens, further research is warranted to better understand the role of these bacteria in fish disease.

Smith Canal Gate Project. (2019). https://doi.org/10.25923/80cz-sg17

The National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 USC 1531 et seq.), and implementing regulations at 50 CFR 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). A complete record of this consultation is on file at the NMFS California Central Valley Office in Sacramento, California.

Steel, A. E., Thomas, M. J., & Klimley, A. P. (2019). Reach Specific Use of Spawning Habitat by Adult Green Sturgeon (Acipenser medirostris) under Different Operation Schedules at Red Bluff Diversion Dam. *Journal of Applied Ichthyology,* 35(1), 22-29. https://doi.org/10.1111/jai.13602

Mature green sturgeon, Acipenser medirostris, enter rivers along the western coast of North America in late winter to late spring and migrate upriver to spawning sites. After spawning, they may leave the river or spend the summer and autumn holding in deep pools before departing from the river with the onset of winter rains. Evidence exists that the seasonal Red Bluff Diversion Dam (RBDD) was an obstacle to the upriver migration of green sturgeon in the Sacramento River in Central California. We compared the migratory movements of green sturgeon under three different dam operation schedules, including post-decommissioning, to assess the impact of this management action. The proportion of green sturgeon carrying acoustic transmitters that moved above the RBDD was higher when the gates were closed on June 15, one month later than the historical closure date of May 15, and increased again after the dam was decommissioned. The application of statistical analyses (generalized linear and additive mixed models) to the detection records of green sturgeon highlighted an improvement in connectivity after dam decommissioning. The data also indicate that interannual variation in river condition is an important driver of sturgeon presence on the spawning grounds.

Threatened Green Sturgeon Rescued from Fremont Weir, Returned to Sacramento River. (2017). *States News Service*. Retrieved from https://cdfgnews.wordpress.com/2017/03/21/threatened-green-sturgeon-rescued-from-fremont-weir-returned-to-sacramento-river/#:~:text=Biologists%20from%20the%20California%20Department,when%20Sacramento%20River%20floodwaters%20receded.

The following information was released by the California Department of Fish and Game (DFG): Biologists from the California Department of Fish and Wildlife (CDFW) recently saved a Sacramento River green sturgeon trapped in the Fremont Weir. The five-and-a-half-foot long fish was stranded in the nearly two-

mile-long concrete weir when Sacramento River floodwaters receded. Sturgeon in this area are migrating up the Sacramento River to spawn above Red Bluff.

Troiano, A. T., & Grue, C. E. (2016). Plasma Cholinesterase Activity as a Biomarker for Quantifying Exposure of Green Sturgeon to Carbaryl Following Applications to Control Burrowing Shrimp in Washington State. *Environmental Toxicology and Chemistry,* 35(8), 2003-2015. https://doi.org/10.1002/etc.3344

Willapa Bay (Washington State, USA) has been 1 of the rare intertidal locations where large-scale pesticide applications occur. Until recently, carbaryl was applied to control burrowing shrimp that decrease commercial oyster productivity. The bay is a critical habitat for green sturgeon (Acipenser medirostris), an anadromous species listed as threatened under the US Endangered Species Act. However, the hazard that carbaryl poses is unknown. Surrogate seawater-acclimated white sturgeon (A. transmontanus) were exposed to 0gL(-1), 30gL(-1), 100gL(-1), 300gL(-1), 1000gL(-1), and 3000gL(-1) carbaryl for 6h, and brain acetylcholinesterase (AChE) and plasma butyrylcholinesterase (BChE) activities were measured. Enzyme recovery was measured in an additional cohort exposed to 1000gL(-1) carbaryl for 6h. Activity of AChE was reduced (p0.001) at concentrations100gL(-1) with recovery in the 1000gL(-1) cohort by 72h. Surprisingly, BChE activity was greater than controls at concentrations300gL(-1) (p>0.05), a finding confirmed in additional fish exposed to 3000gL(-1) for 6h (+30%, p < 0.001) with apparent recovery by 48h. Plasma samples were collected from free-living green sturgeon before and 4d to 5d after application of carbaryl in Willapa Bay. Activity of BChE after application was reduced 28% (p<0.001), indicating exposure to the pesticide. However, the lack of congruence between BChE and AChE activity in captive white sturgeon exposed to carbaryl indicates that further studies are needed to better understand the risk carbaryl exposure poses to green sturgeon.

Weilenman, D. B. (2017). California Delegation Opposes 'California Water Fix'. *Martinez News-Gazette*. Retrieved from Lexis Nexis. No URL available.

What once was called the Bay Delta Conservation Plan now is known as the California WaterFix and Eco Restore. No matter the name, the project involves building two tunnels, each four stories tall and 30 miles long, to carry water from the Sacramento River to State Water Project intake stations and on to the Central Valley. Six California members of Congress, including two who represent Martinez, have weighed in on the project, expressing their opposition to a recent biological opinion that the massive project wouldn't be harmful to the Sacramento-San Juaquin River Delta environment or local economies.

Wyman, M. T., Klimley, A. P., Battleson, R. D., Agosta, T. V., Chapman, E. D., Haverkamp, P. J., . . . Kavet, R. (2018). Behavioral Responses by Migrating Juvenile Salmonids to a Subsea High-Voltage DC Power Cable. *Marine Biology,* 165(8), 1-15. https://doi.org/10.1007/s00227-018-3385-0

Currently, there is large-scale interest in developing marine-based energy sources and extensive subsea power cable networks. Despite growing concern that local perturbations in the magnetic field produced

by current passing through these cables may negatively affect electromagnetically sensitive marine species, e.g., disrupted migration; few studies have examined free-living animals. We used acoustic biotelemetry tracking data to examine movement behaviors and migration success of a magneto-sensitive fish, late-fall run Chinook (LFC) salmon (Oncorhynchus tshawytscha), in relation to the energization of a magnetic field-producing subsea power cable, as well as other potentially influential environmental parameters. We analyzed detection records of tagged LFC salmon smolts during their out-migration through the San Francisco Bay before and after the installation of an 85-km high-voltage direct-current transmission cable. Cable energization did not significantly impact the proportion of fish that successfully migrated through the bay or the probability of successful migration. However, after cable energization, higher proportions of fish crossed the cable location and fish were more likely to be detected south of their normal migration route. Transit times through some regions were reduced during cable activity, but other environmental factors were more influential. Resource selection models indicated that proximity to the active cable varied by location: migration paths moved closer to the cable at some locations, but further away at others. Overall, cable activity appeared to have mixed, but limited effects on movements and migration success of smolts. Additional studies are recommended to further investigate impacts of subsea cables on fish migrations, including potential long-term consequences.

Yolo Bypass Restoration. (2019). https://doi.org/10.25923/t2kf-yq36

This biological opinion is based on the final biological assessment and other related environmental permitting documents prepared in support of the project, and on the best available scientific and commercial information. NMFS concludes that the project is not likely to jeopardize the continued existence of the federally listed as endangered, Sacramento River winter-run Chinook salmon (Oncorhynchus tshawytscha) evolutionarily significant unit (ESU), the threatened Central Valley spring-run Chinook salmon ESU (O. tshawytscha), the threatened California Central Valley steelhead distinct population segment (DPS) (O. mykiss), or the threatened southern DPS of the North American green sturgeon (Acipenser medirostris), and is not likely to destroy or adversely modify their designated critical habitats. NMFS has included an incidental take statement with reasonable and prudent measures and nondiscretionary terms and conditions that are necessary and appropriate to avoid, minimize, or monitor incidental take of listed species associated with the project.

Zarri, L. J., Danner, E. M., Daniels, M. E., & Palkovacs, E. P. (2019). Managing Hydropower Dam Releases for Water Users and Imperiled Fishes with Contrasting Thermal Habitat Requirements. *Journal of Applied Ecology,* 56(11), 2423-2430. https://doi.org/10.1111/1365-2664.13478

The construction of dams on large rivers has negative impacts on native species. Environmental flows have been proposed as a tool to mitigate these impacts, but in order for these strategies to be effective they must account for disparate temperature and flow needs of different species. We applied a multi-objective approach to identify trade-offs in dam release discharge and temperature for imperiled fishes with contrasting habitat requirements, while simultaneously meeting the needs of human water users. Using the Sacramento River (California, USA) as a case study, our model suggests that current management aimed at providing high discharge for downstream water users and cold water for endangered winter-run Chinook salmon (Oncorhynchus tshawytscha) has detrimental impacts on

threatened green sturgeon (Acipenser medirostris), which require warm water for juvenile growth. We developed an optimal dam release scenario that can be used to meet the needs of salmon, sturgeon and human water users. Our results show that dam releases can be managed to successfully achieve these multiple objectives in all but the most severe drought years. Synthesis and applications. This study shows that managing dam releases to meet the needs of a single species can have detrimental effects on other native species with different flow and temperature requirements. We applied a multi-objective approach to balance environmental requirements of multiple species with the needs of human water users. Our findings can be used to guide management of Shasta Dam and our approach can be applied to achieve multi-object management goals in other impounded rivers.