South Delta Salmon Smolt Survival Studies

Patricia Brandes, U.S. Fish and Wildlife Service, Pat_Brandes@fws.gov
Rebecca Buchanan, University of Washington, rabuchan@uw.edu
Joshua Israel, U.S. Bureau of Reclamation, JAisrael@usbr.gov

The escapement of adult salmon to the San Joaquin basin appears to be related to flow during their spring smolt migration period. Studies estimating salmon survival in the south Delta have been ongoing since about the mid - 1980's. The results of early studies indicated that coded wire tagged (CWT) juvenile salmon released in the San Joaquin River just downstream of the junction at the head of Old River (near Lathrop), usually survived at a higher rate to Chipps Island than those released in Old River. Additional studies also indicated that survival to Chipps Island increased as flows increased for CWT fish released near Lathrop, and for CWT fish released at Mossdale or Durham Ferry with a physical rock barrier at the head of Old River. Modeling using the CWT data suggested that survival would be higher through the Delta when a rock barrier was installed as it reduced the proportion of water and fish entering Old River where survival appeared to be lower. In 2008, 2010, 2011 and 2012 juvenile Chinook salmon survival between Mossdale and Chipps Island was estimated using acoustic tags, with survival being low for all years. In addition, the proportion of tagged salmon entering Old River, or route entrainment, was also estimated in these years. Comparisons of both route entrainment and route and reach specific survival between Mossdale to Chipps Island allows us to identify why survival is so low through the Delta and find the mortality hot spots in each route as the fish migrate downstream. These studies can also be used to assess various management actions, such as the physical head of Old River barrier or increases in flow as was done in 2012.

Keywords: Salmon, survival, Delta, Smolt
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 8:20AM – 10:00AM Room 306

Juvenile San Joaquin Steelhead Migration and Survival through the South Delta, 2011 and 2012

Rebecca Buchanan, University of Washington, rabuchan@uw.edu
Joshua Israel, U.S. Bureau of Reclamation, jaisrael@usbr.gov
Pat Brandes, U.S. Fish and Wildlife Service, pat_brandes@fws.gov

The Six-Year Steelhead Study originated in 2011 to address questions about migration and survival of juvenile San Joaquin steelhead through the Delta. Each year, approximately 1500 – 2200 juvenile hatchery steelhead have been tagged using microacoustic tags and monitored as they move through the Delta. Results from the first two years of the study will be presented. In 2011, river flows were high and no barrier was installed at the head of Old River; average survival through the Delta ranged from 0.38 to 0.69 (SE≤0.05). Approximately half the steelhead that arrived at the head of Old River entered Old River, and 38% of the tagged steelhead that reached Chipps Island came via the CVP and SWP water export facilities. In 2012, river flows were considerably lower and a physical barrier was installed at the head of Old River. The large majority of tagged steelhead remained in the San Joaquin River at the head of Old River. Delta survival estimates ranged from 0.24 to 0.32 (SE≤0.03) in 2012, and only 5% of those that reached Chipps Island came via the water export facilities. Delta survival was higher in the San Joaquin route than in the Old River route for 2012 (low flows, barrier) but not in 2011 (high flows, no barrier) (α=0.05). The median travel time to Chipps Island was 5 – 6 days in both years, and ranged up to 35 days in 2011. The lowest survival was observed for fish that entered the interior Delta via Turner Cut. Within the San Joaquin route, the reach between MacDonald and Medford islands had the lowest survival rate per km in both years. Significant improvements to steelhead survival through the Delta may require increasing survival in tidal areas, in addition to keeping steelhead out of the interior Delta.

Keywords: Acoustic telemetry, migration route, Steelhead, survival, travel time
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 8:20AM – 10:00AM Room 306

Sharing Risks: Applicability of the Surrogate Species Approach for San Joaquin River Salmonid Species

Joshua Israel, US Bureau of Reclamation, jaisrael@usbr.gov
Patricia Brandes, US Fish and Wildlife Service, pat_brandes@fws.gov
Kevin Clark, Department of Water Resources, Kevin.Clark@water.ca.gov
Rebecca Buchanan, University of Washington, rabuchan@u.washington.edu

Fall run Chinook and steelhead are members of the same family, Salmonidae, and thus the population response to various drivers may be representative of each other. However, the 2009 VAMP review panel suggested that Chinook salmon are a poor surrogate for steelhead. Thus, the potential to run simultaneous survival studies of juvenile Chinook salmon and steelhead smolts was considered an important objective during the 2011 and 2012 Lower San Joaquin River and South Delta telemetry investigations. During these two years, extensive efforts that would later allow for examining questions concerning surrogacy between fall run Chinook salmon and Central Valley steelhead were made. These included intensive pre-study planning to ensure standardized procedures for surgeries, data processing and coordinated field implementation. Results regarding salmonid route selection and survival from four simultaneous releases in the lower San Joaquin River and South Delta telemetry investigations are considered with environmental and flow data to assess the response of fall run Chinook and steelhead to equivalent environmental drivers. The responses of both species to environmental conditions are compared to evaluate how using one species may or may not reflect a reasonable substitute for the other regarding hypothesized benefits and risks of managing environmental conditions. Finally, this presentation will discuss how surrogacy assumptions influencing the certainty in interpretation were addressed in planning and implementation to increase certainty in results.

Keywords: salmonidae, surrogacy, San Joaquin, biological response
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 8:20AM – 10:00AM Room 306

Sacramento River Reach-Specific Movement and Survival Rates of Outmigrating Winter-Run Chinook Salmon Smolts

Jason Hassrick, Science Division, Bureau of Reclamation Bay-Delta Office, jhassrick@usbr.gov
Arnold Ammann, NOAA and UCSC, arnold.ammann@noaa.gov
Robert Null, Red Bluff Fish and Wildlife Office, Robert_Null@fws.gov
John Rueth, Livingston Stone National Fish Hatchery, John_Rueth@fws.gov
Cyril Michel, NOAA and UCSC, cyril.michel@noaa.gov
Jeremy Notch, NOAA and UCSC, jeremy.notch@noaa.gov
Nicholas Demetras, NOAA and UCSC, nicholas.demetras@noaa.gov
Andrew Pike, NOAA and UCSC andrew.pike@noaa.gov
Sean Hayes, NOAA and UCSC sean.hayes@noaa.gov

Winter-run Chinook salmon (winter-run) are state and federally listed as endangered. In recent years, spawning escapement has declined, with 3-year cohort replacement rates consistently less than 1.0. Causes of this decline are poorly understood. Juvenile winter-run are thought to delay outmigration and rear at unknown locations in the river for a longer duration than other Central Valley salmon runs. In-river juvenile mortality rates are known to be high in other runs. We hypothesized that in-river movement rates would be lower, leading to reduced survival for winter-run than for stocks like the fall-run that migrate out of the river more rapidly. In February to April of 2013, we used Juvenile Salmon Acoustic Telemetry System (JSATS) technology to estimate reach-specific survival rates for hatchery-raised winter-run juveniles during their outmigration to sea. Cumulative survival estimates for 148 fish showed only 20% of juveniles survived beyond a region in the upper Sacramento River between Salt Creek (Rkm 475) and Tisdale Weir (Rkm 287). In stark contrast to all other Central Valley Chinook salmon stocks evaluated so far that exhibit rapid and persistent migratory behavior, surviving winter-run remained within this stretch of river for as long as 30 - 50 days**.** Preliminary migration and survival results of 359 acoustic tagged winter-run released in February 2014 suggest that holding time in the upper river was less than in 2013 and survival was correspondingly higher. More acoustic tracking data are needed to determine whether the delayed outmigration observed during the drought conditions experienced in 2013 are generally characteristic of winter-run. Our findings reveal that juvenile winter-run in-river survival is among the lowest of Central Valley Chinook salmon runs. If rearing occurs in the same area from year to year, we suggest that these data can be used to prioritize targeted restoration efforts for improving juvenile salmon habitat.

Keywords: Sacramento River, winter-run, Chinook salmon, JSATS, outmigration
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 8:20AM – 10:00AM Room 306

Salmon Migration Behavior and Survival in Sacramento River - Knights Landing to the Delta

Anna Steel, University of California, Davis, annaesteel@gmail.com
Brian Mulvey, U.S. Army Corps of Engineers, Brian.M.Mulvey@usace.army.mil
Natalie McNair, U.S. Army Corps of Engineers, Natalie.N.Houghton-Mcnair@usace.army.mil
David Smith, U.S. Army Engineer Research and Development Center, David.L.Smith@usace.army.mil

New levee designs are being implemented by the US Army Corps of Engineers along the middle reaches of the Sacramento River to increase available habitat features for outmigrating salmonids. We are seeking to understand how these new levee designs are affecting Chinook survival and migration behavior. We have designed telemetric studies to gather information on juvenile salmon movement behavior, survival and migration rates through the targeted reaches to complement electrofishing surveys conducted at specific levee repair sites. In 2013 we used ultrasonic VEMCO transmitters to tag approximately 600 late-fall Chinook salmon juveniles from Coleman National Fish Hatchery, and detected these fish at a series of receiver gates as they migrated from the release site near Knights Landing, CA toward Clarksburg, CA. In this first year of the study we found that survival rates were higher in the upper reaches, but decreased as fish slowed and approached areas with tidal influence around Sacramento. We also saw indications of temporal variation in survival, possibly corresponding with the striped bass migration period. Using an existing database of bank habitat features as well as a high-resolution hydrodynamic model, we examined how levee features might affect migration speeds. We are also using the mean free-path length model (Anderson et al 2005) to explore predation patterns within the reach-specific survival estimates. The results of this analysis will be incorporated into upcoming phases of levee repair in the Sacramento River basin, to improve current practices and increase the survival of our declining salmonid species.

Keywords: acoustic, telemetry, Chinook, salmon, behavior, habitat, migration, survival, river, levee
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 8:20AM – 10:00AM Room 306

Survival and Movement Rates of Wild Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) Smolts from Mill and Battle Creeks through San Francisco Bay - 2013-2014

Jeremy Notch*, NOAA Fisheries, jeremy.notch@noaa.gov
Arnold Ammann, NOAA Fisheries, arnold.ammann@noaa.gov
Sean Hayes, NOAA Fisheries, sean.hayes@noaa.gov
Matthew Johnson, Department of Fish and Wildlife, matt.johnson@dfw.ca.gov
James Earley, US Fish and Wildlife Serivce, james_earley@fws.gov
Matt Brown, US Fish and Wildlife Service, matt_brown@fws.gov
Andrew Pike, NOAA Fisheries, andrew.pike@noaa.gov

Spring-run Chinook salmon (*Oncorhynchus tshawytscha*) are state and federally listed as a threatened species in California. Historically spring-run represented the largest component of Chinook salmon in California's central valley, but today wild spring-run Chinook are only established in Mill, Deer, Butte, Clear and Battle Creeks. The number of returning adult fish to these tributaries varies between 500 – 1500 fish, with the exception of Butte Creek which receives 6,000-15,000 adults. Previous studies of hatchery produced Chinook indicate that emigrating smolts experience high levels of mortality in the Sacramento River, Sacramento-San Joaquin River Delta and San Francisco Bay, but no studies of survival of wild spring-run smolts during their migration to sea have yet been conducted. In 2013-2014 we used Juvenile Salmon Acoustic Telemetry System (JSATS) technology to track reach-specific movement and survival rates of wild Chinook smolts from natal streams to the Pacific Ocean. Emigrating smolts were captured in rotary screw traps. In 2013 we captured and tagged 59 smolts from Mill Creek, and in 2014 tagged 36 smolts in Mill Creek and 80 smolts in Battle Creek. In 2013 the highest levels of mortality during downstream migration occurred between Woodson Bridge and Colusa, and cumulative survival to the Golden Gate was ~2%. These smolts also emigrated later in the spring compared to hatchery released smolts which potentially exposed them to warmer water temperatures and increased rates of predation. Our findings provide new information on the behavior and survival of wild spring-run smolts. Understanding how survival of these smolts relates to flows could help water management adjust flows to benefit these fish. More acoustic tracking data are needed during periods of high, turbid flow to determine if movement and survival rates are higher compared to the low flow conditions that were present during this study.

Keywords: Chinook salmon, spring-run, Sacramento River, San Francisco Bay, Predation
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 10:20AM – 12:00PM Room 306

Reach-Specific Movement and Survival Rates of Emigrating Feather River Spring-Run Chinook Salmon Smolts

Arnold Ammann, National Marine Fisheries Service, arnold.ammann@noaa.gov
Ryon Kurth, California Department of Water Resources, Feather River Program, ryon.kurth@water.ca.gov
Jason Kindopp, California Department of Water Resources, Feather River Program, Jason.Kindopp@water.ca.gov
Andrew Hampton, California Department of Water Resources, Feather River Program, andrew.hampton@water.ca.gov
Andrew Pike, National Marine Fisheries Service, andrew.pike@noaa.gov
Sean Hayes, National Marine Fisheries Service, sean.hayes@noaa.gov

Hatchery-origin Feather River spring-run Chinook salmon smolts are released off-site, with half the production released in the Feather River and the other half west of the Delta. Differences in escapement rate between the two release sites suggest that mortality for the smolts released in the Feather River must be significant. We determined reach-specific movement and survival rates for smolts released in the Feather River for 2012-2014 using the Juvenile Salmon Acoustic Telemetry System (JSATS). We also examined the effect of direct versus net pen held release method (2013) and day versus night release timing (2014). The number of tagged fish released was 139, 302 and 300 for years 2012, 2013 and 2014 respectively. Survival was lowest for reaches in the Feather River compared to reaches through the Sacramento River, Delta, and SF Bay. Compared to survival rates of other Chinook runs, the reaches in the Feather River are particularly bad. There was no clear effect of direct versus net pen release method on initial survival. Causes of the low survival in the Feather River are not clearly understood. It is likely due to predation by other fish species. Acoustic telemetry provides valuable information on emigrating Feather River spring-run smolts that can be used by hatchery managers to adjust release timing, location, and methods to maximize survival. Determining what survival rates are and how they relate to river flow, water temperature and distribution and abundance of predators is critical to the long term management of the Bay-Delta ecosystem.

Keywords: Chinook salmon, smolts, survival, telemetry, Feather River, spring-run migration, movement
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 10:20AM – 12:00PM Room 306

Eliminating Bias in Survival Estimates Due to the Effect of Tag Failure on Right-Skewed Travel Time Distributions: A Bayesian Approach

Adam Pope, U.S. Geological Survey, Western Fisheries Research Center, apope@usgs.gov
Russell Perry, U.S. Geological Survey, Western Fisheries Research Center, rperry@usgs.gov
Jason Romine, U.S. Geological Survey, Western Fisheries Research Center, jromine@usgs.gov

Tag loss or failure is a primary consideration when estimating survival from marked or telemetered animals. Traditional mark-recapture methods used to estimate animal survival cannot distinguish between tag loss and mortality, and so tag loss may lead to negatively biased survival estimates. In particular, fish telemetry studies inherently involve limitations due to battery power such that tags will fail at some point. When tags fail, estimating survival requires accounting for the probability of tag failure in the model.

Current methods try to account for tag failure by modeling tag failure as a function of observed travel times through the study area. However, travel times are only observed for fish whose tags do not fail. Consequently, missing information from fish with longer travel times may still lead to negatively biased estimates of tag failure and survival even when tag failure is included in the model. In this presentation we use Bayesian methods within a complete data likelihood structure to simulate missing values from a travel time distribution. This approach allowed us to recover the shape of a complete travel time distribution, given observed travel time data and observed tag failure times from an auxiliary tag life study, and thus the method may be used to obtain unbiased estimates of tag failure and survival.

Keywords: mark-recapture, tag failure, MCMC, telemetry
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 10:20AM – 12:00PM Room 306

The Importance of Identifying and Quantifying Fish Behaviors to Predict the Migration Rate of Juvenile Salmonids

David Delaney, Cramer Fish Sciences, david.delaney@fishsciences.net
Paul Bergman, Cramer Fish Sciences, pbergman@fishsciences.net
Brad Cavallo, Cramer Fish Sciences, bcavallo@fishsciences.net
Jenny Melgo, Cramer Fish Sciences, jennym@fishsciences.net
Kevin Clark, Department of Water Resources, kevin.clark@water.ca.gov

Predicting the movement of a species is important for conservation and management, but remains a challenge. As part of the California Department of Water Resources Stipulation Study, we examined how well a physical model can predict the movement of acoustically-tagged steelhead (*Oncorhynchus mykiss*) and investigated underlying biological mechanisms limiting model accuracy. During the spring of 2012, we conducted a mark-recapture experiment to examine the movement patterns of steelhead emigrating through the south Sacramento-San Joaquin Delta. We released approximately 500 juvenile steelhead near Buckley Cove in the lower San Joaquin River. The quantitative statistical analyses determined that a purely physical model in the form of the Delta Simulation Model II Hydro Particle Tracking Model was not able to predict the movement of steelhead tags. The model greatly underestimated the steelhead tag movement rate through the study area as steelhead tags were traveling significantly greater distances than passive particles. We also documented some behaviors of steelhead that could explain the discrepancies between the passive particles and steelhead tag data. Our findings suggest that migrating steelhead exhibit a complex set of behaviors that are not captured by simple physical models. Additional studies are needed to better understand these behaviors and ultimately improve forecasting of salmonid migrations. By understanding and predicting how salmonids migrate through the Delta, this can inform how to minimize the time that salmonids are in the Delta- where they have low survival probabilities- determine which routes have the fastest migration rates, and when export operations should be conducted to minimize loss. Overall, this research has both ecological, economic, and management implications.

Keywords: Steelhead, DSM2, migration, selective tidal-stream transport, diurnal/ nocturnal movement
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 10:20AM – 12:00PM Room 306

Out to Sea and Home Free? Shifting the Salmon Freshwater-Ocean Survival Paradigm: Is Selection Now Favoring Shorter Fresh Water Life Histories?

Sean A. Hayes, Southwest Fisheries Science Center & UC Santa Cruz, sean.hayes@noaa.gov
Arnold J. Ammann, Southwest Fisheries Science Center, arnold.ammann@noaa.gov
Jason L. Hassrick, Science Division, Bureau of Reclamation Bay-Delta Office, jhassrick@usbr.gov
A. Peter Klimley, Wildlife Fish and Conservation Biology, UC Davis apklimley@ucdavis.edu
Ryon Kurth, California Department of Water Resources, ryon.kurth@water.ca.gov
Steven T. Lindley, Southwest Fisheries Science Center & UC Santa Cruz, steve.lindley@noaa.gov
Joe Merz, Cramer Fish Sciences, jmerz@fishsciences.net
Cyril J. Michel, Southwest Fisheries Science Center & UC Santa Cruz, cyril.michel@noaa.gov
Jeremy Notch, Southwest Fisheries Science Center & UC Santa Cruz, jeremy.notch@noaa.gov
Robert Null, United States Fish and Wildlife Service, Red Bluff Office, Robert_Null@fws.gov

Variable ocean conditions contribute to large fluctuations in salmon survival and escapement. For California salmon populations this idea is coupled with an assumption of stable, abundant input of juveniles into the marine environment annually from continuous, large-scale hatchery production. Because of this, there is a tendency to attribute large fluctuations in escapement solely to variable ocean conditions. However recent studies on hatchery and wild smolts from multiple stocks in California's Sacramento River have assessed survival and interannual production of juvenile life stages using acoustic telemetry. These studies suggest instream mortality may be much greater and more variable than previously suspected. For example, out-migration mortality rates from basins several hundred kilometers upstream to the Golden Gate Bridge for hatchery fish range from 85-98%, typically within their first two weeks post hatchery release, yielding fewer and more variable contributions to the ocean. Given known escapement trends, this implies that marine survival rates are much higher, with only 80-90% mortality over the next two years for all fish that make it past the Golden Gate. Further, recent otolith microchemistry analysis suggests naturally produced fry may contribute as much as 20% to the returning adult population, and monitoring surveys revealed that annual catch-per-unit-efforts of fry may vary by 2 orders of magnitude. It is possible that sub-yearling and fry life histories that minimize time in river and race to sea are now favored by 'natural' selection forces over the yearling life histories that were more prevalent historically. Given continuing anthropogenic impacts to freshwater habitats, there is potentially a need to shift the paradigm that the ocean component of the salmon freshwater-ocean survival trade-off is the primary source of mortality, and rather may be a place of refuge at times. This hypothesis can be tested by salmon life cycle models under development.

Keywords: marine survival, freshwater, survival, salmon, life history strategy
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 10:20AM – 12:00PM Room 306