How Long Does it Take for Selenium to Bioaccumulate in the Diet and Tissues of Sturgeon?

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In trying to answer the question "how much is too much" with respect to selenium in the Bay-Delta, attention rightly has been focused on the introduced Asian overbite clam that bioaccumulates selenium especially efficiently, and on the vulnerable sturgeon species that feed on this clam. In the Bay-Delta environment of fluctuating selenium and migrating sturgeon, to assess the risks of selenium to sensitive life stages of sturgeon, it is essential to understand the time delay between exposure to selenium in ambient water, and bioaccumulation of selenium in the tissues of the sturgeon species. Hitherto, estimating these lag times has been a matter of guesswork. Now, a statistical method has been demonstrated that enables us to provide more objective estimates. The method was developed using selenium monitoring data from the Grassland Bypass Project in the Kesterson area of the San Joaquin valley. The method can be used to infer estimated selenium bioaccumulation lag times of roughly 50-120 days for overbite clams, 178 days for white sturgeon, and 247 days for green sturgeon. Reliability of these estimates will be discussed, along with implications for risk of selenium to sturgeon species.

Keywords: selenium, bioaccumulation lag, trophic level, sturgeon, overbite clam
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Fin Ray Microchemistry as a Tool to Reconstruct the Migratory History of White Sturgeon *Acipenser transmontanus*

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The objective of this study was validation of fin ray microchemistry (i.e., strontium isotope; 87Sr:86Sr ratios) analysis to identify White Sturgeon *Acipenser transmontanus* movement patterns within freshwater portions of the San Francisco Estuary watershed. This approach has high potential to provide valuable management information regarding juvenile and adult sturgeon habitat and behavior. To identify how time and water source are archived in pectoral fin ray microchemistry, we exposed rapidly growing juvenile hatchery sturgeon in laboratory tanks to two water sources exhibiting distinctive 87Sr:86Sr signatures for different periods of time. We also assessed how diet affected fin ray microchemistry by feeding a subset of fish a marine-derived diet, while others were fed a diet whose microchemistry matched that of the water source. We detected distinct shifts in fin ray microchemistry in sturgeon that were exposed to a water source for only two weeks. Diet did not significantly influence resulting fin ray microchemistry in the majority of the experimental sturgeon. For one of the water sources, fin ray strontium values matched those of the water source; for the other water source fin rays reached a uniform, but lower, strontium value as compared to that of the water source. The mechanism behind this disparity was explored with a follow-up experiment. Findings of these controlled laboratory studies have important implications for applying this methodology to field-collected fin ray samples.

Keywords: sturgeon, life history, microchemistry, migration, spawning, rearing, fin ray
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Selenium in San Francisco Estuary White Sturgeon

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Selenium is an essential trace element that is toxic at high levels and has been shown to adversely impact reproduction in white sturgeon. To protect this sensitive species, the San Francisco Bay Regional Water Quality Control Board established the North San Francisco Bay Selenium (Se) TMDL. The monitoring target for the TMDL was established as ≤11.3 ug/g dry weight in white sturgeon muscle tissue. The Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) has conducted long-term monitoring of selenium in white sturgeon throughout the Bay since 1997, and since 2014 has conducted two additional studies to develop non-lethal tissue monitoring methods to assist with the implementation of the TMDL. Non-lethal sampling methods to monitor for compliance with the TMDL are important due to the declining abundance of white sturgeon.

Muscle plug, muscle fillet, ovary, liver, fin ray, and otolith samples collected through various sampling efforts (fishing derbies, California Department of Fish and Wildlife sturgeon trammel net surveys, and RMP Status and Trends monitoring) between 2009 and 2016 were analyzed for Se concentrations. Microchemical analyses of Se in annual growth zones of otoliths and pectoral fin rays are being conducted to measure patterns of temporal exposure to Se. Se concentrations were relatively stable between 0.4 and 0.5 ppm in pectoral fin ray sections corresponding to the period of 1998-2015. Additionally, muscle plug sampling was determined to be a viable non-lethal technique for monitoring attainment of the TMDL target. Muscle plug Se concentrations are within the range of previously measured muscle tissue Se concentrations and are significantly correlated with muscle fillet Se concentrations. Additional relationships among Se in other tissues will indicate whether muscle plugs or other non-lethally collected tissue measurements (fin rays) are good proxies for Se accumulation in tissues of toxicological interest (ovaries, liver).

Keywords: selenium, non-lethal sampling, sturgeon, muscle plugs
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Fish on the Edge: Assessing Environmental Constraints for Recruitment of White Sturgeon in the San Joaquin River, California.

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Inadequate recruitment is a hallmark of declining sturgeon populations throughout the world. Efforts to understand and address the processes that regulate recruitment are of foremost importance for successful management and recovery. Prior to 2011, San Francisco Estuary White Sturgeon *Acipenser transmontanus* were only known to spawn in the Sacramento River, California. Although sturgeon captured in the San Joaquin River were reported by anglers, no direct evidence existed of spawning within the river. We assessed potential White Sturgeon spawning locations by deploying artificial substrate samplers and benthic drift nets during late winter and spring of 2011-2016 from river kilometers 115.2 to 145.3 of the San Joaquin River. Collections of fertilized eggs, compared with hydrology data, confirm that White Sturgeon spawn within the San Joaquin River during wet and dry water-year conditions; however, we were unable to document spawning during critical water-year conditions. Time of spawning was estimated by determining egg stage-of-development at time of capture coupled with available water temperatures. Time of spawning was also estimated from the collection of endogenous larval sturgeon (0-2 days post-hatch). Comparing environmental data with the spawning information and adult sturgeon telemetry data appears to demonstrate the importance of variable streamflow and temperature relief during late winter and early spring. Small pulse flow augmentations intended to benefit juvenile salmonids appear to have triggered White Sturgeon migration within this system throughout 2011–2016 and spawning during 2012 and 2016. Understanding the effects of water management on spawning and subsequent recruitment is necessary to increase White Sturgeon recruitment and aid in enhancing the San Francisco Estuary population.

Keywords: White Sturgeon, spawning, recruitment, flow augmentation, water management
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Applying a Simplified Energy-Budget Model to Explore the Effects of Temperature and Food Availability on Life History of the Green Sturgeon (*Acipenser medirostris*)

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The southern distinct population segment (sDPS) of North American green sturgeon (*Acipenser medirostris*) are listed as threated under the endangered species act. These fish use the Sacramento River and the Bay Delta as breeding and rearing habitat, and are potentially impacted by water management practices. Understanding of these impacts helps to answer key and wide range of problems in the conservation of the species and support decision-making processes. Particularly, it is crucial to understand the interaction between the life history of the organism and their environment. Empirical studies might help to understand some of these interactions; however, it is impossible to assess all possible organisms–environment interactions experimentally alone, and it is also dangerous to extrapolate results beyond the range of the observation points. We here use a simplified energy-budget model based on Dynamic Energy Budget theory to explore the effects of temperature and food limitation on the life history Green Sturgeon. We show here how the various model parameters can be estimated from different laboratory and field observations. Using the parameterized model, we are able describe the growth and reproduction data of Green Sturgeon obtained from primary and secondary data sets. Using our simulation model, we are able to predict the combined effect of food density and temperature on the growth and reproduction of Green Sturgeon. We are also able to characterize the nature of interaction of temperature and food limitation. We argue the model can easily be integrated with physical models to assess and predict the effects of temporal and spatial temperature change on the life history of Green Sturgeon.

Keywords: energy-budget model, DEB, DEBkiss, Green Sturgeon, environmental stressors, organism–environment interactions
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