2011 Georgiana Slough Non-Physical Fish Barrier

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A non-physical fish barrier, called the Bio-Acoustic Fish Fence™ (BAFF, Fish Guidance Systems; Southamton, UK), was evaluated in 2011.The approximately 650 foot long BAFF was deployed in the Sacramento River just upstream of the divergence of Georgiana Slough. Acoustic telemetry was used to estimate BAFF deterrence and overall efficiency for 1,500 Chinook salmon smolts implanted with Hydroacoustic Technology, Inc. (Seattle, WA) acoustic tags. Deterrence efficiency, the percentage of fish that showed greater than a 25 degree turn away from the BAFF, was 50.4% with the BAFF on and 28.5% with BAFF off. This improvement of 21.9% deterrence translated into improved overall efficiency, the percentage of Chinook smolts continuing passed the divergence in the Sacramento River, with overall efficiency equal to 90.8% with the BAFF on compared to 73.4% with the BAFF off. Statistical analyses showed these differences, both deterrence and overall efficiency, were significant. And, the statistically significant differences between BAFF on and BAFF off occurred under low and high light conditions as well as under low and high across barrier velocities. A Generalized Linear Model analysis showed the two most important predictors of a Chinook remaining in the Sacramento were cross-stream position and BAFF on or off. The predation rate on Chinook smolts in the area of the BAFF was 3.7%.

Keywords: Sacramento River, barrier, Chinook, salmon, hydroacoustic, biotelemetry

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 1

Effectiveness of a Non-Physical Barrier on Route Entrainment of Migrating Juvenile Salmonids in the Sacramento-San Joaquin River Delta

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The interior of the Sacramento-San Joaquin River Delta is a location of high mortality for out-migrating ESA listed juvenile salmonids, relative to alternative migration routes. Reducing entrainment to the interior delta is one approach to increasing juvenile salmonid survival. In the spring of 2011, a non-physical barrier (Bio-Acoustic-Fish-Fence or BAFF) was placed at the confluence of the Sacramento River and Georgiana Slough in an effort to deter smolts from entering Georgiana Slough and passing into the interior delta. The BAFF uses a combination of intermittent light, a bubble curtain, and modulated sound to deter fishes. Concurrently, 1,500 smolts were acoustically tagged and passively telemetered to determine the effectiveness of the BAFF at reducing entrainment into Georgiana Slough. Overall, 7.7% of the fish were entrained into Georgiana Slough when the BAFF was on, and 22.3% were entrained when the BAFF was off, but a number of other factors influenced performance of the BAFF. The effectiveness of the BAFF declined with increasing river discharge, likely because increased water velocities reduced the ability of fish to avoid being swept across the BAFF into Georgiana Slough. The BAFF reduced entrainment probability by up to 40 percentage points near the critical streakline which defines the streamwise division of flow vectors entering each channel. However, the effect of the BAFF declined moving in either direction away from the critical streakline. Our study shows how acoustic telemetry provided novel insights about how behavior and the environment interacted to influence the performance of a non-physical behavioral barrier in an applied setting.

Keywords: acoustic telemetry, salmon, non-physical barrier, migration, strobe lights, bubble-curtain, sound

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 2

Advantages of a Shuttle Box System in Capturing Behavior of the Endangered Delta Smelt

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Recent evidence has demonstrated that physical habitat parameters, especially water clarity, temperature, and salinity, are strong determinates of delta smelt distribution within the Sacramento-San Joaquin Estuary. To gain a better understanding of the smelts' movement patterns within the estuary, we explored the use of an electronic shuttle box system (LoligoSystems©) which allows for continuous recording and control of environmental variables and simultaneous tracking of their movement and position. Our previous behavior trials tested delta smelt under static conditions (unpublished data) but, as tested, these trails were less productive. By using the shuttle box system, individuals are able to behaviorally modulate their exposure to different levels of an environmental variable (e.g. water clarity, temperature, and salinity). Preliminary analysis of delta smelt temperature trials in the shuttle box system indicates that significant differences can be distinguished, in terms of residence time, between acclimation (13°C±1) temperature and final temperature (18°C ±1)through the use of this dynamic system. Understanding the delta smelts volitional movements in a dynamically changing laboratory setting improves the ability to understand and interpret field data. In order to develop strong management tools for delta smelt conservation and recovery, it is critical to understand the environmental parameter levels that are beneficial to the animal, and the tipping point(s), or boundary conditions, where parameters are negative, and the subjects choose, repeatedly, to move out of that environment.

Keywords: shuttle box, temperature, delta smelt, behavior, endangered, conservation management

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 3

Comparison of Effective Population Sizes for the Two Splittail Populations in the San Francisco Estuary

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Splittail (*Pogonichthys macrolepidotus*) is a fish species of special concern endemic to the San Francisco Estuary. Although a number of studies on the life history and habitat use of splittail have been conducted, a majority assumed that the species is composed of a single panmictic population. Therefore, the discovery of two genetically distinct splittail populations (one spawning in the Central Valley and another in the Napa and Petaluma rivers) indicates that our understanding of the species' ecology is incomplete. As part of an overarching interdisciplinary study to better understand the species' population dynamics, we have identified new genetic markers and estimated the effective population size (Ne) of the two discrete populations. Effective population size provides crucial information for conservation and wildlife management to predict the persistence of populations. We present our results obtained through the use of over thirteen microsatellite markers genotyped from age-0 splittail of multiple year-class (2002-03, 2011) collected from several known major spawning grounds. Furthermore, we also report on the discovery of 24 novel microsatellite loci which cross-amplified and were polymorphic for at least one of five additional California cyprinid species (*Ptychocheilus grandis*, *Siphateles bicolor*, *Lavinia exilicauda*, *Orthodon microlepidotus* & *Mylopharodon conocephalus*).

Keywords: *Pogonichthys macrolepidotus*, effective population size, cyprinidae, microsatellite

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 4

Toxicity of Selenium to White and Green Sturgeon

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Fish of the genus *Acipenser* (sturgeon) are likely to be among the most vulnerable to selenium exposure in the San Francisco Estuary because these fish feed predominantly on benthic invertebrates, including the Asian clam, *Corbula amurensis*. This clam is an efficient bioaccumulator of selenium. The best data available for the most sensitive endpoint for sturgeon come from studies in which the survival of larvae was monitored following micro-injection of organic selenium (L-selenomethionine) into the yolk sacs of newly hatched larvae. Benchmark larval selenium concentrations from these studies were translated, by means of regressions, to selenium concentrations in the tissue and diet of adult white and green sturgeon. This analysis indicates that white and green sturgeon are among the most sensitive of fish to adverse effects of selenium, with the listed green sturgeon being the more sensitive of these two species. These levels of sensitivity evidently put sturgeon at substantial risk at current levels of exposure in the San Francisco Bay area. Selenium concentrations in food items of sturgeon in the San Francisco Bay area are almost always high enough that they may cause at least 10 percent mortality in hatchling green sturgeon (≥3.58 µg/g), and they are frequently high enough that they may cause at least 10 percent mortality among hatchling white sturgeon (≥10.8 µg/g) as well.

Keywords: sturgeon, selenium, toxicity, sensitivity, criteria

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 5

Comparative Acoustic Tag Detections at Control Sites versus Artificial Reefs Sites in the San Francisco Estuary

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Vemco VR2W (69kHz) receivers installed at two reef sites in San Francisco Bay detected Chinook salmon, striped bass, white & green sturgeon, 7-gill shark, and steelhead. Sites include locations on both sides of SF Bay; Marin Rod and Gun Club to the west and Berkeley to the east. Analysis of data collected from January 2009 through May 2012 for the number of detections, duration of unique visits, and repeated visits clearly shows that fish are detected more often and stay longer at the artificial reef sites than featureless mudflats which are characteristic of the control sites. At the Berkeley site the pattern of detections suggest primarily striped bass, sturgeon, and 7-gill sharks. The pattern of striped bass detections suggest a long period of time at the reef site, then leave for extended periods, and then return again indicating a territorial range for some individuals. The detection patterns at the Marin Rod and Gun Club suggest extensive utilization by salmonids due to the repeated detections at multiple receivers over an extended period of time. Notably both adult salmon and steelhead gilts were detected at the MRGC site.

* striped bass - DWR funding, pm Cynthia LeDoux-Bloom

Keywords: acoustic, biotelemetry, salmon, artificial reefs, sturgeon, striped bass, vemco

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 6

Population Dynamics and Predation Impacts of Three Invasive Hydrozoan Jellyfish in the Upper San Francisco Estuary

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The wide temperature and salinity ranges of three introduced hydromedusae (*Blackfordia virginica, Maeotias marginata*, and *Moerisia lyonsi*) spatially and temporally overlap with several protected fish species in the San Francisco Estuary (SFE), including delta smelt and longfin smelt. In addition, the zooplankton diets of these hydromedusae overlap with those of protected fish, resulting in the potential for competition. Here we report the distribution, abundance, and feeding ratesof hydromedusae within four brackish-water tributaries of the SFE (Petaluma River, Napa River, Suisun Slough, and Montezuma Slough) during 2010 and 2011. Medusae and their prey were sampled weekly and environmental variables were recorded. Their distributions were similar to that reported in the literature with *B. virginica* and *M. lyonsi* found at all four sites and *M. marginata* found in the sloughs. All three species were found at similar temperatures (19–22°C), but *B. virginica* and *M. lyonsi* occurred at higher salinities (16–19) than *M. marginata* (2–4). Abundances of *B. viriginica* were higher than previously reported, and abundances of *M. lyonsi* and *M. marginata* were within the range previously reported. Feeding rates of *B. virginica* were measured in laboratory incubations with natural prey. Feeding rates ranged from 2 to 12 liters cleared of prey per medusa per day. Using clearance rates from laboratory experiments, at the maximum abundance of *B. virginica* in the Napa River, the calculated predation impact on adult *Acartia* sp. (calanoid copepod) was 150% per day, much higher than typical prey population growth rates. Thus, *B. virginica* may suppress prey populations. The high clearance rate of *B. virginica* combined with the spatial and temporal overlap with protected fish suggests a strong potential for competition. Monitoring hydromedusae is necessary to predict potential negative impacts on vulnerable fish populations in both the tributaries and the open bay of the SFE.

Keywords: Hydromedusa, *B. virginica*, San Francisco Estuary, Predation Impacts, Distribution

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 7

Feeding of Adult Delta Smelt During Their Yearly Spawning Migration into the Upper San Francisco Estuary

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Since their protection under California State and Federal Endangered Species Acts, delta smelt have become a major focus of environmental and water management in the San Francisco Estuary. As a result, numerous studies have been conducted to fill gaps in knowledge about delta smelt life history, habitat requirements, and factors limiting abundance. The Delta Smelt Turbidity Study was designed to provide critically needed information about the annual spawning migration of delta smelt into the upper estuary. Goals of the ongoing study include determination of the extent of prey selectivity in migrating delta smelt, and assessment of diet variability at the adult life stage. To address these goals, zooplankton were sampled concurrently with hourly fish sampling over a full tidal cycle every day from December 21, 2010 to January 1, 2011. Gut samples from a selection of delta smelt collected during sampling were analyzed to compare prey availability to prey ingested. Previous studies of the diet of juvenile delta smelt have emphasized pelagic invertebrates, specifically calanoid copepods as their main food source, whereas the most frequent prey organisms ingested by delta smelt sampled during this study were cladocerans and epibenthic amphipods. Comparison of zooplankton samples to gut samples suggests delta smelt selected for amphipods, although abundance of amphipods is not well characterized by sampling with plankton nets. If further sampling and analysis confirms this finding, it implies a very different foraging strategy and perhaps a different foraging habitat for adult delta smelt than for juveniles. Information of this kind is critical to understanding adult delta smelt foraging behavior and identifying foraging habitats. This information will also be useful in constructing and refining life-cycle models of delta smelt. With refinement, these models may help devise and evaluate management strategies to reduce delta smelt mortality and restore delta smelt habitat in the estuary.

Keywords: delta smelt, migration, diet selectivity, feeding habitat

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 8

Persistence of Delta Smelt DNA in the Gut of Mississippi Silversides and Other Preliminary Experiments for Detecting Prey in Non-Native Fish Stomachs Using Real-Time PCR

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The Bay-Delta Conservation Plan has identified predation by non-native piscivores as a major stressor to threatened native fish in the delta. Our primary objective is to investigate the frequency of predation by non-native bass and the native Sacramento pikeminnow on larval and sub-adult threatened and endangered species using quantitative PCR. The data on incidence of predation will be used to identify locations non-native piscivores prey heavily on at-risk species. With this data habitat restoration efforts can focus on areas that minimize danger to at-risk species.

Genetic gut content analysis offers two notable advantages over visual gut contents studies. The sensitivity of the method allows us to identify prey species for a longer time post-ingestion and species composed of soft tissue, namely larval fish, can be identified. Our current objective is to characterize the genetic assay and optimize the methods to be used in the primary study. We conducted a series of preliminary experiments in which we fed delta smelt larvae to Mississippi silverside and striped bass in a controlled environment. Three questions were addressed during these experiments: How long is DNA of a prey fish detectable in the stomach of a predator? Can we detect multiple prey of a given species in a stomach using microsatellite DNA? Lastly, what method of preservation keeps the most usable DNA intact during field sampling?

DNA barcoding and qPCR will be introduced and the results from our preliminary experiments will be discussed.

Keywords: predation, qPCR, delta smelt, silverside, chinook salmon bass, genetics

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 9

Food Web Relationships for Delta and Longfin Smelt

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Several analyses have identified zooplankton prey density as an important factor affecting the abundance of longfin and Delta smelt in the San Francisco Estuary. We analyzed numerous factors that influence zooplankton abundance in an attempt to develop statistical correlations that link these factors to each other and to zooplankton densities in different parts of the estuary. We compared our results to those from more complex food web mathematical models. Our analyses produced statistically significant but relatively weak relationships between zooplankton densities and the densities of certain classes of phytoplankton. We confirmed the strong relationships between the densities of certain classes of phytoplankton and filtration rates of the clam, *Potamocorbula amurensis*. We found relationships between phytoplankton densities and concentrations of ammonium and between concentrations of ammonium and densities of zooplankton. We found evidence that ammonium concentrations are linked to inflow to the Delta, with inflow providing the dilution of ammonium loadings from wastewater treatment plants.

Keywords: food web, delta smelt, longfin smelt, zooplankton, phytoplankton, nutrients

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 10

Habitat Affinity Analysis as a Tool to Guide Environmental Restoration for Delta Smelt

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Habitat restoration efforts in the Sacramento-San Joaquin Delta in central California move forward under the state's ambitious Bay Delta Conservation Planning process, despite a paucity of information on the habitat needs of many of the plan's targeted species. The endemic delta smelt, protected as threatened under the federal Endangered Species Act, is a primary focus of those efforts despite key uncertainties regarding many aspects of its relationship with the estuary's physical and biotic resources. Here we carry out habitat affinity analysis for multiple life stages of the delta smelt drawn from time-series data from four trawl surveys, and data on environmental attributes taken from throughout the distribution of the fish. Ranges of conditions acceptable to delta smelt for each of seven environmental attributes were identified. Low turbidity and high water temperatures render a large portion of the estuary seasonally unacceptable to delta smelt. Within areas that experience largely acceptable water quality conditions, patterns of delta smelt occurrences indicate that habitat occurs where deep channels adjoin shallow-water circumstances and extensive patches of emergent vegetation. Habitat suitability indices show that favored environmental circumstances vary with life stages, and delta smelt move as they mature to access suitable areas with environmental attributes in acceptable ranges. Areas that exhibit highest geometrically weighted average HSI values for environmental attributes are displayed on maps, and can be viewed as representing potential priority target areas for habitat restoration efforts. Delta smelt should benefit in priority target areas with channel modification and directed wetlands restoration efforts.

Keywords: delta smelt, affinity analysis, habitat suitability index

Wednesday, October 17, 2012: Room 311-313, Fish Biology (III) – Order 11

The Pelagic Organism Decline and the Game of Clue

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Several hypotheses have been advanced to explain the sharp decline in abundance of four pelagic fish in the San Francisco estuary early this century. This study examined the hypothesis that because the declines exhibited by those species were initiated within a year or two of each other, they were caused by a common environmental stressor, or by a very few such factors. Many other fish species that co-occur in the same waters showed no similar declines and, in some cases, showed sharp increases in abundance, suggesting that the factor(s) acting on the four pelagic fishes did not act on the others. In this study the search for common and uncommon stressor factors was restricted to environmental factors that exhibit direct effects on reproduction and survival. Data was assembled on each of specifics (for example, specific zooplankton species preyed upon) of these factors for each of the four pelagic fishes and for species of fish that did not exhibit a sharp decline in abundance early this century. The search for common factors proceeded much like the game of *Clue*, in which a succession of clues combine to reveal the identity of the murderer, the location of the crime, and the weapon. Among those candidate environmental factors acting on fish in the San Francisco Estuary, the availability of select zooplankton (prey density) is the most likely common factor that explains the pelagic organism decline; predation on fishes and turbidity are other candidates. If confirmed by more rigorous, quantitative analyses, management actions to reverse declines in the abundances of the four pelagic fish can be better focused and are more likely to succeed.

Keywords: food web, pelagic fish, environmental stressors

Wednesday, October 17, 2012: Room 311-313, Fish Biology (III) – Order 12

The Spatial and Temporal Distribution of Delta and Longfin Smelt

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These two species of fish are of major concern in the San Francisco Estuary. Their distribution affects their susceptibility to entrainment, their co-occurrence with important prey species, and other important attributes of their habitat. We evaluated data from routine surveys that sample for these fish. We attempted to correct catch data for gear efficiency and to eliminate sources of bias that could be quantified. We considered changes in bathymetry and, therefore, water volume, over time in different parts of the estuary. Using corrected catch and water volume data, we estimated the fraction of each species in different parts of the estuary for each survey over the last several decades with respect to both fish density and abundance. We compared these distributions with seasonal values of X2, the distance of the 2 ppt isohaline from the Golden Gate Bridge, to test the importance of X2 as a factor affecting distribution. We also compared distributions with turbidity and investigated several other factors that might influence distribution. We conclude that that longfin smelt are never found in significant percentages near the export pumps, that delta smelt move short distances toward fresh water sources when estuary waters become turbid in the early winter, rather than making an upstream migration run, and that effects of winter or spring X2 on the distribution of delta and longfin smelt are questionable. Previous analyses have reported relationships between X2 and distributions of delta and longfin smelt, although these analyses have not covered the currently known range of the fishes or evaluated mechanisms behind the relationship. The understanding of the relationship between X2 and the fishes' distribution is evolving, which will affect the possible management actions that could be taken, helping to identify effective and efficient options from an ecological perspective.

Keywords: delta smelt, longfin smelt, X2, distribution, migration

Wednesday, October 17, 2012: Room 311-313, Fish Biology (III) – Order 13

FLaSH: Multivariate Analyses of Delta Smelt Health Indices in the Upper San Francisco Bay Delta Estuary

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The Fall Low Salinity Habitat (FLaSH) study examined the potential effects of habitat quality on the health, nutrition, and reproductive status of delta smelt, *Hypomesus transpacificus*, in the San Francisco Estuary (SFE). In collaboration with the California Department of Fish and Game (CDFG), researchers from state, federal agencies and the University of California set out to investigate the impacts of increased freshwater outflow in the fall of 2011 on delta smelt. Samples were collected from CDFG long-term fish monitoring surveys, the Summer Tow Net, Fall Midwater Trawl and the Spring Kodiak Trawl *during fall 2011 to spring 2012.*This study used a novel epidemiological approach to identify patterns and potential causative factors affecting delta smelt health in the upper San Francisco Estuary. Due to confounding variables, univariate analyses did not show any clear trends or causative effects among measured health indices and recorded water quality parameters. Multivariate analyses such as canonical and multiple linear regression methods were utilized to assess several potential predictors such as salinity, temperature and turbidity, simultaneously. *Over 700 delta smelt fish were used to model the presence of any causative relationship while controlling for confounding effects. The multivariate analysis revealed a significant causative correlation between multiple biomarkers and water quality parameters of salinity, temperature and turbidity. This study is still ongoing and additional years of analysis will enhance the precision of the method.*

Relevance: This study demonstrates multivariate analysis as a novel managerial tool for environmental studies of delta smelt. Researchers can apply this analytical tool to evaluate multiple independent predictor variables while alleviating bias from measured confounders.

Keywords: Delta smelt, modeling, habitat

Wednesday, October 17, 2012: Room 311-313, Fish Biology (III) – Order 14

Revisiting Longfin Smelt Population Dynamics in the San Francisco Estuary

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The San Francisco Estuary population of Longfin smelt (LFS), *Spirinchus thaleichthys,* has declined precipitously, with current abundance estimated at 3-4 orders of magnitude lower than in recent decades. Although a significant long term correlation has long been reported between LFS recruitment and Delta outflow or its covariates, other covariates reflecting a changing food web – changes in exotic clam distribution, plankton composition, and dissolved ammonium – have been suggested as potentially important, and previous studies have not included LFS stock-recruit relationships (SRR) in their regression models.

This study first examined how Delta outflows were correlated with inter-generational LFS population change (using Fall Midwater Trawl data; FMWT), and what levels of outflow related to LFS population growth. Then we developed an alternate version of the model that could be applied to time series of Delta outflow. This alternative model explicitly accounted for the influence of spawning stock, including density dependence that appears to have historically influenced longfin smelt abundance in years when Delta outflow was low. We used this model to evaluate what effect the eight decades of changes to Delta outflow alone may have had on LFS.
We found that SRR (sum of the two-prior-years FMWT) combined with estimates of spring Delta outflow was most successful in removing the time trend in regression residuals, enabling us to isolate the effect of flow. SRR was nonlinearly related to spring Delta outflow because of density dependence, and inter-generational population growth was observed only when spring Delta outflow exceeded 1259 m3/s.

Our study is directly relevant to management of the imperiled LFS population, as it demonstrates the importance of Delta outflow, its interaction with SRR, and the potential for density dependence at low flow conditions. The results of this study also point to the value of long-term population monitoring (the FMWT dataset).

Keywords: *Spirinchus thaleichthys*; Delta outflow; water exports; stock-recruit; density dependence, longfin.

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