Predation in the North Delta: Tales from the Digestive Goo

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Predation in the Sacramento-San Joaquin Delta has been identified as a major stressor to declining native fish populations. While predation is a universal process for biota of nearly all trophic levels, a primary concern for native fishes in the Delta is that predation pressure from introduced, highly effective predators such as Striped Bass (*Morone saxatilis*), Largemouth Bass (*Micropterus salmoides*), and Smallmouth Bass (*Micropterus dolomeiu)* may limit population recovery or even exacerbate species declines. We investigated predation patterns in the North Delta, a region that is heavily used by many native species for rearing and migration. To elucidate predation patterns, we sampled predator populations in 2012-2014 via gill netting in different habitats and migration corridors in the North Delta commonly used by native fish. Targeted non-native predator species, as well as the native Sacramento Pikeminnow (*Ptychocheilus grandis*), had their digesta removed and screened for the presence of 14 prey species of interest using genetic assays. A single target prey species was found in 17-50% of predators, depending on the predator species, and multiple prey species were detected in 15% of predators. Striped Bass were the most commonly sampled predator (~54% of catch), with common prey being Threadfin Shad (*Dorosoma petenense*), Sacramento Pikeminnow, and Mississippi Silverside (*Menidia beryllina*). Among non-Striped Bass predators, Striped Bass was the most commonly detected prey item, comprising 22% of detections. Understanding patterns of predation on native fish populations, and the environmental parameters correlated with increased predation, is critical for being able to manage and restore the Delta for native fish species.

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Predator Densities and Associated Salmonid Smolt Mortality around Water Diversions

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State-of-the-art fish screens on large water diversions effectively prevent juvenile salmon from being entrained by the diversion, but the physical structure and their prey-concentrating effect may attract predators and create a local predation problem. We are assessing the impact of predation near two large diversions on juvenile Central Valley Chinook salmon (*Oncorhynchus tshawytscha*) using a combination of acoustic telemetry, a DIDSON camera, and tethering. We expect to answer these questions:

(1) Is predator density higher near water diversions relative to nearby areas?
(2) Do predators express site fidelity to the diversions?
(3) Is the relative smolt predation rate near the diversions higher than nearby areas? What about seasonal and diel predation rate dynamics?
(4) What proportion of the predators' diets consists of smolts near the diversions?
(5) All factors combined, does this result in higher than average smolt mortality rates near the diversions?

During a pilot season in 2011 on one diversion on the Sacramento River, we gained limited insight into these questions. Predator densities were lowest near the diversion, and highest near the riverbank. Striped bass (*Morone saxatilis*) did not seem to express site fidelity while Sacramento pikeminnow (*Ptychocheilus grandis*) did. Finally, relative predation rates around the diversion were near average, with the highest relative predation rates near the riverbank.

In the 2012 and 2013 seasons, we added a second diversion representing a different design model, allowing the comparison of predator-prey dynamics between different commonly-used diversion designs. We will present data from the more intensive second and third seasons.

This project was conceived in response to the knowledge gap regarding how large water diversions influence predator-smolt dynamics; the majority of research on the impacts of diversions on salmonids concentrate on dewatering and lethal entrainment into pumps.

Keywords: water diversion, predation, salmon, smolt, striped bass, Sacramento, pikeminnow
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Making the Connection between Fish Predation Hot Spots and Regional Hydrodynamics

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Based on the literature review and presentations at the 2013 State of the science workshop on fish predation on Central Valley salmonids in the Bay-Delta Watershed (July 2013; www.dfg.ca.gov/erp/predation.asp), we identified predation hot spot locations throughout the Delta. We superimposed these hot spots on a map with additional knowledge of circulation patterns of the Delta, transport timescales, and the connection between channels to identify six distinct regions of the Delta. We then hypothesized predation risk from low to moderate to high for each region. In this regional assessment, it is clear that anthropogenic structures (e.g. gates, bridge piers), bathymetry, channel connections, hydrodynamics, both tides and freshwater input, and operations are all key controlling physical factors for the locations of predation hot spots. In this talk, we will discuss the physical factors contributing to predation hot spots in each of the six regions and discuss some engineering design criteria that should be considered when modifying existing facilities, such as Clifton Court Forebay.

Keywords: fish predation, hydrodynamics, predation hot spots, operating structures, bathymetry
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Interactive Effects of Habitat Alterations and a Non-Native Predator, Striped Bass, on Native Juvenile Salmon Mortality

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Human stressors are leading causes of declines in species and biodiversity driving wide scale ecosystem changes. Additionally, multiple human stressors, including non-native species and habitat alterations, can interact with complex consequences on native species. Human-modified habitats can change non-native predator functional and aggregative responses with additive impacts on native prey species. We assessed how the non-native predator, striped bass (*Morone saxatilis*), and habitat alterations (small diversion dam and other altered habitats) interact to influence mortality on native juvenile Chinook salmon (*Oncorhynchus tshawytscha*) migrating to sea on the lower Mokelumne River, CA (USA). Striped bass relative abundance and diet surveys across natural and human-altered habitats assessed functional and aggregative responses of striped bass. Striped bass showed elevated per capita consumption of juvenile salmon and behavioral aggregation (estimated as catch per unit effort – CPUE) at a small diversion dam site (Woodbridge Irrigation District Dam: per capita consumption= 3.54 juvenile salmon and CPUE= 0.189) over other altered (0 juvenile salmon; CPUE= 0.0024) and natural habitats (N/A; CPUE= 0.0003) creating a localized area of heightened predation. At this predation hotspot, experimental predator removals, diet energetic analysis, and before-after impact assessment estimated striped bass consumption of the population of out-migrating juvenile salmon to be between 10-29%. Striped bass per capita consumption rates among the three approaches were 0.92%, 1.03-1.55%, and 0.96-1.11% respectively. This study highlights how interactions between multiple stressors can exacerbate consequences for native species and are important to examine when predicting ecological impacts from stressors and planning local management strategies.

Keywords: predation, striped bass, juvenile salmon, predator removal, diversion dam, interactions
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Using a Predator Density Manipulation Study to Quantify Salmon Smolt Predation in the San Joaquin River

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Telemetry studies that track downstream migration and mortality of salmonids in the Central Valley have demonstrated high mortality rates (80-99%) during emigration through the freshwater and estuarine portions of the watershed. In recent years, estimated survival rates for juvenile Chinook salmon in the lower San Joaquin River declined to approximately 5%, despite increased river flows and reduced spring water exports. The hypothesized cause of these low survival rates is a combination of factors that includes piscine predation by non-native species. Although predation has been suggested as a major cause of salmon smolt mortality, there is insufficient research in the San Joaquin Delta to rigorously evaluate this hypothesis. For a relatively-defensible consideration of potential management actions, more studies are needed to quantify predator density, movement, and predation rates, as well as examine how environmental and anthropogenic factors interact to influence predation of salmon smolts. To address this research need, a predation study is underway in the San Joaquin River in collaboration with the DWR, DFW, USFWS, USGS and USBR. This study revolved around a predator density manipulation in nine 1-km river reaches (3 control; 3 predator removal; 3 predator addition). Effects were assessed before/after manipulations with 1) release of >3000 acoustically tagged Chinook salmon and steelhead smolts, 2) capture/release of acoustically tagged piscine predators (striped bass, largemouth bass, channel catfish, and white catfish), 3) quantification of relative salmon smolt predation using drifting tethered smolts in each of the study reaches, 4) quantification of predator density and fish habitat using hydroacoustic imaging, 5) determination of prey items using genetic analysis of predator stomach contents, and 6) species diversity and abundance surveys. A total of 1,531 predators were captured and removed/relocated from 37hr of electrofishing. Preliminary results for each of the study components will be presented and future work will be outlined.

Keywords: Predator, salmon, smolt, San Joaquin River
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