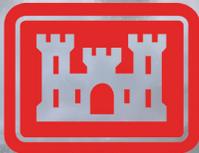


2011 Anadromous Fish Evaluation Program

US Army Corps of Engineers – Northwestern Division
November 28 – December 1, 2011



**US Army Corps
of Engineers®**

2011 Anadromous Fish Evaluation Program Annual Review

November 28-December 1, 2011

Whitman College
Maxey Hall
345 Boyer Avenue
Walla Walla, Washington 99362

Sponsored by
US Army Corps of Engineers
Northwestern Division



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of Engineers®**

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Welcome

The US Army Corps of Engineers, Northwestern Division, Walla Walla District (Corps), warmly welcomes you to the 2011 Anadromous Fish Evaluation Program (AFEP) review at Whitman College in Walla Walla, Washington. This annual review provides researchers with an opportunity to share and discuss their recent research regarding anadromous fish on the lower Columbia and Snake Rivers. This booklet is provided as a resource and reference to guide you through the activities of the next four days. It includes a daily agenda, list of presenters, and abstracts of their presentations.

We hope your attendance at the conference and stay in Walla Walla will be informative and enjoyable. This year's program includes four days of interesting presentations, bringing together scientists from universities, research laboratories, and federal agencies. Together, these presentations represent the scope and depth of current Federal Columbia River Power System (FCRPS) hydrosystem research which aims to improve the passage conditions to maximize survival of ESA-listed anadromous fish species in the Columbia River basin. In addition, we have the opportunity to include presentations from research funded by the Bonneville Power Administration and Grant County Public Utility District in this year's event.

The conference will be opened by a keynote speaker and the AFEP coordinators. Each day, members of the Corps will facilitate the meeting through a series of presentations related by their focus around fish passage through the FCRPS hydrosystem.

These studies will cover:

- Estuary Studies
- Lamprey Studies
- Predation Studies
- Programmatic Sediment Management Plan
- Bull Trout Studies
- Turbine Survival Program Studies
- Passage & Survival Studies
- Adult Salmon & Steelhead Studies
- System Survival
- Delayed Mortality/ Transportation Studies

Your participation is vital to the goals of this program. We welcome you again and are grateful for the time, effort, care, and expertise you bring to this endeavor.

Background

The Corps has sponsored biological studies continuously since 1952 in an integrated, applied research program. This program is intended to enhance understanding and improve anadromous fish passage conditions at multi-purpose projects on the Columbia and lower Snake Rivers in Oregon and Washington. These monitoring, research, and evaluation studies are managed under the AFEP. The AFEP is coordinated with federal, state, and tribal fish agencies who provide both technical and policy-level input to the Corps on study objectives, experimental design, and methodologies. Most of these studies are integral components of the Columbia Fish Mitigation Program (CRFM), a large Corps construction account that funds numerous fish passage improvements at Columbia and Snake River mainstem dams. Study objectives are closely linked to those improvements in order to answer biological questions in a timely manner.

Historically, Corps-funded studies have focused on project-specific adult and juvenile fish passage issues. However, this has been expanded to include system-level and reach survival studies, as well as estuarine habitat, juvenile and adult lamprey and bull trout studies. Most passage facilities and river operations have been developed and refined in response to studies on adult fish ladders and collection channels, juvenile bypasses with turbine intake screens, juvenile fish transportation, spill for juvenile fish passage, and a comprehensive set of project/hydrosystem operating criteria.

The AFEP studies evaluate passage success, survival, and fish condition for surface bypass technologies, transportation, conventional bypass systems, spill, total dissolved gas, adult migration/passage, in-river passage, and turbine passage. Most are developed as integral components of larger studies and evaluation features of CRFM related to new passage technologies, while others evaluate existing project features.

Purpose

The main purpose of AFEP is to produce scientific information to assist the Corps in making informed biological, engineering, design, and operational decisions for the eight mainstem Columbia and Snake River projects in order to provide safe, efficient passage through this migration corridor. Each project has multiple authorized purposes and uses, including migratory fish passage, and is affected by several environmental and project operating statutes. These include the Endangered Species Act, Clean Water Act, National Environmental Policy Act, Northwest Power Planning Act, and Fish and Wildlife Coordination Act. At the current time, ESA guidelines for the protection of listed species strongly influence the Corps' entire fish program. Biological opinions prepared by National Marine Fisheries Service and US Fish and Wildlife Service include measures to evaluate and make decisions on new passage technologies and system configurations. The resulting biological studies not only have a high priority in AFEP, but are conducted to answer key questions about behavior, survival, and the condition of fish as they migrate through the mainstem Columbia and Snake Rivers, thus facilitating decisions on the operation and configuration of the river system.

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| MONDAY, NOVEMBER 28, 2011 | | | | |
|----------------------------------|---|-------------------|------------------------|--|
| Time | Title | Study Area | Presenter | Affiliation |
| 12:00 | Opening Remarks | | | |
| 12:05 | Keynote Speaker | | | |
| 12:15 | Moderator Introduction - Cindy Studebaker | | | |
| 12:20 | Evaluation of Life History Diversity, Habitat Connectivity, and Survival Benefits Associated with Habitat Restoration Actions in the Lower Columbia River and Estuary | Estuary Studies | Heida Diefenderfer | Pacific Northwest National Laboratory |
| 12:40 | Multi-Scale Action Effectiveness Research: Juvenile Salmon Ecology and Restoration of Tidal Freshwater Habitats | Estuary Studies | Nichole Sather | Pacific Northwest National Laboratory |
| 13:00 | The Contribution of Tidal Fluvial Habitats in the Columbia River Estuary to the Recovery of Diverse Salmon ESUs | Estuary Studies | Daniel Bottom | NOAA Fisheries |
| 13:20 | Evaluating Cumulative Ecosystem Response to Restoration Projects in the Columbia River Estuary | Estuary Studies | Ronald M. Thom, Ph.D. | Pacific Northwest National Laboratory |
| 13:40 | Post Construction Assessment of Fishes, Habitats and Tide Gates in Sloughs on Mainland Julia Butler Hansen NWR | Estuary Studies | Jeffrey R. Johnson | US Fish & Wildlife Service |
| 14:00 | Break | | | |
| 14:10 | Moderator Introduction - Steve Juhnke | | | |
| 14:15 | Mitigation of Post-Handling Fungal Infections in Juvenile Pacific Lampreys: Identification of an Optimal Anesthetic and Application of Prophylactic Treatments | Lamprey Studies | Helena E. Christiansen | US Geological Survey |
| 14:35 | Video Monitoring to Determine Pacific Lamprey Ladder Escapement and Behavior at McNary and Ice Harbor dams | Lamprey Studies | Frank Loge | UC Davis |
| 14:55 | Use of Non-Invasive Methods to Evaluate Pacific Lamprey Counts and Passage Behavior at John Day Dam - 2011 | Lamprey Studies | Christopher A. Peery | US Fish & Wildlife Service |
| 15:15 | Automated Visual Event Detection and Classification Software: AVEDac | Lamprey Studies | Frank Loge | UC Davis |
| 15:35 | Estimating upstream passage metrics and performance in Pacific lamprey from the Columbia River Hydrosystem | Lamprey Studies | Christopher Caudill | Idaho Cooperative Fish and Wildlife Research Unit & Department of Fish and Wildlife Resources, University of Idaho |
| 15:55 | Break | | | |
| 16:05 | Identifying passage bottlenecks for adult Pacific lamprey at Bonneville and The Dalles dams: meta-analysis results | Lamprey Studies | Matthew Keefer | Idaho Cooperative Fish and Wildlife Research Unit & Department of Fish and Wildlife Resources, University of Idaho |
| 16:25 | Pacific lamprey monitoring with DIDSON (Dual-Frequency Identification Sonar) at Bonneville Dam at Bonneville Dam | Lamprey Studies | Christopher Caudill | Idaho Cooperative Fish and Wildlife Research Unit & Department of Fish and Wildlife Resources, University of Idaho |

| MONDAY, NOVEMBER 28, 2011 | | | | |
|----------------------------------|---|-------------------|---------------------|--|
| Time | Title | Study Area | Presenter | Affiliation |
| 16:45 | Improving Adult Pacific Lamprey Passage at Bonneville Dam Using Lamprey Passage Structures and Refuge Boxes | Lamprey Studies | Mary L. Moser | NOAA Fisheries |
| 17:05 | Using the Juvenile Salmon Acoustic Telemetry (JSATS) System to Evaluate Adult Pacific Lamprey Movements and Fate in Columbia River Reservoirs | Lamprey Studies | Christopher Caudill | Idaho Cooperative Fish and Wildlife Research Unit & Department of Fish and Wildlife Resources, University of Idaho |
| 17:25 | Adult lamprey data mining: using models to prioritize sites for fishway passage improvements and to predict lamprey run timing and size | Lamprey Studies | Matthew Keefer | Idaho Cooperative Fish and Wildlife Research Unit & Department of Fish and Wildlife Resources, University of Idaho |
| 17:45 | Closing Remarks | | | |

| TUESDAY, NOVEMBER 29, 2011 | | | | |
|-----------------------------------|---|---------------------------------------|--------------------|---------------------------------------|
| Time | Title | Study Area | Presenter | Affiliation |
| 9:00 | Moderator Introduction - David Trachtenberg | | | |
| 09:05 | Avian Predation on the Columbia Plateau: A Synthesis of Research Results | Predation Studies | Allen Evans | Real Time Research |
| 09:30 | Benefits to Columbia River Anadromous Salmonids from Potential Reductions in Avian Predation on the Columbia Plateau | Predation Studies | D.E. Lyons | Oregon State University |
| 09:55 | Avian Predation in the Columbia River Estuary and Monitoring Implementation of the Caspian Tern Management Plan | Predation Studies | Dan Roby | Oregon State University |
| 10:20 | Break | | | |
| 10:30 | Electronic Recovery of Passive Integrated Transponder (PIT) Tags on Avian Breeding Colonies in the Columbia River Basin, 2011 | Predation Studies | Scott H. Sebring | NOAA Fisheries |
| 10:55 | Avian Predation at John Day and The Dalles Dams 2011: Estimated Fish Consumption Using Direct Observation | Predation Studies | Mike Jonas | US Army Corps of Engineers |
| 11:20 | Juvenile Steelhead Survival and Predator-Prey Interactions Using JSATS through the Priest Rapids Reservoir in 2011 | Predation Studies | Audrey Thompson | Blue Leaf Environmental |
| 11:45 | Lunch | | | |
| 12:45 | Moderator Introduction - David Trachtenberg | | | |
| 12:50 | Seasonal Use of Shallow Water Habitat in the Lower Snake River Reservoirs by Juvenile Fall Chinook Salmon | Programmatic Sediment Management Plan | Kenneth F. Tiffan | US Geological Survey |
| 13:15 | Habitat Quality and Fish Species Composition/Abundance at Selected Shallow Water Locations in the Lower Snake River Reservoirs | Programmatic Sediment Management Plan | Evan Arntzen | Battelle |
| 13:40 | Moderator Introduction - Dean Holecek | | | |
| 13:45 | Use of the Mainstem Columbia River by Walla Walla Basin Bull Trout | Bull Trout Studies | Donald Anglin | US Fish & Wildlife Service |
| 14:10 | Monitoring Sub-adult and Adult Bull Trout Passage Through Lower Granite, Little Goose and Lower Monumental Bypass Facilities | Bull Trout Studies | Carrie Bretz | US Fish & Wildlife Service |
| 14:35 | Break | | | |
| 14:45 | Moderator Introduction - Dennis Schwartz | | | |
| 14:50 | Development of External and Neutrally Buoyant Acoustic Transmitters for Juvenile Salmon Turbine Passage Evaluation | Turbine Survival Program Studies | Z. Daniel Deng | Pacific Northwest National Laboratory |
| 15:15 | The Effects of Neutrally Buoyant Externally Attached Transmitters on Predator Avoidance and Swimming Performance of Juvenile Chinook Salmon | Turbine Survival Program Studies | Jill M. Janak | Pacific Northwest National Laboratory |
| 15:40 | Eliminating Bias in the Study of Barotrauma Associated with Passage through Hydroturbines Using a Novel Transmitter Design | Turbine Survival Program Studies | Brett D. Pflugrath | Pacific Northwest National Laboratory |

| TUESDAY, NOVEMBER 29, 2011 | | | | |
|-----------------------------------|---|----------------------------------|--------------------|---------------------------------------|
| Time | Title | Study Area | Presenter | Affiliation |
| 16:05 | Pathways of Barotrauma in Juvenile Salmonids Exposed to Simulated Hydroturbine Passage: Boyle's Law vs. Henry's Law | Turbine Survival Program Studies | Richard S. Brown | Pacific Northwest National Laboratory |
| 16:30 | The Effect of Rapid and Prolonged Decompression on Juvenile Brook Lamprey and Pacific Lamprey | Turbine Survival Program Studies | Alison H. Colotelo | Pacific Northwest National Laboratory |
| 16:55 | Closing Remarks | | | |

| WEDNESDAY, NOVEMBER 30, 2011 | | | | |
|-------------------------------------|---|----------------------------------|------------------|---------------------------------------|
| Time | Title | Study Area | Presenter | Affiliation |
| 09:00 | Moderator Introduction - Brad Eppard | | | |
| 09:10 | Lower Columbia River Survival Study, 2011: Methods | Passage & Survival Studies | Christa Woodley | Pacific Northwest National Laboratory |
| 09:35 | Evaluation of Model Assumptions in the JSATS Compliance Studies | Passage & Survival Studies | J. R. Skalski | Pacific Northwest National Laboratory |
| 10:00 | Lower Columbia River Survival Study, 2011: BiOp and Fish Accords Compliance Testing at John Day Dam | Passage & Survival Studies | James Hughes | Pacific Northwest National Laboratory |
| 10:25 | Break | | | |
| 10:35 | Results of the JSATS Compliance Studies at The Dalles Dam, Spring 2011 | Passage & Survival Studies | J. R. Skalski | Pacific Northwest National Laboratory |
| 11:00 | Lower Columbia River Survival Study, 2011: BiOp and Fish Accords Compliance Testing at Bonneville Dam | Passage & Survival Studies | Gene Ploskey | Pacific Northwest National Laboratory |
| 11:25 | Efficacy of Single-Suture Vs Double-Suture Incision Closures in Seaward-Migrating Juvenile Chinook Salmon Implanted with JSATS Acoustic Transmitters | Passage & Survival Studies | Richard Brown | Pacific Northwest National Laboratory |
| 11:45 | The Efficacy of Ultraviolet Irradiation for Sterilizing Tools Used for Surgically Implanting Transmitters into Fish | Passage & Survival Studies | Ricardo Walker | Pacific Northwest National Laboratory |
| 12:05 | Lunch | | | |
| 13:05 | Effects of Total Dissolved Gas on Chum Salmon Fry Survival, Growth, Gas Bubble Disease, and Seawater Tolerance | Passage & Survival Studies | Dr. David Geist | Pacific Northwest National Laboratory |
| 13:30 | Estimate of Direct Effects of Steelhead Kelt Passage through the First Powerhouse Ice Trash Sluice and Second Powerhouse Corner Collector at Bonneville Dam | Passage & Survival Studies | Joanne L. Fulmer | Normandeau Associates |
| 13:55 | How Spill Operations Affect Survival of Fish Passing McNary Dam: A Multi-Year Analysis of Survival Data Collected at McNary Dam, 2004-2009 | Passage & Survival Studies | Noah S. Adams | US Geological Survey |
| 14:20 | Visualizing and Quantifying Fish Behavior at McNary Dam 2006-2009 | Passage & Survival Studies | Noah S. Adams | US Geological Survey |
| 14:45 | McNary Dam Oregon Shore Fish Ladder Intake Screen Monitoring, 2011 | Passage & Survival Studies | Russell Moursund | Moursund Research Group |
| 15:10 | Break | | | |
| 15:25 | Moderator Introduction - Brad Eppard | | | |
| 15:30 | Current Status and Restoration Potential for Mainstem spawning Fall Chinook in the McNary Tailrace and Upper John Day Reservoir | Adult Salmon & Steelhead Studies | Joe Skalicky | US Fish & Wildlife Service |
| 15:55 | Hydroacoustic Evaluation of Adult Steelhead Fallback and Kelt Passage at McNary Dam, Winter 2010-2011 | Adult Salmon & Steelhead Studies | Kenneth Ham | Battelle |
| 16:20 | Hydroacoustic Evaluation of Overwintering Summer Steelhead Fallback and Kelt Passage at The Dalles Dam, 2011 | Adult Salmon & Steelhead Studies | Fenton Khan | Pacific Northwest National Laboratory |
| 16:45 | Closing Remarks | | | |

| THURSDAY, DECEMBER 1, 2011 | | | | |
|-----------------------------------|---|--|------------------|---|
| Time | Title | Study Area | Presenter | Affiliation |
| 09:00 | Moderator Introduction - Dean Holecek | | | |
| 09:05 | PIT-Tag Reach Survival Estimates, 2011 | System Survival | Steven G. Smith | NOAA Fisheries |
| 09:30 | Initial Results from the 2011 COAST Study: Lower River, Estuary, and Early Marine Survival and Movements of Yearling Chinook Salmon | System Survival | Erin Rechisky | Kintama Research Services Ltd. |
| 09:55 | Snake River Basin Differential Delayed Mortality Synthesis | Delayed Mortality/Transportation Studies | J.J. Anderson | Anderson Consultant, University of Washington Battelle |
| 10:20 | A Study to Determine Seasonal Effects of Transporting Fish from the Snake River to Optimize a Transportation Strategy | Delayed Mortality/Transportation Studies | Steven G. Smith | NOAA Fisheries |
| 10:45 | Break | | | |
| 11:00 | Snake River Sockeye Pilot Transportation Study 2009-2011 | Delayed Mortality/Transportation Studies | Dean Holecek | US Army Corps of Engineers |
| 11:25 | Alternative Barging Strategies to Improve Survival of Transported Juvenile Salmonids | Delayed Mortality/Transportation Studies | Bill Muir | NOAA Fisheries |
| 11:50 | Identifying Overwintering Location and Natal Origin for Snake River Fall Chinook Salmon | Delayed Mortality/Transportation Studies | Rich Zabel | NOAA Fisheries |
| 12:15 | Closing Remarks | | | |

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Evaluation of Life History Diversity, Habitat Connectivity, and Survival Benefits Associated with Habitat Restoration Actions in the Lower Columbia River and Estuary

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Background

RPA Actions 58, 59, and 60 of the NOAA biological opinions on the effects of the federal Columbia River hydropower system on anadromous fish (2000-2010) describe the three research areas covered by this project: habitat connectivity index, early life history diversity index, and restoration-associated survival benefits. The primary goal of this study is to establish scientific methods to quantify habitat restoration benefits to listed salmon and trout in the lower Columbia River and estuary (LCRE) in these three research areas.

Methods

In 2011, we continued to develop quantitative measurement methods in the three research areas. First, to index habitat connectivity, we demonstrated structural, hydrologic, and functional methods. Second, in developing an index of early life history diversity (ELHD), we examined traditional species diversity indices by incorporating a suite of metrics associated with juvenile salmon life history attributes. Third, to quantify habitat benefits from restoration for juvenile salmon, we developed the conceptual basis for a numerical model including a review of physiological indicators of fitness that are suitable for application in the LCRE. Additionally, we began a task to identify restoration actions that will best enable and accelerate the development of restored or created tidal wetland plant communities in the LCRE.

Results/Management Action

For habitat connectivity change analysis at the estuary scale, we developed a land-cover reclassification protocol for determining the historical baseline and contemporary areas of salmon habitat, as well as a GIS-based least-cost modeling methodology to hydrologically route and calculate distances between salmon habitats including main channel, off channel, wetland, and tributary sites. We developed and employed a semi-automated rapid extraction technique to identify dike features in LiDAR data; the result of this approach is a GIS layer representing dike features for the entire LCRE, which will be further refined by a human analyst. Our preliminary analysis of a relatively small data set (spatial and temporal) of beach seine and hydrologic data from Cottonwood Island detected a significant trend of increased catch density during the ebb tide in the main channel and a similar although not significant trend in the off channel, and no relationship between water depth and salmon density. By retrofitting existing species diversity indices we've transitioned from a binary approach toward one that incorporates densities of juvenile salmon and their respective early life history attributes. The ELHD index provides managers with a high-level indicator to track biological performance under RPA 58.2. We identified the critical elements and linkages of a conceptual model of benefits to juvenile salmon from hydrologic reconnection in LCRE habitats, and reviewed key literature to support narrative explanations of the mechanisms included in the model. We conducted a comprehensive literature review on the physiological responses of juvenile salmon to environmental metrics in the LCRE. From this we designed companion field and laboratory research protocols to investigate remaining uncertainties critical to accurate numerical modeling of salmon response to habitat restoration. We began to identify the elevation distribution of common invasive plant species to inform engineering designs for habitat restoration.

Multi-Scale Action Effectiveness Research: Juvenile Salmon Ecology and Restoration of Tidal Freshwater Habitats

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Background

The overall goal is to evaluate the effectiveness of juvenile salmon habitat restoration in the lower Columbia River and estuary (LCRE). Our research approach combines site- as well as landscape-scale objectives aimed at characterizing attributes of juvenile salmon ecology in shallow tidal freshwater habitats. Site scale action effectiveness research is occurring in the vicinity of the Sandy River delta (SRD; rkm 192-208), and sampling at the landscape-scale is being conducted in the LCRE between the confluences of the Cowlitz and Lewis rivers (rkm 110-141). A BACI design is being implemented at the SRD with monitored metrics sampled on a monthly basis, including a suite of biotic as well as environmental variables; fish community composition, prey, diet and genetic stock identification of juvenile Chinook salmon, vegetative community composition, and hydrologic conditions. The landscape-scale element of our study applies a rotational sampling scheme using a random stratified sampling approach. Sites are segregated into three habitat strata and sampled on a seasonal basis for estimation of juvenile salmon density at the landscape scale. Acoustic telemetry is used to determine residence time of juvenile Chinook salmon in winter.

Results

During 2010-2011, we captured 29 species of fish, of which 15 were non-native and comprised approximately 22% of the total catch. The most abundant species, threespine stickleback, accounted for 68% of the total catch. Unmarked Chinook salmon were the most abundant salmon species with greatest densities observed during spring and summer months. The mean size of unmarked Chinook salmon was typically smaller than marked hatchery Chinook salmon captured during similar time periods.

Residence times for juvenile Chinook salmon of differing life history strategies within the vicinity of the Sandy River delta was revealing. We found that fish tagged upstream as part of other studies did not yield extended residence time during spring and summer months. However, fish tagged near the site of capture during winter time periods demonstrated mean residence of 34 and 25 days in 2010 and 2011, respectively.

Summary

This study contributes to the implementation of the Reasonable and Prudent Alternatives 59, 60, and 61 of the 2008 Biological Opinion on operation of the Federal Columbia River Power System. Additionally, this study is aligned with the goals and objectives of the NPCC's Fish and Wildlife Program by contributing to an empirically based understanding of habitat use by juvenile salmon in the LCRE. Addressing uncertainties associated with juvenile salmon and habitat restoration provides managers with information that can be used to prioritize restoration projects to mitigate FCRPS effects on target species.

The Contribution of Tidal Fluvial Habitats in the Columbia River Estuary to the Recovery of Diverse Salmon ESUs

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Background

Progress to recover at-risk Columbia River salmon stocks is hampered by uncertainties about stock-specific salmon distributions and the influence of estuary habitat on adult returns. We conducted field surveys and expanded modeling activities to determine the estuary's contributions to genetic and life history diversity, habitat opportunities, and adult returns.

Methods

Chinook salmon were sampled bimonthly in each of three habitat types in six of eight estuary reaches (C – H), March 2010 - July 2011. Paired beach and purse seine samples also were collected at Point Adams Beach (reach A) biweekly from March through July to index outmigrant genetic and life history composition and to compare with ongoing surveys in the Columbia River plume. PIT detectors were deployed at two wetland channels to monitor the origins of tagged salmon entering each site, March-September, 2011. We examined habitat opportunity dynamics for juvenile salmon, extending estuary circulation models to upstream boundaries at Bonneville Dam and Willamette Falls. We began developing new life-cycle models, and expanded existing models, to assess the estuary's contributions to life-cycle success.

Results

Diversity of genetic stocks was greatest in reaches E and F, where four stocks each contributed >10% of samples. Two stocks of fall Chinook salmon from the Lower Columbia River (LCR) ESU were major contributors in all six reaches of the upper estuary but comprised larger proportions of fish in C-E (82% - 65%) than in F (55%), G (55%) and H (26%). These stocks also accounted for 83% of the 2010 outmigrant samples at Point Adams Beach. Upper Columbia River (UCR) summer/fall run fish utilized nearshore habitats in all reaches, with relatively small proportions in reaches A and C-D (1% - 5%) and increasing proportions in E (20%), F (21%), G (26%), and H (62%). Willamette River spring Chinook salmon juveniles accounted for ~10% of the samples collected in Reach E, 15% in reach F, but < 8% in other reaches. Snake River fall run fish were relatively rare but occurred in E-H, comprising ~4% of catches in H. Nearly 2/3 of twenty-one PIT tagged individuals detected at the Russian Island emergent wetland were LCR fall Chinook. We also detected Snake River fall, UCR spring Chinook, coho salmon, and UCR and Snake River steelhead. Fewer individuals (n = 11) were detected at the second PIT site at Woody island, including LCR, UCR, and Snake River fall Chinook; and spring Chinook, coho, and Snake River (Grande Ronde) steelhead..

We began developing a high-resolution circulation model to compare habitat opportunities for stock groups with different seasonal-use patterns. Modeling of seasonal and interannual variability in habitat opportunity is in progress, and simulation databases have been created to analyze climate-change scenarios. We began examining the estuary's contributions to life-cycle success of Snake River fall Chinook juveniles using otolith micro-chemistry and micro-structure. For spring-migrant populations, we began incorporating survival information derived from acoustic tagging studies into existing life-cycle models. We also are examining the contribution of estuary habitats to the population viability of lower Columbia River and Willamette River populations.

Evaluating Cumulative Ecosystem Response to Restoration Projects in the Columbia River Estuary

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Background

The action agencies are making interventions in the 235-km lower Columbia River and Estuary ecosystem (LCRE) that are intended to be restorative, particularly hydrologic reconnection actions such as dike breaching and tide gate replacement, as offsite mitigation in response to the 2000 to 2010 biological opinions on effects of the hydropower system on anadromous fish. The Cumulative Effects study culminated in March 2011 with publication of a levels-of-evidence approach to causal inference used to estimate the effects of large-scale, multi-jurisdictional habitat-improving interventions on the LCRE.¹ The study also produced the monitoring protocols being used to standardize action-effectiveness assessment in the LCRE² and numerous other technical results documented in seven annual reports. This presentation reports activities undertaken to close out the Cumulative Effects study.

Methods

Final-year activities include (1) outreach at regional, national and international levels; and (2) synthesis of the cumulative effects of early-stage ecosystem-restoration actions in the tidal freshwater and estuarine areas of the LCRE floodplain and main-stem islands. This cumulative effects synthesis considers the working hypothesis that a cumulative beneficial effect on salmon has resulted from the federal restoration program for this culturally and economically significant regional resource.

Results/Management Action

On August 1, 2011, we presented a three-hour workshop, “Assessing Cumulative Ecosystem Effects of Multiple Restoration Projects,” at the National Conference on Ecosystem Restoration (NCER) in Baltimore, MD. Chief co-sponsors of the conference include the U.S. Army Corps of Engineers, U.S. Geological Survey, and U.S.D.A. Natural Resources Conservation Service. In attendance at our workshop were representatives from four Corps Divisions and HQ, NOAA, the EPA, Bureau of Reclamation, USGS, and others.

We are presently synthesizing multiple lines of evidence including data collected under the auspices of the Lower Columbia River Estuary Partnership and Bonneville Power Administration in conjunction with data collected by this study. Lines of evidence include the following: (1) causal criteria analysis of peer-reviewed literature; (2) verification of ecological relationships by analysis of field-collected data (ancillary hypothesis testing); (3) GIS modeling to aggregate site-scale effects and assess net ecosystem improvement; (4) quantification of potentially non-additive modes of accumulation, e.g., indirect, time lag, space crowding, and cross-boundary; (5) adaptation of control chart methods to evaluate the trajectories of ecosystem change relative to reference conditions; and, (6) assessment of countervailing processes at the landscape scale. The product will be an analysis as well as a description of the process employed.

¹ Diefenderfer HL, RM Thom, GE Johnson, JR Skalski, KA Vogt, BD Ebberts, GC Roegner, and EM Dawley. 2011. “A Levels-of-Evidence Approach for Assessing Cumulative Ecosystem Response to Estuary and River Restoration Programs.” *Ecological Restoration* 29:111-132.

² Roegner, GC, HL Diefenderfer, AB Borde, RM Thom, EM Dawley, AH Whiting, SA Zimmerman, and GE Johnson. 2009. *Protocols for monitoring habitat restoration projects in the lower Columbia River and estuary*. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-97. <http://www.nwfsc.noaa.gov/publications/displayinclude.cfm?incfile=technicalmemorandum2009.inc>

Post Construction Assessment of Fishes, Habitats and Tide Gates in Sloughs on Mainland Julia Butler Hansen NWR

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Background

Restoring tidally influenced wetlands to improve conditions for juvenile anadromous salmonids is an important component of many recovery and management plans and regulatory requirements. However, considerable uncertainty exists concerning appropriate restoration activities because the information necessary to determine the effectiveness of specific actions is lacking. The U.S. Fish and Wildlife Service is assessing an aquatic habitat restoration project at Julia Butler Hansen National Wildlife Refuge (JBH) to determine the effectiveness of the restoration and to provide information to managers on the utility of specific actions at future restoration sites. In 2009 and 2010, self-restrained tide gates were installed to replace top-hinge tide gates or were installed at sloughs that were closed at their historical mouth by a levee. These new tide gates are designed to provide habitat and fish passage benefits when compared to traditional tide gates.

Methods

We collected base-line condition data at treatment and reference sloughs before construction (2007 - 2008) to describe fish passage opportunity, habitat parameters, and fish community composition and found fundamental differences in fish communities and temperature regimes. Post-construction data was collected spring 2010 and 2011 after the first three (2009) and the last two (2010) new gates were installed. Three of these gates were installed in sloughs where a levee had previously closed off the historical mouth. Two of these gates replaced old gates.

Results/Management Action

Water temperature profiles collected post construction have approached that of reference sloughs. Numerically, more salmon were captured in treatment sloughs after installation of the new tide gates. Similarity index (Sorensen Similarity Index), calculated to compare fish communities of a reference slough to one of the previously closed slough, show a significant increase post construction. This increased similarity between treatment and reference sloughs is driven by the increased number of native fish species (i.e. juvenile salmon) captured in treatment sloughs.

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Mitigation of Post-Handling Fungal Infections in Juvenile Pacific Lampreys: Identification of an Optimal Anesthetic and Application of Prophylactic Treatments

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Background

Studies of endangered salmon stocks have required extensive tagging programs to monitor limiting factors and survival. Pacific lamprey *Entosphenus tridentatus* are now also facing severe population declines, yet little is known about juvenile lamprey passage, life history, or adult return rates because until now, these small fish could not be tagged for unique identification of live individuals. Previously, we developed a simple and effective method for tagging juvenile lampreys with passive integrated transponder (PIT) tags and showed that tagging *per se* did not affect survival. Mortality in tagged and untagged control fish, however, was frequently associated with fungal infection, which occurred at a high rate in captive fish.

Methods

In this study, we tried to mitigate fungal infections first by reducing irritation and stress caused by anesthesia and then by treating tagged fish briefly with a prophylactic immediately after tagging. We tested four anesthetics and determined that MS-222 and BENZOAK® (20% benzocaine) were the most effective for anesthetizing juvenile lampreys to handleable and caused the least irritation to fish when used at 100 and 60 mg/L. We also showed that fish anesthetized with BENZOAK® may have lower rates of fungal infection than those anesthetized with MS-222 or AQUI-S® 20E (10% eugenol). When fish anesthetized with MS-222 or BENZOAK® were given a 30 min prophylactic treatment with Stress Coat®, hydrogen peroxide, or salt immediately after tagging, few fish presented with fungal infections. However, untreated, tagged control fish also showed little if any fungal infections, making it difficult to determine if the prophylactic treatments were successful.

Results/Management Action

We recommend anesthesia with MS-222 or BENZOAK® and then tagging with a 20–24 h recovery period followed by immediate release. If field studies show that lampreys are not reaching salt water (where fungal infections are mitigated) within 1–2 weeks after release, further study of prophylactic treatments may be warranted.

Video Monitoring to Determine Pacific Lamprey Ladder Escapement and Behavior at McNary and Ice Harbor dams

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Background

Enumeration of escapement is central to the management of Pacific lamprey and other anadromous fishes. Evaluations of Pacific lamprey passage at Bonneville and The Dalles Dam revealed biases in the estimated counts because adult lamprey population estimates have relied on dam counts conducted at sites and times (daylight) more appropriate for adult salmonid enumeration. The majority of lamprey passage occurs at night, and there is mounting evidence that adult lamprey bypass count stations at some dams via picket leads used to crowd adult salmonids into the count window. In 2011, USACE raised the picket leads off the ladder floor at all dams on the Columbia and Snake rivers by one and one half inch to promote passage of lamprey through this section, further potentially affecting lamprey counts at the count window. In this study, we use video and other non-invasive technologies to establish lamprey passage behavior and performance at ladder structures and work towards providing accurate enumeration of lamprey ladder escapement.

Methods

Low-light video cameras were installed behind the pickets at McNary and Ice Harbor fish ladders. At McNary Oregon shore ladder, additional cameras were placed on the nearest downstream weir from the count station to evaluate whether lamprey could be accurately enumerated in this location, and whether those counts reflect what is counted in the window plus pickets. To determine lamprey behavior and investigate the efficacy of underwater monitoring in a high-velocity environment, cameras were placed on a frame and lowered into the McNary Oregon shore ladder entrance. DIDSON sonar cameras were installed at the ladder exit of McNary and the turnpool at Ice Harbor to explore the feasibility of using high-resolution sonar to enumerate and/or characterize lamprey behavior at these locations.

Results/Management Action

The total day and night lamprey counts at the McNary Dam Oregon Shore Fishway window totaled 949 during the period July 9-September 14. We observed 618 upstream passage events behind the pickets in video footage at the same location, with video counts comprising 43.7% of the day window count and 127.7% of the night window count (total escapement = 1,567). Window and picketed lead counts were significantly correlated among nights. Roughly 65% of lamprey counted in video used the gap at the bottom of the picket to pass, while 7.8% moved downstream through this gap. Recirculation through the count window and pickets (and vice versa) was estimated by calculating the probability downstream and upstream events occurring within the same hour. Additionally, the highest frequency of lamprey passing under the pickets was seen in the camera nearest the count window slot. Evaluation of DIDSON and other video observations at all locations are underway and results will be presented covering the peak lamprey passage at both dams. The results of this analysis suggest monitoring of alternative lamprey passage routes or monitoring additional locations will be essential to obtaining accurate escapement estimates.

Use of Non-Invasive Methods to Evaluate Pacific Lamprey Counts and Passage Behavior at John Day Dam - 2011

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Background

Critical for any management action directed at reversing the declines of Pacific lamprey is to have reliable estimates of population size, to be able to track changes over time, and to help set priorities for research and restoration efforts. Developing accurate counts of lamprey is difficult because lamprey are primarily nocturnal in their behavior, and they are able to use alternate routes that bypass fish count stations. In 2009, we tested use of underwater video cameras to count adult Pacific lamprey passing north-shore fishway at John Day Dam. In 2011, this effort was expanded to both fishways at The Dalles and John Day dams.

Methods

A total of 13 video cameras were installed in the fishways at The Dalles and John Day dams to observe upstream passage of adult Pacific lamprey. Video cameras were installed inside each of the four count stations at the two projects to observe nighttime movements (standard fish counters recorded day time lamprey counts), and nine underwater cameras were used to observe lamprey that moved through picketed leads and thus bypass the count station slots. All cameras were connected to multi-channel DVR to record video images.

Results/Management Action

Cameras were operational 24 hrs/d from 16-18 May until 17 October 2011. Image quality varied significantly based on water visibility and lighting conditions. In some cases, infrared (IR) lighting had to be replaced with white light sources to make nighttime images usable. Commercially available DVR equipment has proven to be relatively inefficient to record and process the quantity of video images generated. Video data is currently being processed using two different software packages and with manual viewing. Results from the three methods will be compared to determine the most effective methods to generate lamprey counts from video imaging.

Automated Visual Event Detection and Classification Software: AVEDac

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Background

Underwater video monitoring at various locations within fish ladders at dams along the Columbia and Snake rivers has increased annually. Most of the monitoring aims to establish lamprey passage behavior at ladder structures and provide accurate enumeration of lamprey ladder escapement. The increase in amount of video places a high burden on the amount of time human annotators spend processing these data. To help address this issue, an automated visual event detection and classification software (AVEDac) was developed in 2010.

AVEDac is a multi-tiered software stack for acquiring and processing of underwater video in order to enumerate and classify fish. It is composed of three main modules: video acquiring, event detection and tracking, and classification. The first two are console applications written in C++ and run with Linux on a Beowulf cluster, and the latter is a graphical interface written in Java that runs on a Macintosh operating system.

Methods

The video acquiring module extracts video from the DVRs installed at various dams either through the internet or offline. Video was collected at locations behind picket leads, at count windows, and at ladder entrances of McNary and Ice Harbor dams. This module is a fully automated process that runs on a daily schedule and produces videos for subsequent processing by other modules of this software stack.

The event detection and tracking module extracts moving objects from these videos. It currently features an adaptive background subtraction algorithm with special filters that reduce noise and improve detection in low light and poor visibility conditions.

The classification module is the top of the software stack. The classification algorithm is trained against a library of different classes (salmon, lamprey). Visual events are analyzed and the moving objects are fit to one of these classes.

Results/Management Action

On average, through the use of DVR motion detection, 24 hours of video was condensed to 8 hours. The automated acquiring module used to retrieve this video involves little operator input, less than 10 minutes per day. This video is time-stamped and improves accuracy of subsequent phases of processing.

Compared to 2010, the event detection and tracking module processing speed has been increased by a factor of 50, and reduces an eight-hour clip of video (with motion detection) to only two hours, on average. The Beowulf cluster has the capacity to process real-time video from 640 cameras. Accuracy of event detection and tracking has been improved and forms a solid basis for both the classification module and generates highly condensed video clips suitable for human annotation.

Improvements to the accuracy of the classification module are ongoing. New algorithms using feature and movement-based classification are being tested, together with efforts for building better training libraries.

Use of underwater video continues to be a valuable tool for use in answering questions of lamprey abundance and behavior in fish passage structures. AVEDac improves analysis of video by removing irrelevant events, detecting and tracking relevant events, and substantially reducing time spent by human annotators to review video.

Estimating Upstream Passage Metrics and Performance in Pacific Lamprey from the Columbia River Hydrosystem

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Background

Declining counts of adult Pacific lamprey (*Lampetra tridentata* / *Entopbennus tridentatus*) in the Columbia and Snake rivers have sparked concern about the influence of dams on migration success during spawning migration. Monitoring migration behaviors is an important part of understanding how dams and environmental factors affect lamprey passage success, distribution to spawning areas, and prioritizing limited conservation funds among locations in the Hydrosystem. An ideal prioritization would consider knowledge of both patterns of movement and the underlying mechanisms affecting migration behavior.

Methods

In 2011, we collected adult lampreys at Bonneville Dam and tagged them with half-duplex passive integrated transponder (HD-PIT) tags. Lamprey passage was monitored at Bonneville, The Dalles, John Day, McNary, and Priest Rapids dams on the Columbia River, and at the four lower Snake River dams. A second group of lampreys was tagged with both HD-PIT tags and acoustic transmitters (JSATS) and was monitored in reservoirs and at some tributary sites. Our primary objectives for this summary were to estimate lamprey escapement past the monitored sites, to assess the final known distribution of tagged fish, and to integrate 2011 results with those from HD-PIT, JSATS, and radio-tagged lampreys from previous years. We will present findings within a broad conceptual context for evaluating passage metrics and upstream migration “success” for Pacific lamprey.

Results/Management Action

We tagged 929 adult lampreys HD-PIT tags and 85 with HD-PIT tags and acoustic transmitters in 2011. At this writing, some lampreys tagged in 2011 were still active, monitoring sites were still deployed, and data were not yet fully processed. Preliminary results show high attrition rates occurred as the lamprey run progressed upstream, consistent with findings in previous years. The multi-year comparative analysis indicates that lamprey passage at dams is sensitive to environmental and operational conditions, but also that major behavioral patterns repeat across years. Standardized passage metrics (i.e., adjusted for among-year differences in lamprey size and environmental conditions) provide some evidence for incrementally improving lamprey performance at dam fishways in response to structural and operational changes.

We conclude, however, that determining true migration success in adult Pacific lamprey continues to be difficult because the underlying motivation(s) for migration past dams remains unknown. Available data suggest that migration behavior in lamprey differs fundamentally from salmonid fishes and that comparing passage metrics among dams is tenuous. Prioritization for lamprey managers in the short term should continue to focus on addressing known passage issues and addressing the critical uncertainties about adult lamprey migration behavior.

Identifying Passage Bottlenecks for Adult Pacific Lamprey at Bonneville and The Dalles Dams: Meta-Analysis Results

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Background

This project is part of a multi-year effort to understand and improve the passage performance of adult Pacific lamprey (*Lampetra tridentata* / *Entosphenus tridentatus*) at lower Columbia River dams. The objectives addressed in this retrospective meta-analysis were to: (1) identify fishway passage bottlenecks at Bonneville and The Dalles dams; and (2) to help prioritize sites where fishway modifications can increase lamprey passage efficiency.

Methods

We compiled data from 3,250 adult lampreys collected and radio-tagged at Bonneville Dam over ten years (1997-2002, 2007-2010). To identify fishway bottlenecks, we individually reviewed all fishway entrance events by lampreys at Bonneville ($n = 5,227$) and The Dalles ($n = 1,114$) dams, and determined the outcome of each event (passed dam or exited to tailrace). For each failed event, we identified the specific fishway turn-around location. We then used a series of statistical models to assess lamprey passage performance in relation to which fishway was used, lamprey size, and a suite of environmental conditions (i.e., date, water temperature, river discharge, tailwater elevation). To help identify sites for fishway modifications, we evaluated potential effects of improving lamprey passage at the identified bottlenecks on upstream escapement.

Results/Management Action

At Bonneville Dam, lamprey passage probability was highest for fish that encountered warm water temperature and low tailwater elevation, for those that entered at Powerhouse 1 fishway openings, and for larger fish. Passage was least efficient for those that entered Powerhouse 2 south openings and was poor dam-wide at high tailwater elevation. Bonneville bottlenecks were concentrated in the lowest fishway segments, including collection channels and transition pools, and in the serpentine-weir segments near top-of-ladder exits. Lampreys that turned around in lower fishway segments were far more likely to make additional passage attempts than those that turned around in upper segments. At The Dalles Dam, lampreys that entered the main east fishway openings were most likely to pass the dam and performance improved as water temperature increased and tailwater elevation decreased. Performance was least efficient for those that entered the west powerhouse and south spillway openings, and was intermediate at the north-shore opening. Consistent with the Bonneville results, most lampreys turned around in lower fishway segments at The Dalles Dam.

Results overall indicated that a variety of factors affected lamprey passage performance at each dam. Most important were passage route, tailwater elevation, and water temperature. There were also likely local effects, such as high fishway water velocity at serpentine weirs, that restricted passage. Priority sites for relieving passage bottlenecks at Bonneville Dam include: (1) the southern end of the Powerhouse 2 collection channel, (2) the Powerhouse 2 junction pool, (3) transition areas of the B-Branch and Cascades Island fishways, (4) serpentine weir segments of both fishways, and (5) the Powerhouse 1 collection channel and transition area. At The Dalles Dam, priority sites include: (1) the east fishway transition area, and (2) the north fishway collection and transition area.

Pacific Lamprey Monitoring with DIDSON (Dual-Frequency Identification Sonar) at Bonneville Dam

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Background

Monitoring adult Pacific lamprey (*Lampetra tridentata* / *Entosphenus tridentatus*) migration behaviors at Columbia River basin dams is important for identifying areas of difficult passage. DIDSON (Dual-Frequency Identification Sonar) evaluations may provide new insights into lamprey behavior and help identify sites and structural configurations needed to improve lamprey attraction, passage, or collection at dams. The scale of DIDSON imagery (<10 m) can potentially complement data collected using lampreys monitored with passive (i.e., PIT tags) and active (i.e., radio transmitters) telemetry systems. In summer 2011, we completed a DIDSON pilot study at Bonneville Dam to evaluate potential applications of this technology for evaluating lamprey behavior and passage.

Methods

Two DIDSON cameras were deployed from June 9 to September 2, 2011 among six locations at Bonneville Dam (Washington-shore junction pool, Cascades Island fishway entrance, Powerhouse 2 north upstream and downstream entrances, and Powerhouse 2 south upstream and downstream entrances). Data were collected in high frequency mode at each location for periods of 24 to 72 hours. DIDSON imaging was collected in landscape mode to obtain the horizontal distribution of lampreys in the water column and to assess the direction of lamprey movements. Images were also collected in portrait mode to identify lamprey depth distributions. Lamprey data collected from DIDSON image files included number of lamprey observed, range from camera (m) and angle from center for each passage event, and locations and durations of lamprey attachment to structures. We also summarized the presence / absence of white sturgeon, a lamprey predator.

Results/Management Action

We collected ~1400 hrs of DIDSON imagery at Bonneville Dam in 2011. Stratified random sampling of the DIDSON imagery is currently underway with multiple viewers and example imagery will be presented. Qualitative preliminary findings indicate that we can: (1) develop repeatable protocols for lamprey identification, (2) infer lamprey swimming direction, including entrance and exit behavior, (3) quantify differences in day- versus night-time activity, (4) identify lamprey depth distributions at the monitoring sites, and (5) enumerate sturgeon activity in the junction pool. This year's pilot study will provide information for future DIDSON deployments and data processing techniques and will help inform lamprey passage improvements.

Improving Adult Pacific Lamprey Passage at Bonneville Dam Using Lamprey Passage Structures and Refuge Boxes

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Background

Efforts to increase adult Pacific lamprey passage in 2011 included structural and operational changes to improve lamprey access to and passage through lamprey passage structures (LPSs) at Bonneville Dam. First, the picketed leads at both auxiliary water supply (AWS) channels were raised by at least 3.8 cm to allow more room for lamprey to pass under them and access LPSs located in the channels. This treatment was in place for a month at the beginning of the lamprey run (May 25 – June 29). Second, we tested whether lamprey would use refuge boxes installed along the bottom of the WA-shore AWS channel, thereby improving lamprey retention in this area. Finally, at the Cascades Island LPS, we conducted tests to determine whether reducing water volume through the lower part of this structure would improve collection efficiency and/or passage success.

Methods

Lamprey using each LPS were enumerated and collection efficiency was defined as the number of lamprey using a LPS divided by the expanded daytime count at the corresponding count window. We also implanted 929 lamprey with passive integrated transponders (PITs) and released them downstream from Bonneville Dam. These fish were used to assess overall route selection, passage timing, and use of refuge boxes.

Results/Management Action

Lamprey collection efficiency at each LPS was significantly higher during the time that pickets were raised (WA-shore LPS = 49.0%, Bradford Island LPS = 125.8%) than during the following month, when pickets were lowered to protect salmonids (WA-shore LPS = 20.8%, Bradford Island LPS = 40.2%). Twenty lamprey (approximately 18% of the 112 at the top of the WA-shore fishway) were detected in the refuge boxes. Most of these fish entered during the night. They resided in the refuge boxes for a mean of 9.1 h (range = 0 - 23 h). Lamprey use of Cascades Island LPS in 2011 was the highest of any previous year of operation (n = 485) and 7 PIT-tagged lamprey were detected at antennas integrated into this LPS. However, experiments to determine passage rates and passage success indicated that only 38% of PIT-tagged fish released into the structure successfully ascended to the trap at its terminus on their first attempt (mean passage time = 3.8 h, range = 1.4 – 6.2 h). Six fish (38%) fell back within the structure before eventually entering the trap (mean passage time = 15.3 h, range = 5.5 – 32.5 h), and four fish (25%) fell back and did not re-ascend. These data suggest that improvements to the exit area and rest boxes are needed to retain lamprey and improve passage success at this site.

Using the Juvenile Salmon Acoustic Telemetry (JSATS) System to Evaluate Adult Pacific Lamprey Movements and Fate in Columbia River Reservoirs

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Background

Declining numbers of adult Pacific lamprey in the Columbia River basin highlight the need for a greater understanding of their movement and behavior, particularly in reservoir and tailrace habitats because substantial number of adult lamprey have had final records in the Bonneville reservoir in past radiotelemetry studies. Acoustic telemetry is well suited for deep reservoir habitats, provides longer battery life and may reduce tag effects. In this study, we evaluated the effectiveness of the Juvenile Salmon Acoustic Telemetry System (JSATS) for monitoring the migration of JSATS-tagged adult Pacific lampreys through reservoir, tailrace, and tributary habitats. We also conducted a preliminary evaluation of JSATS tag detection efficiency in fishway environments at Bonneville Dam.

Methods

We tagged 85 adult lampreys with JSAT tags from 11 June through 3 September 2011 with tags rated for 60 days ($n = 20$) or 400 days ($n = 65$). Lampreys were released into Bonneville reservoir at Stevenson, WA (rkm 243; $n = 62$) or below Bonneville Dam (rkm 232.3; $n = 23$). We established gates using one or two autonomous receivers at nine locations from the Bonneville Dam tailrace to The Dalles Dam tailrace (rkm 305). One site was 300 m inside of the mouth of the Klickitat River (rkm 291). Adult lampreys were also monitored on cabled arrays used in juvenile salmonid JSATS studies. Detection efficiency of JSATS test tags was evaluated at seven locations within the Bonneville Dam Bradford Island Fishway.

Results/Management Action

The 23 adults released to the Bonneville Dam tailrace have been undetected ($n = 9$; 39%), or last detected in the Bonneville tailrace ($n = 8$; 35%), in the Bonneville reservoir ($n = 2$; 9%), or in the The Dalles tailrace ($n = 4$; 17%). Mean travel time from release to the first detection in The Dalles tailrace was 7.3 d (median 7.1, range 2.8-13.4 d). Mean migration rate from release to first detection in The Dalles tailrace was 15.2 km/d (median 10.6 km/d, range 5.4-32.3 km/d). All 62 fish released at Stevenson were detected on at least one receiver in the array and 58 (94%) were first detected on the Stevenson receivers. Twenty-two (35%) were last detected in The Dalles tailrace and 4 (6%) were last detected in the Klickitat River. The mean travel time from release to the first detection in The Dalles tailrace was 4.2 d (median 1.8 d, range 1.1-23.8 d). The mean migration rate from release to the first detection in the tailrace of The Dalles was 29.7 km/d (median 34.7 km/d, range 2.6-56.5 km/d).

In the Bradford Island fishway, we detected the test transmitters at all seven locations tested, though detection range was limited in some locations. Additional testing will determine the range of application for JSATS in fishway environments.

Continued monitoring of the 400-day tags through winter and spring 2011-2012 will provide important information on the final distribution of adult lamprey and help determine to what degree adult lamprey overwinter in reservoirs prior to spawning in reservoir tributaries.

Adult Lamprey Data Mining: Using Models to Prioritize Sites for Fishway Passage Improvements and to Predict Lamprey Run Timing and Size

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Background

Over the last 14 years, Pacific lamprey research and enumeration efforts in the Columbia River basin have produced several substantial databases on adult lamprey behavior, dam passage efficiency, migration timing, and upriver escapement. We are currently using the research datasets to test hypotheses about lamprey migration in the FCRPS and to evaluate potential effects of improving lamprey passage performance at dams. Similarly, we are using the enumeration datasets to generate in-season predictions of the timing and size of adult lamprey runs at the FCRPS dams.

Methods

This presentation will provide results from two adult lamprey modeling exercises. First, we developed a series of lamprey escapement and distribution models that were parameterized using historic data from radio- and HDX-PIT tagged fish. These simulation models rely on random sampling from existing data distributions and are constrained by user-selected criteria regarding lamprey passage improvements at dams and/or lamprey migration speeds. We used the models to assess: (1) how increased passage efficiency at an FCRPS dam will affect lamprey escapement to upriver sites, and (2) the relative upriver escapement benefits of passage improvements at single versus combinations of dams. The second group of models is designed to improve in-season predictions of adult run timing and size. We build upon the previous temperature-based model at Bonneville Dam by including count data from recent years (including the unusually cold 2011 run) plus day-of-year (date) and date plus temperature effects.

Results/Management Action

The escapement simulation models provide several insights into how to best prioritize lamprey passage improvements among dams. Because more lampreys encounter Bonneville Dam than any other dam, increased passage efficiency at Bonneville generally results in larger positive effects on upstream escapement than improvements at other dams. For example, a 10% increase in passage efficiency at Bonneville increased predicted escapement to upriver sites by 15-60% over baseline values, whereas a 10% efficiency increase at The Dalles Dam had relatively modest effects at upstream sites and had no effects at downstream sites. Simulation models that reduced lamprey passage times at individual dams had much smaller positive effects on escapement than models that increased dam passage efficiency. However, results also suggest that slow lamprey passage at dams may significantly constrain upstream migration distances for adult migrants when considered independently from dam passage efficiency.

The revised in-season run timing / run size models improve upon the temperature-based model used in recent years. In test applications using data from previous years, the new models had greater precision and narrower confidence intervals than the temperature-only model. Examples from Bonneville Dam and from upriver dams will be presented.

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Avian Predation on the Columbia Plateau: A Synthesis of Research Results

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Background

Caspian terns, double-crested cormorants, American white pelicans, California gulls, and ring-billed gulls are native piscivorous colonial waterbirds that nest in the Columbia Plateau region. As part of a comprehensive study, we evaluated the impact of these predators on the survival of juvenile salmonids during 2004-2011. Data from 2011 are still being analyzed and will be presented, where available.

Results

Numbers of Caspian terns nesting in the region remained stable at between 800 and 1,000 breeding pairs at five colonies; the two largest colonies were on Crescent Island in the Columbia River and on Goose Island in Potholes Reservoir, WA. Numbers of nesting double-crested cormorants decreased slightly, from about 1,500 breeding pairs to about 1,200 breeding pairs at four separate colonies; the largest breeding colonies were at Potholes Reservoir and on Foundation Island in the Columbia River. Numbers of American white pelicans counted at the lone colony on Badger Island in the Columbia River increased during the study, from about 1,000 adults to 2,000 adults. Numbers of gulls, the most numerous colonial waterbirds in the region, declined during the study but >65,000 adults still nested at 20 different colonies. During the study new bird colonies emerged and disappeared and inter-colony movements were documented, indicating that populations of colonial waterbirds in the study area were dynamic and changing.

We used bioenergetics methods to estimate prey consumption by Caspian terns nesting on Crescent Island and double-crested cormorants nesting on Foundation Island. Taken together, the Crescent Island tern colony and Foundation Island cormorant colony consumed ca. 1 million juvenile salmonids annually. Estimated annual consumption by Foundation Island cormorants ranged from 470,000 to 880,000 smolts, while that of Crescent Island terns ranged from 330,000 to 500,000 smolts. Relative to salmonids, consumption of Pacific lamprey was minor, with fewer than 10,000 macrophthalmia consumed annually by both colonies combined. We used recoveries of passive integrated transponder (PIT) tags on bird colonies to estimate predation rates on specific salmonid stocks. Minimum predation rates by Crescent Island terns on in-river migrating Snake River steelhead (ca. 8%) and by Goose Island terns on upper Columbia River steelhead (ca. 10%) were substantial. Minimum predation rates by Foundation Island cormorants on Snake River steelhead (ca. 2%) and Snake River sockeye (ca. 2%) were not as high. Minimum predation rates by gulls and pelicans were generally minor (< 1% of available smolts) compared to those of tern and cormorant colonies. Results demonstrated that avian predation on smolts was condition- and size-dependent, varied temporally, and was influenced by river conditions and rearing environment (hatchery vs. wild).

Predation rates on PIT-tagged smolts that were adjusted for colony size (consumption per bird) were substantially higher for terns and cormorants nesting at colonies in the Columbia Plateau region compared to those in the estuary. Thus, while inland colonies of terns and cormorants are much smaller than their estuary counterparts, inland colonies can be more reliant on salmonids as a food source. This greater reliance, coupled with lower diversity and numbers of available salmonid stocks compared to the estuary, is responsible for the unexpectedly high impact of some inland tern and cormorant colonies on specific salmonid populations, particularly steelhead stocks. Based on the results of this study, a management plan for inland bird colonies is currently being developed for regional consideration.

Benefits to Columbia River Anadromous Salmonids from Potential Reductions in Avian Predation on the Columbia Plateau

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Background

Predation on juvenile salmonids during out-migration is considered potentially limiting to the recovery of anadromous salmonid populations from the Columbia River basin that are listed under the ESA. We examined the potential benefits of reducing avian predation associated with five colonies of piscivorous waterbirds in the Columbia Plateau region for three evolutionarily significant units (ESUs) of Chinook salmon, one of sockeye salmon, and two distinct population segments (DPSs) of steelhead trout from the Upper Columbia River and Snake River basins.

Methods

Using predation rate data based on recoveries of smolt passive integrated transponder (PIT) tags at bird colonies and the framework of a simple deterministic, age-structured, matrix population growth model, we translated potential changes in smolt survival due to reductions in avian predation into increases in the average annual population growth rate (λ) at the ESU/DPS level. Estimates were produced for a range of reductions in avian predation and for a range of levels of compensatory mortality.

Results

The greatest potential benefit from reductions in predation by birds from a single colony in the Columbia Plateau region was for Upper Columbia River steelhead when predation by Caspian terns nesting on Goose Island (Potholes Reservoir near Othello, WA) was reduced; up to a 4.2% (hatchery-raised smolts) or 3.2% (wild smolts) increase in λ was possible if predation were completely eliminated and compensatory mortality did not occur. Potential benefits for Snake River ESUs were lower, in part because significant portions of those ESUs are transported and thus inaccessible to avian predators in the Columbia Plateau region. The greatest potential benefit possible for a Snake River salmonid ESU/DPS resulting from reductions in avian predation was for steelhead if predation by Caspian terns nesting on Crescent Island (near Pasco, WA) was eliminated and for sockeye if predation by double-crested cormorants nesting on Foundation Island (near Pasco, WA) was eliminated (ca. 0.5% increase in λ for each case, assuming no compensatory mortality).

Management to reduce predation on salmonids by Caspian terns nesting at the Goose Island colony would offer the greatest benefits per managed bird. Management to reduce predation by Caspian terns from two other colonies in the Columbia Plateau region (Crescent Island and Blalock Islands) would provide the next largest incremental benefit. Adding reductions in predation by Foundation Island cormorants and gulls (*Larus* spp.) nesting on Miller Rocks (near Maryhill, WA) to reductions in Caspian tern predation would also enhance benefits to salmonids, but at a lower marginal benefit rate per managed bird. Cumulative potential benefits for eliminating predation by birds nesting at all five colonies in the Columbia Plateau region considered here were generally comparable to estimates of benefits from dispersing approximately two-thirds of the large Caspian tern colony in the Columbia River estuary; benefits were greater, however, for Upper Columbia River steelhead from eliminating predation by birds nesting at the five Columbia Plateau colonies.

Our analysis indicates that, at current bird colony sizes, actions to reduce avian predation on juvenile salmonids in the Columbia Plateau region will not by themselves recover any ESA-listed population of anadromous salmonids. Reductions in avian predation in this region could, however, result in increases in salmonid population growth rates comparable to some other salmonid recovery efforts in the Columbia Basin, particularly for Upper Columbia River and Snake River steelhead populations.

Avian Predation in the Columbia River Estuary and Monitoring Implementation of the Caspian Tern Management Plan

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Background

We continued field studies in 2011 to (1) assess the impact of avian predation on survival of juvenile salmonids in the Columbia River estuary, (2) monitor the efficacy of on-going Caspian tern management designed to reduce their impact on smolt survival in the estuary, and (3) test management strategies to limit nesting habitat availability for double-crested cormorants on East Sand Island.

Results/Management Action

The Caspian tern colony on East Sand Island, the largest in the world, consisted of about 7,000 breeding pairs in 2011, a substantial decline from 2010 (ca. 8,300 breeding pairs). The Caspian tern colony on East Sand Island did not produce a single fledgling this year, the first time complete breeding failure has been recorded at this colony. The proximal factor responsible for colony failure and the decline in colony size was intense disturbance by bald eagles and associated gull predation on tern eggs and chicks. La Niña climate conditions and exceptionally high river flows also negatively influenced nesting success. The average proportion of juvenile salmonids in tern diets during the 2011 nesting season was 36%, similar to 2009-2010.

Caspian tern management actions continued in 2011, with the USACE further reducing the area of suitable tern nesting habitat on East Sand Island to 2.0 acres, 40% of its former area. This habitat restriction caused Caspian terns to nest at higher densities (0.85 nests/m²) than previously seen in the Columbia River estuary. The Portland District has built a total of eight new islands as alternative tern nesting sites since early 2008, five in interior Oregon and three in the Upper Klamath region of northeastern California. Four of these eight new islands supported nesting Caspian terns in 2011, including the new 2-acre rock-core island at Tule Lake National Wildlife Refuge, where 34 pairs nested. Adverse weather conditions, apparent low forage fish availability, and avian nest predators limited Caspian tern nesting and fledgling production at these alternative islands in 2011; however, a substantial number of terns from the Columbia River estuary are visiting these sites as 92 terns originally banded in the Columbia River estuary were seen at the Upper Klamath islands this past season.

The large double-crested cormorant colony on East Sand Island consisted of about 13,000 breeding pairs in 2011, similar to 2010 (ca. 13,600 breeding pairs). Juvenile salmonids represented about 20% of the double-crested cormorant diet in 2011, compared to ca. 17% in 2010. Although an estimate of smolt consumption by the double-crested cormorant colony in 2011 is not yet available, estimated consumption is likely to be similar to that in 2010, when about 19 million smolts were consumed by cormorants nesting at this colony. In 2011, we initiated a pilot study to test strategies for limiting the size of the East Sand Island cormorant colony. An eight-foot-high privacy fence was built to bisect the colony and visually separate 15% of the 2010 nesting area from the remainder of the colony. Using human disturbance to haze cormorants during the nest initiation period, cormorants were successfully dissuaded from using this 15% of their former nesting area. Cormorants on the other side of the fence nested normally, unaffected by the hazing activities. No detrimental effects of hazing activities were observed on non-target bird species that also use this portion of the island.

Electronic Recovery of Passive Integrated Transponder (PIT) Tags on Avian Breeding Colonies in the Columbia River Basin, 2011

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Background

During 2011 biologists with NOAA Fisheries and Pacific States Marine Fisheries Commission collaborated with researchers from Oregon State University and Real Time Research to quantify the effects of predation on PIT-tagged salmonids by piscivorous waterbirds throughout the Columbia River basin. We sampled recently vacated nesting and loafing sites utilized by Caspian terns (*Hydroprogne caspia*), cormorants (*Phalacrocorax spp.*), gulls (*Larus spp.*), and pelicans (*Pelecanus spp.*) at colonies in the Columbia River estuary, near the Snake River confluence, on the Columbia Plateau, and other locations.

Methods

PIT tags were physically recovered using magnets or electronically recovered using handheld or flat-plate antennas. We evaluated the vulnerability of fish by species, run, rear type, origin, and inriver or transport migration history by calculating weighted seasonal predation rates of fish previously detected at or released from dams located further upstream of avian colonies. We PIT-tagged and released approximately 3,000 subyearling fall Chinook salmon from four hatcheries downstream of Bonneville Dam: Big Creek Hatchery, Deep River net pens, North Toutle Hatchery, and Warrenton Hatchery to document vulnerabilities of fish released into the lower Columbia River. We estimated PIT tag detection efficiency by sowing PIT tags on avian colonies at intervals throughout the breeding season. All predation rates were adjusted for detection efficiency measurements specific to each avian colony by dividing the proportion recovered on each avian colony after the end of the breeding season.

Results/Management Action

We detected a total of 64,210 PIT-tagged juvenile salmonids migrating through the Columbia River basin during 2011 on bird colonies. We recovered 38% of PIT tag codes from avian nesting and loafing sites in Lake Celilo, Lake Wallula, Potholes Reservoir, and other upriver locations. We recovered 62% of PIT tag codes from avian nesting and loafing sites in the Columbia River estuary (i.e., East Sand Island, Miller Sands Island). Colony-specific detection efficiency measurements ranged from 40-84%.

Weighted seasonal predation rates by birds nesting on East Sand Island of fish detected passing either Bonneville Dam or instream pair-trawl detection facilities were 3.2% for spring/summer Chinook salmon, 2.3% for fall Chinook salmon, and 10.7% for steelhead. In comparison, seasonal predation rates of fish released from transport barges at Skamania Landing were 2.5% for spring/summer Chinook salmon, 2.3% for fall Chinook salmon, and 8.5 for steelhead. We did not detect significant differences in seasonal predation rates between transported or inriver conspecifics migrating through the lower Columbia River during the same period ($P > 0.05$).

A concern during recent years was the proportions of PIT-tagged subyearling fall Chinook salmon released downstream of Bonneville Dam and consumed by avian predators, which have exceeded 30% during some years. We estimated that an average of 24% of subyearling fall Chinook salmon released from lower Columbia River hatcheries were consumed by double-crested cormorants and Caspian terns nesting on East Sand Island. Predation of hatchery subyearling Chinook salmon by avian species nesting on East Sand Island continues to be one of the highest predation rates measured anywhere in the Columbia River basin.

Avian Predation at John Day and The Dalles Dams 2011: Estimated Fish Consumption Using Direct Observation

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Background

Avian predators continue to be a highly visible source of smolt mortality below hydropower dams. If severe, this mortality may impede FCRPS dams from meeting BiOp required survival goals for ESA listed salmonids. In 2011 the Fish Field Unit was tasked with determining the impact of avian predators on fish passing John Day and The Dalles dams. Our objectives were: 1) Determine species composition and numbers of piscivorous birds; 2) Estimate fish consumption and attack location of gulls; 3) Determine the effectiveness of intense boat hazing and avian deterrent line arrays at John Day and The Dalles dams.

Methods

To quantify avian consumption of fish, observers used binoculars to count gulls (*Larus californicus*), the number of attacks (i.e. dives), and to determine if an attack was successful (e.g. fish in bill) during the smolt outmigration between 10 April to 28 July 2010.

Gull collection for diet analysis was not permitted this year. Rather than reporting smolt consumption we report fish consumption estimates which include smolt, juvenile lamprey, and other fish. Additionally, counts of other fish eating birds were collected.

Results/Management Action

The daily abundance of gulls at John Day Dam ranged from zero on 15 April & 28 July to a high of 30 on 29 April with a seasonal mean of 5.7 gulls. At The Dalles Dam the daily abundance ranged from zero on 28 July to a high of 63 on 23 May with a seasonal mean of 14.7 gulls.

At John Day Dam preliminary estimates of fish consumption, which includes additive and compensatory sources of mortality, were 6,000 (95% CI 4,000 – 8,000). This is a reduction of 32,000 (84%) from 2010 when an estimated 38,000 fish were consumed. Gulls attacks were spatially uneven. We produced geospatial maps that show hot spots immediately downstream of the avian lines, primarily on the spillway side of the river.

At The Dalles Dam preliminary estimates of fish consumption, which includes additive and compensatory sources of mortality, were 16,000 (95% CI 13,000-20,000). This is a reduction of 70,000 (81%) from 2010 when an estimated 86,000 fish were consumed. Here also, gulls attacks were heterogeneous, focused immediately downstream of the avian lines, primarily on the spillway side of the river.

Hazing from boats and avian line arrays were as successful in protecting covered areas in 2011 and 2010. Because the deterrent effort was similar in both years we attribute the decreases in fish consumption to natural variation in the number of foraging gulls, not level of deterrent effort. Regardless, the management objective of reducing predation was achieved in both years.

Juvenile Steelhead Survival and Predator-Prey Interactions Using JSATS through the Priest Rapids Reservoir in 2011

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Background

Public Utility District No. 2 of Grant County, Washington (Grant PUD) owns and operates two hydropower projects on the mid-Columbia River; Wanapum and Priest Rapids dams. Both developments (dam and reservoir) strive to meet a performance standard of 93% survival for downstream migrant juvenile steelhead. Steelhead survival estimation has been completed annually at both developments since 2006 but performance standards have only been met at the Wanapum Development in 2008 and 2009. Survival standards for steelhead have not been achieved at the Priest Rapids Development. While survival through Priest Rapids Dam has been high, we believe steelhead losses have primarily occurred in the Priest Rapids Reservoir due to piscivorous fish and bird activity. This study was designed to measure the survival of downstream migrant juvenile steelhead and to determine where losses from predators occur in the reservoir.

Methods

A total of 53 JSATS receivers were deployed in cross-river arrays at one-mile increments between Wanapum and Priest Rapids dams. Receivers were also deployed in the forebay of each dam and downstream of Priest Rapids Dam. Nearly two hundred predatory fish (northern pikeminnow, walleye, and smallmouth bass) were captured, tagged, and released in April 2011. Acoustic tags were implanted into 1,032 juvenile steelhead smolts randomly selected from run-of-the-river fish; smolts were released upstream of Wanapum Dam in 18 unique release groups, one release per day, starting on May 8, 2011. Test fish were estimated to be 78% hatchery-reared and 22% wild. Array detection efficiencies were highly variable (range 13-97%), depending on the number of receivers per array and the hydraulic conditions at each array.

Results/Management Action

The 2011 steelhead survival through the Priest Rapids Development was estimated at 97%, which is 7% higher than the highest survival rate in the last five years. For the first time, Grant PUD has met the performance standard of 93% Development survival. High river flows likely contributed to high survival rates as river flows were twice the 10-year average (300 kcfs in 2011, 150 kcfs 10-year average). High flows contributed to faster steelhead travel time through the Reservoir (40% faster in 2011 than the 2006-2010 average) that likely limited the exposure time of smolts to piscivorous predators. Additionally, steelhead losses that did occur (3%) were in loosely defined hot-spots that overlapped with the movement of tagged northern pikeminnow. These hot-spots included the tailrace of Wanapum Dam, the entrance to Crab Creek, and the reservoir immediately upstream of the Priest Rapids Dam forebay. Additional losses from avian predation were confirmed by the recovery of acoustic tags at bird colonies. Though this study was designed to identify zones of migratory steelhead loss between Wanapum and Priest Rapids dams, the measured losses were fewer than expected. We were able to directly measure predation events by northern pikeminnow on migrating smolts, and identify in-river hot-spots of predation.

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Seasonal Use of Shallow Water Habitat in the Lower Snake River Reservoirs by Juvenile Fall Chinook Salmon

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Background

The U.S. Army Corps of Engineers is preparing a long-term management plan for sediments that affect the authorized project purposes of the lower Snake River reservoirs. We conducted a study to describe juvenile fall Chinook salmon use of a selected group of shallow water habitat complexes in the lower Snake River reservoirs from spring 2010 through winter 2011. These complexes had been dredged in the past, had received dredge disposal material, or were candidates for future disposal.

Methods

We beach and lampara seined 12 stations within each habitat complex weekly from April through July to describe use by various groups of juvenile fall Chinook salmon during spring and early summer rearing. We sampled again (bi-weekly) from September through early November to describe habitat use by reservoir-type juveniles. We also used radiotelemetry to describe use of shallow-water and pelagic habitats by reservoir-type juveniles throughout the fall and winter. The seasonal timing and abundance of reservoir-type juveniles in Lower Granite and Little Goose reservoirs was estimated from monthly hydroacoustic surveys.

Results/Management Action

Natural fry and parr were present within all four shallow water habitat complexes from early spring through early summer, and parr ($N = 40,345 \pm 18,800$) were more abundant than fry ($N = 24,615 \pm 5,701$). Water < 2 m deep was highly used for rearing by natural fall Chinook salmon subyearlings (fry and parr combined; hereafter, natural subyearlings) based on duration of use and relative group abundances during spring and summer, whereas the 2–6-m depth interval was more highly used by migratory hatchery fall Chinook salmon subyearlings and spring, summer, and fall Chinook salmon yearlings. Overall mean spring-summer apparent density of natural subyearlings was 15.5 times higher within the < 2-m depth interval than within the 2–6-m depth interval. Density of natural subyearlings also decreased in shallow water habitat complexes the farther downstream they were located from the riverine spawning areas. Reservoir-type juveniles (or fish likely to become reservoir-type juveniles) were present in the lower Snake River reservoirs from fall 2010 through winter 2011. Monthly abundance of reservoir-type juvenile fall Chinook salmon in Lower Granite Reservoir peaked in October 2010 ($N = 27,290$) and decreased over time, whereas monthly abundance of reservoir-type juveniles in Little Goose Reservoir increased over time to a peak ($N = 30,045$) in March 2011. Use of shallow water habitat by reservoir-type juveniles was limited during our study. We only collected 38 reservoir-type juveniles in shallow water habitat sites in beach and lampara seines during the fall. Radiotelemetry data revealed that though many tagged fish passed shallow water habitat sites, relatively few fish entered them and the median time fish spent within a given site was less than 1.4 h. Fish located away from study sites by mobile tracking were pelagically oriented, and generally not found over shallow water or close to shore. These findings will provide guidance for future sediment management actions.

Habitat Quality and Fish Species Composition/Abundance at Selected Shallow Water Locations in the Lower Snake River Reservoirs

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Background

The Walla Walla District Corps of Engineers (Corps) has begun development of a Programmatic Sediment Management Plan (PSMP) to manage dredged material in all four reservoirs on the lower Snake River. The primary goal of this study is to characterize existing high-suitability habitats for rearing salmonids so that dredged material can eventually be used to create similar habitat features.

Methods

Twenty-four locations throughout the lower Snake River were studied from November, 2010 through September, 2011, to assess habitat quality and biological integrity with an emphasis on seasonal variability. Fish species composition and abundance were determined using beach seines, electrofishing, and snorkeling with an emphasis on natural fall Chinook subyearling habitat as an indicator of existing high quality habitat. In order to establish the presence or absence of larval Pacific lamprey in deepwater habitat (>1 m), a submersible electroshocking sled coupled to an optical camera was developed. Trophic level considerations were made by collecting phytoplankton, periphyton, zooplankton, and macroinvertebrates on a seasonal basis. Water quality was evaluated using temperature, dissolved oxygen (DO), pH, and specific conductance. Sediment samples were collected to determine grainsize distribution and organic content.

Results/Management Action

Fish sampling yielded 12,834 fish from 28 different species. There were 2,649 Chinook salmon, including 642 natural fall Chinook subyearlings—primarily found in the region surrounding Lower Granite Dam. Predators were primarily northern pikeminnow (n=97) and smallmouth bass (n=264). Of these, 50% were found within the same region as Chinook salmon. Other predators were located within Ice Harbor and Lower Monumental Reservoirs. One bull trout (293mm) was sampled in April at the mouth of the Tucannon River. No larval lampreys were detected during field sampling (July–September, 2011). Macroinvertebrate family diversity was highest at sites within Lower Granite Reservoir. Relative abundances of orders that are important food sources for juvenile salmonids (Diptera, Tricoptera, Amphipoda, and Plecoptera) generally ranged from 60–90% throughout the lower Snake River. Zooplankton densities peaked in Lower Granite Reservoir during spring and were lowest during summer. Water quality was generally favorable, although summer temperatures frequently exceeded 20°C, approaching 24°C in Lower Granite Reservoir, and DO was often supersaturated within Ice Harbor Reservoir. Sediment grainsize distribution showed that locations dominated by silt were within embayments, areas where tributaries entered reservoirs, or locations within Ice Harbor Reservoir. Generally, Chinook salmon were found at locations dominated by medium to very coarse sand or gravel. The organic content of substrates was slightly higher at locations where Chinook salmon were found (3.2% versus 2.6%). Principal component analysis will be used to group sites by similar type and rank overall habitat quality of each location studied.

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Use of the Mainstem Columbia River by Walla Walla Basin Bull Trout

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Background

A significant gap in our knowledge of migratory bull trout *Salvelinus confluentus* life history is associated with their use of the mainstem Columbia and/or Snake rivers. Very little data is available regarding movements within the mainstem, the use of mainstem habitats, or bull trout presence and/or passage at the mainstem dams. To better understand bull trout mainstem use, we continued an acoustic telemetry study to monitor migratory bull trout movements, habitat use, and presence/passage at Columbia and/or Snake river mainstem dams.

Methods

During FY2011, we conducted our sampling effort for bull trout during the October through February time period when most of the emigration from the Walla Walla Basin occurs. During this time, 29 PIT-tagged bull trout were detected at the Oasis Road Bridge PIT array moving towards the Columbia River. We used rotary screw traps at two locations in the lower Walla Walla River, and a fyke net at one location near the mouth to capture migratory bull trout for acoustic tagging. Two remote hydrophones were deployed near the mouth of the river to monitor movement of tagged fish into the Columbia River, and mobile tracking was the primary method used to monitor movements and habitat use within the mainstem.

Results/Management Action

Twelve bull trout were captured in the rotary screw traps between November 2010 and February 2011, and subsequently tagged with both an acoustic transmitter and a PIT tag. Seven of the tagged bull trout were detected entering the Columbia River from November through February. Two of these fish were located during mobile tracking surveys between the mouth of the Walla Walla River and McNary Dam. Both fish utilized mainstem habitats that exceeded 40 feet deep. Four of the seven bull trout that entered the Columbia River were subsequently detected returning to the Walla Walla River from March through June. No acoustic tagged or PIT tagged bull trout from the Walla Walla Basin were detected at or near mainstem dams during the year. Weather and river conditions limited our ability to conduct mobile tracking surveys to determine the extent of movements and distribution within the Columbia, and to collect more detailed habitat use data. During the upcoming year, we plan to expand our sampling effort to deploy more acoustic transmitters into emigrating bull trout. We also plan to deploy a network of stationary hydrophones to better define the spatial and temporal aspects of mainstem movements and distribution. We intend to continue PIT tagging bull trout in mid-basin areas to maintain a tagged population of bull trout for detection at the Oasis Road Bridge PIT detection array and at mainstem dams.

Monitoring Sub-adult and Adult Bull Trout Passage Through Lower Granite, Little Goose and Lower Monumental Bypass Facilities

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Background

The incidental collection of bull trout (*Salvelinus confluentus*) at juvenile bypass facilities; the observation of bull trout within adult fish ladders (Batelle 2004); and radio telemetry and PIT tag research (Faler et al. 2003,2004, 2005, 2006, 2007; Bretz 2008, 2009) has shown that bull trout utilize the mainstem Snake River as overwintering habitat and as a migratory corridor. The loss of migratory corridors through habitat fragmentation associated with hydropower facilities has been identified as a threat to the diversity, stability and persistence of bull trout populations (Rieman and McIntyre 1993). The extent to which Federal Columbia River Power System (FCRPS) operations alter the migratory patterns of bull trout or impede passage is unknown.

Radio telemetry and PIT tag research conducted by Faler et al. (2003, 2004, 2005, 2006, 2007) and Bretz (2008,2009) has documented the use of the mainstem Snake River by bull trout originating from the Tucannon River; however, none of the bull trout tagged as part of these studies were subsequently observed at Lower Snake River dams. The inability to confirm the use of Lower Snake River dam facilities by bull trout originating from the Tucannon River suggests that (1) the bull trout utilizing fish facilities are migrating from tributaries other than the Tucannon River, and/or (2) the methods used by Faler and Bretz were inadequate for identifying the origin of bull trout found within the Lower Snake River dams fish facilities.

The advent of conservation genetic techniques has greatly advanced the ability of researchers to identify distinct bull trout populations with increasing resolution. This study used genetic assignment to identify bull trout populations that are utilizing the FCRPS facilities.

Methods

All bull trout collected within the separator and/or subsample were measured, weighed, PIT-tagged and a tissue sample was collected. Tissue samples were sent to the Abernathy Fish Technology Center for genotyping and genetic assignment. Genotyping was performed by DNA extraction, PCR amplification, electrophoresis and electrophoretic analysis using GeneMapper v4.0. The statistical software programs WHICHRUN and ONCOR were used to assign bull trout of unknown origin to the most likely baseline population.

Results/Management Action

Results of the WHICHRUN analysis assigned 11 of 12 fish to the Tucannon River as their first most likely population. Confidence values for these population assignments ranged from 10.49 to 4,000,000. The individual that did not assign to the Tucannon River was assigned to the NF Imnaha River with a likelihood ratio of 218.5. The program ONCOR provided identical population assignments for the 12 unknown origin fish; the same 11 fish were assigned to the Tucannon River and the one remaining fish was assigned to the NF Imnaha River. The probability of all population assignments made using ONCOR was 1.0. Although previous tagging studies did not document Tucannon River bull trout using fish collection facilities at the lower Snake River Dams (Faler et al. 2003, 2004, 2005, 2006, 2007; Bretz 2008, 2009), genetic assignment results indicate that Tucannon River bull trout are using the collection facilities.

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Development of External and Neutrally Buoyant Acoustic Transmitters for Juvenile Salmon Turbine Passage Evaluation

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Background

Fish can sustain injury or mortality when they pass through hydroelectric facilities.

Methods

To develop a method to monitor the passage and survival of juvenile salmonids without bias through turbines within the Federal Columbia River Power System, we developed and fabricated two designs of neutrally buoyant transmitters: Type A (sutured to the dorsal musculature of the fish anterior to the dorsal fin) and Type B (two-part design attached with wire pushed through the dorsal musculature, ventral to the dorsal fin). To determine the efficacy of the two designs under non-turbine passage-related conditions, fish had one of the tags attached and were held for 14 days to determine any potential effects of the tags on growth, survival and tissue damage. We also evaluated the attachment method by monitoring tag retention. These two neutrally buoyant tag designs were compared to nontagged individuals and those surgically implanted with current Juvenile Salmon Acoustic Telemetry System (JSATS) transmitters and passive integrated responder (PIR) tags. In addition, two suture materials (Monocryl and Vicryl Rapide) were tested for attachment of Type A tags.

Results/Management Action

When compared with non-tagged individuals, fish tagged with Type A tags did not differ significantly with respect to growth or mortality over a 14-d holding period. However, fish tagged with Type B transmitters had lower growth rates than the nontagged controls or other tag treatments. The efficacy of two designs was also compared to nontagged individuals under shear exposure. Fish were exposed to a submerged, 6.35-cm-diameter water jet at velocities ranging from 3.0 to 12.2 m/s in a water flume to simulate turbine conditions within the Columbia River basin. Throughout the shear exposure study, no mortalities or tag loss were observed. There was also no significant difference in the rates of shear injury between untagged fish and fish tagged with Type A or Type B tags. When tissue damage was assessed for tagged individuals exposed to shear forces, those tagged with Type A tags showed lower rates and severity of injury when compared to Type B-tagged fish. Overall, Type A tags may be a viable tag design for juvenile Chinook salmon passing through hydropower facilities.

The Effects of Neutrally Buoyant Externally Attached Transmitters on Predator Avoidance and Swimming Performance of Juvenile Chinook Salmon

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Background

Previous research found that rates of mortality and injury increased with increasing tag burden in juvenile Chinook salmon that were surgically implanted with acoustic transmitters (tag burden range 0.0% to 6.6%) and subjected to rapid decompression similar to pressures experienced by fish during passage through turbines in the Federal Columbia River Power System (FCRPS). This research suggested that the additional mass of the transmitter and/or the volume of the transmitter inside the body cavity increased the likelihood of mortal injury during rapid decompression, thus creating a tagging bias that likely leads to inaccuracies in survival studies of fish passing through turbines. These results led to this investigation of whether a neutrally buoyant externally attached transmitter could provide more accurate estimates of survival during turbine passage. In order to use tagged fish as a representative of the entire population, the assumption is made that the fish's behavior, movement, and survival are unaffected by the presence of the transmitter or the tagging process. The presence of an externally attached telemetry tag is often associated with the potential for impaired swimming performance (i.e., snags and drag) as well as increased susceptibility to predation, specifically for smaller fish such as juvenile salmon.

Methods

The effects of a neutrally buoyant externally attached acoustic transmitter on the swimming performance of juvenile Chinook salmon were examined by comparing critical swimming speeds (U_{crit}) for fish tagged with two different neutrally buoyant external transmitters (Type A and B), nontagged individuals, and those surgically implanted with the current Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic transmitter. Further testing was then conducted to determine if predator avoidance ability was affected due to the presence of Type A tags when compared to nontagged fish.

Results

Fish tagged with the Type A and B designs had lower U_{crit} when compared to nontagged individuals. However, there was no difference in U_{crit} among fish tagged with Type A or B designs compared to those with surgically implanted tags. No difference was detected in the number of tagged and nontagged fish consumed by rainbow trout throughout the predation trials. The results of this study support further testing of the efficacy of a neutrally buoyant externally attached telemetry tag for survival studies involving juvenile salmonids passing through hydroturbines.

Eliminating Bias in the Study of Barotrauma Associated with Passage through Hydroturbines Using a Novel Transmitter Design

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Background

The investigation described in this presentation shows the effects of an externally attached neutrally buoyant tag design on mortal injury rates for fish exposed to rapid decompression associated with turbine passage. Based on the results of previous studies it was determined that external attached neutrally buoyant tag design should be the focus of further studies.

Methods

Tagged and nontagged individuals acclimated to a pressure of 21.2 psia (15-ft water depth equivalent) were exposed to nadir pressures of 1.6 to 11.6 psia in the Mobile Aquatic Barotrauma Laboratory hypo/hyperbaric chambers. Rates of mortal injury were then assessed for all individuals.

Results/Management Action

The rates of mortal injury were not significantly different for tagged and nontagged juvenile Chinook salmon, indicating that juvenile Chinook salmon tagged with the externally attached neutrally buoyant tags are not at a greater risk for mortal injury than nontagged conspecifics. This contrasts with previous research that has shown the negatively buoyant surgically implanted tags or injected PIT tags increase the rates of mortal injury for juvenile Chinook salmon experiencing rapid decompression. Our results further support the efficacy of this novel tag design for use in turbine passage survival studies in the Columbia River basin.

Pathways of Barotrauma in Juvenile Salmonids Exposed to Simulated Hydroturbine Passage: Boyle's Law vs. Henry's Law

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Background

On their seaward migration, juvenile salmonids commonly pass hydroelectric dams. Fish passing by the turbine blade may experience rapid decompression, the severity of which can be highly variable and may result in a number of barotraumas. The mechanisms of these injuries can be due to expansion of existing bubbles or gases coming out of solution; governed by Boyle's Law and Henry's Law, respectively.

Methods

This presentation combines re-analysis of published data with new experiments to gain a better understanding of the mechanisms of injury and mortality for fish experiencing rapid decompression associated with hydroturbine passage.

Results/Management Action

From these data it appears that the majority of decompression related injuries are due to the expansion of existing bubbles in the fish, particularly the expansion and rupture of the swim bladder. This information is particularly useful for fisheries managers and turbine manufacturers, demonstrating that reducing the rate of swim bladder ruptures by reducing the frequency of occurrence and severity of rapid decompression during hydroturbine passage could reduce the rates of injury and mortality for hydroturbine passed juvenile salmonids.

The Effect of Rapid and Prolonged Decompression on Juvenile Brook Lamprey and Pacific Lamprey

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Background

Fish passing downstream through hydroelectric facilities may pass through hydroturbines where they experience a rapid decrease in pressure as they pass by the turbine blade which can lead to barotraumas including ruptured swim bladders, exophthalmia and emboli and hemorrhaging in the fins and tissues. The main mechanism for these injuries in juvenile Chinook salmon has been identified as the expansion of existing gases, particularly those present in the swim bladder. Another mechanism for barotrauma can be gases coming out of solution and the rate of this occurrence may vary among species. The inflation and rupture of the swim bladder has been shown to influence the rate and severity of other barotraumas. For fishes lacking a swim bladder, such as lamprey, the rate and severity of barotraumas occurring due to rapid decompression is likely to be decreased, however, this has yet to be extensively studied.

Methods

The objective of this study was to investigate the influence of exposures to low pressures (i.e., rapid decompression associated with hydroturbine passage and exposure to low pressures for long periods of time) for juvenile lamprey and compare the associated barotrauma to the previously published responses of juvenile Chinook salmon.

Results/Management Action

The results of this study suggest that differences in morphology and physiology (i.e., lack of swim bladder) of juvenile lamprey reduce their susceptibility for barotraumas due to hydroturbine passage. This information bridges a gap in knowledge of how hydropower facilities influence the downstream migration of juvenile lamprey.

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Lower Columbia River Survival Study, 2011: Methods

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Background

Studies were conducted in the spring 2011 at John Day, The Dalles, and Bonneville dams to obtain dam passage and forebay to tailrace survival estimates.

Methods

The experimental design was based on that developed for assessment of the survival of juvenile salmonids past lower Columbia River dams and used previously to provide estimates with statistical characteristics meeting 2008 Biological Opinion and 2008 Fish Accords requirements. JSATS acoustic telemetry methods were used to obtain survival estimates. Because of the rigorous statistical requirements for dam passage survival estimates and their importance in the process of validating the performance of dam structures and operations for fish passage conditions that meet Biological Opinion requirements, extensive QA/QC, and documentation of data flow is a requirement for BiOp Measures studies.

Results

The experimental design for the 2011 studies, the data flow during the conduct of the study, and the QA/QC measures implemented for critical study elements will be presented.

Evaluation of Model Assumptions in the JSATS Compliance Studies

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Background

Fish implanted with JSATS tags were released from seven different locations (rkm 161–190) during the conduct of the compliance studies of dam passage survival at John Day, The Dalles, and Bonneville dams in spring 2011. For valid estimates of survival, assumptions of the release-recapture models must be confirmed. Therefore, an important component of the JSATS survival analyses is in the tests of assumptions.

Methods

A total of eight different analytical approaches were used to assess the validity of the JSATS survival studies and to avoid sources of potential bias. Among the evaluations include tests for tagger effects, tag-lot effects, delayed handling mortality, and inspections of downstream mixing of release groups, and adequate tag life. An integral part of the protocol involved independent tag-life studies in order to adjust the survival estimates for the probability of tag failure.

Results/Management Action

No evidence was found for any tagger or tag-lot effects that might influence survival results. Tagger effort and tag lots were also balanced across release groups in order to minimize any effects that might have gone undetected. There was also no indication that the survival of JSATS-tagged smolts was affected by time inriver. This finding permitted the virtual releases at the face of the dams to use all available fish and improve the precision of the survival studies. The integrated three-dam study provided benefits of economy of scale requiring 22% less tagged fish than three independent dam investigations.

Lower Columbia River Survival Study, 2011: BiOp and Fish Accords Compliance Testing at John Day Dam

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Background

The purpose of this study was to estimate fish passage and survival metrics, as called for in the 2008 Biological Opinion and 2008 Fish Accords, for yearling Chinook salmon (CH1) and juvenile steelhead (STH) passing John Day Dam (JDA) at rkm 349 during spring 2011. A planned summer study of subyearling Chinook salmon was cancelled due to high river discharge.

Methods

The spring study estimated dam-passage and forebay-to-tailrace-passage survival rates using a virtual/paired release (VIPRE) model design and active tag life adjusted survival (ATLAS) software. The study also estimated spill passage efficiency, fish passage efficiency, and travel time metrics, including project passage time, forebay residence time, and tailrace egress time. A Juvenile Salmon Acoustic Telemetry System (JSATS) tag weighing 0.438 g in air and PIT tags were surgically implanted in 4502 live CH1 and 4580 live STH at the John Day Dam (JDA) Smolt Monitoring Facility. Live fish were released daily along line transects across the Columbia River near Roosevelt, WA (rkm 390), the JDA tailrace (rkm 346), and Celilo, OR (rkm 325). Release times at each site were shifted by 12 h on alternate days and releases at successive sites downstream of JDA were synchronized to allow for mixing of fish in common tailwater reaches. Out of 4502 live tagged CH1, 2510 (55.8%) were released upstream of JDA near Roosevelt, WA; 1193 (26.5%) were released in the JDA tailrace; 799 (17.75%) were released in the JDA tailwater near Celilo, OR; nine (0.2%) died during overnight holding after surgery. Out of 4580 live tagged STH, 2587 (56.5%) were released upstream near Roosevelt, WA; 1196 (26.1%) were released in the JDA tailrace; 797 (17.4%) were released in the JDA tailwater near Celilo, OR; two (0.04%) died during overnight holding after surgery. A total of 24 dead tagged fish were released in JDA spillway discharge (15 CH1 and 9 STH) to test the assumption that dead tagged fish were not detected on downstream survival detection arrays. Fish detected at the JDA forebay entrance array or at the dam face were regrouped to form virtual releases of fish, and routes of passage through the dam were determined by 3D and 2D tracking as well as last detection data. Capture histories were formed from detections and non-detections of tagged fish on seven survival detection arrays located downstream of JDA at rkm 325, 309, 275, 234, 161, 113, and 86.2.

Results/Management Action

Data analyses are ongoing, but we anticipate presentation of final estimates for 2011, and those results should inform management decisions.

Results of the JSATS Compliance Studies at The Dalles Dam, Spring 2011

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Background

Spring 2011 was the second year of JSATS compliance studies at The Dalles Dam. High flow conditions in 2011 interrupted the 40% spill conditions during the latter half of the Chinook salmon and steelhead investigations and cancelled the summer subyearling Chinook salmon study. Two years of successfully conducted survival studies per species are required for the compliance studies in the 2008 BiOp.

Methods

The virtual/paired-release design was used to estimate dam passage survival at The Dalles. Dam passage survival is defined as smolt survival from the face of the dam to the tailrace mixing zone or the BRZ. The 2008 BiOp specifies for compliance that dam passage survival estimates for spring migrants should be greater than or equal to 0.96 with an estimated standard error less than or equal to 0.015. The sample sizes of the JSATS tagged virtual releases from the face of The Dalles Dam were 4258 and 4336, respectively, for yearling Chinook salmon and steelhead. The releases forming the paired releases below The Dalles Dam were, on average, 800 fish per location, per fish stock. Alternative day and nighttime fish releases were performed between 29 April and 29 May 2011.

Results/Management Action

Estimates of dam passage survival were calculated for yearling Chinook salmon and steelhead during the early period of the study (29 April to 17 May), before high flows interrupted the 40% spill, and for the entire spring investigation. The 2010 and 2011 results are compared and contrasted for both dam passage survival and Fish Accord measures.

Lower Columbia River Survival Study, 2011: BiOp and Fish Accords Compliance Testing at Bonneville Dam

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Background

The purpose of this study was to estimate fish passage and survival metrics, as called for by the 2008 Biological Opinion and 2008 Fish Accords, for yearling Chinook salmon (CH1) and juvenile steelhead (STH) passing Bonneville Dam (BON) at rkm 234 during spring 2011. A planned summer study of subyearling Chinook salmon was cancelled due to high river discharge.

Methods

The spring study estimated dam-passage and forebay-to-tailrace-passage survival rates using a virtual/paired release (VIPRE) model design and active tag life adjusted survival (ATLAS) software. The study also estimated spill passage efficiency, fish passage efficiency, and travel time metrics, including project passage time, forebay residence time, and tailrace egress time. A Juvenile Salmon Acoustic Telemetry System (JSATS) tag weighing 0.438 g in air and PIT tags were surgically implanted in 7716 live CH1 and 7772 live STH at the John Day Dam (JDA) Smolt Monitoring Facility. Live fish were released daily along line transects across the Columbia River near Roosevelt, WA (rkm 390), the JDA tailrace (rkm 346), Celilo, OR (rkm 325), The Dalles Dam (TDA) tailrace (rkm 307), Hood River, OR (rkm 275), the BON tailrace (rkm 233), and Knapp, WA (rkm 161). Release times at each site were shifted by 12 h on alternate days, and releases at successive sites downstream of BON were synchronized to allow for mixing of fish in common tailwater reaches. Out of 7716 live tagged CH1, 6100 (79.1%) were released at five sites upstream of BON; 798 (10.3%) were released in the BON tailrace; 794 (10.3%) were released in the BON tailwater at rkm 161; 24 (0.3%) died during overnight holding after surgery. Out of 7772 live tagged STH, 6180 (79.5%) were released at five sites upstream of BON, 798 (10.3%) were released in the BON tailrace; 794 (10.2%) were released in the BON tailwater near rkm 161; 6 (0.08%) died during overnight holding after surgery. A total of 50 dead tagged fish were released in the BON spillway discharge or in the B2CC (28 CH1 and 22 STH) to test the assumption that dead tagged fish were not detected on downstream survival detection arrays. Fish detected at the BON forebay entrance array or at the dam face were regrouped to form virtual releases, and routes of passage through the dam were determined by 3D and 2D tracking as well as last detection data. Capture histories were formed from detections and non-detections of tagged fish on three survival detection arrays located 73, 121, and 148 km downstream of BON.

Results/Management Action

Data analyses are ongoing, but we anticipate presentation of final estimates for 2011, and those results should inform management decisions.

Efficacy of Single-Suture Vs Double-Suture Incision Closures in Seaward-Migrating Juvenile Chinook Salmon Implanted with JSATS Acoustic Transmitters

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Background

Reductions in the size of acoustic transmitters implanted in migrating juvenile salmonids have resulted in the ability to make a shorter incision—one that may warrant only a single suture for closure. However, it is not known whether a single suture will sufficiently hold the incision closed when outward pressure is placed on the surgical site – for example, when seaward-migrating salmon experience pressure changes associated with passage at hydroelectric dams. The objective of this research was to evaluate the effectiveness of single-suture incision closures on juvenile Chinook salmon *Oncorhynchus tshawytscha* that were subjected to simulated turbine passage.

Methods

A Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic transmitter (0.30 g in air) and a passive integrated transponder tag (0.10 g in air) were implanted in each fish; incisions were closed with either one suture or two sutures.

Results/Management Action

After exposure to simulated turbine passage, we examined fish for expulsion of transmitters, suture tearing, incision tearing, expulsion of viscera through the incision, and mortal injury. This study will assist in determining whether a single suture is sufficient to close incisions on juvenile salmonids implanted with the 2012 JSATS transmitters.

The Efficacy of Ultraviolet Irradiation for Sterilizing Tools Used for Surgically Implanting Transmitters into Fish

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Background

Telemetry is commonly used throughout the world to examine the behavior of fish, and transmitters are commonly surgically implanted into the coelom of fish. This requires the use of surgical tools such as scalpels, forceps, needle holders and sutures. When implanting several fish for large telemetry studies, it is common for surgical tools to be sterilized or at least disinfected between use so that pathogens are not spread among fish. However, autoclaving tools can take a long period of time, and chemical sterilants or disinfectants can be harmful to both humans and fish, and have varied effectiveness. Ultraviolet (UV) radiation is commonly used to sterilize water in aquaculture facilities. However, this technology has not been widely used to sterilize tools used to surgically implant transmitters in fish.

Methods

To determine its efficacy for this use, a UV sterilizer was used to sterilize surgical tools that were exposed to four aquatic organisms that typically lead to negative health issues in salmonids. These organisms included: *Aeromonas salmonicida*, *Flavobacterium psychrophilum*, *Renibacterium salmoninarum*, and *Saprolegnia parasitica*. Surgery tools were exposed to the bacteria by dipping into a confluent suspension of three varying concentrations. After exposure to the pathogen culture, tools were placed into a mobile Millipore UV sterilization apparatus. The tools were then exposed for three different time periods; 2, 5, or 15 min.

Results/Management Actions

This technique appears to provide a quick alternative to other sterilization techniques that may be less harmful to both humans and fish, while not producing chemical waste.

Effects of Total Dissolved Gas on Chum Salmon Fry Survival, Growth, Gas Bubble Disease, and Seawater Tolerance

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Background

Spill operations in the early spring at Bonneville Dam when chum salmon sac-fry are present in the gravel can raise river total dissolved gas (TDG) concentrations to levels that exceed the state water quality criteria for protection of juvenile salmon. The objective of this study was to document the effect of TDG levels ranging up to 130% saturation on survival and growth, gas bubble disease (GBD), and seawater adaptation in chum salmon fry of varying developmental stages.

Methods

Three life stages of chum salmon fry (early, middle, and late) were exposed to six levels (<100%, 105%, 115%, 120%, 125%, and 130%) of TDG. Survival and growth were monitored from initial exposure to emergence. Necropsies done at 48-h post exposure and at emergence documented GBD. X-ray images at emergence documented gas bubble formation. Seawater tolerance was assessed by exposing post-emergent fry to saltwater for three days. Finally, histological preparations of gills were used to count chloride cells as a seawater readiness assessment.

Results/Management Action

Mortality increased in all stages as dissolved gas concentrations exceeded 115% TDG. For the early and middle stages, the lethal concentration resulting in 50% mortality (LC50) was 128.7% TDG (95% CI 127–130% TDG); an LC50 was not estimated for the late stage. Fish exposed early in their development were more tolerant of elevated TDG; about 90% of the early stage fry tolerated 120% TDG twice as long as the middle stage, and almost three times as long as the late stage. Growth rate from hatch to emergence was not a function of TDG. There was no evidence that exposure time significantly affected growth, with the only exception that the mean weight at emergence of early stage fish exposed to 130% TDG was significantly less than control fish. There were significantly more gas bubbles in the bodies of exposed fish than in control fish, with most bubbles in the nares, gastrointestinal tracts, and yolk sacs. Fish were found to have half the maximum ratio of bubble to body area at 116.9% TDG (95% CI 115–119% TDG) in the middle and late stages, and at 118.6% TDG (95% CI 117–121%) in the early stage. Seawater tolerance did not differ among TDG treatments, but early stage fish showed significantly higher ratios of chloride cell counts when compared to late stage fish, suggesting this stage was more tolerant to seawater at the time of emergence. Taken together, our findings suggest that TDG concentrations above 115% resulted in the highest mortality and the most signs of GBD in each life stage. Tolerance to elevated TDG appeared to diminish as fish approached emergence. This information will be useful to determine if water quality variances will be necessary and protective of chum salmon fry present in the gravel below Bonneville Dam during early spring spill operations.

Estimate of Direct Effects of Steelhead Kelt Passage through the First Powerhouse Ice Trash Sluice and Second Powerhouse Corner Collector at Bonneville Dam

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Background

The U.S. Army Corps of Engineers (Corps), Portland, Oregon, sponsored an investigation in March 2011 at Bonneville Dam (BON) to assess the direct effects (survival and condition) on adult steelhead kelts, *Oncorhynchus mykiss*, in passage through Bonneville Dam First Powerhouse Ice-Trash-Sluice (BON 1 ITS) and Bonneville Dam Second Powerhouse Corner Collector (BON 2 CC). The primary objective was to evaluate the performance of BON 1 ITS to BON 2 CC with respect to passage survival and condition of adult steelhead kelts.

The statistical criterion of the study was to release a sufficient number of fish to obtain a precision (ϵ) on survival and injury estimates $\pm 10.0\%$, 90% of the time.

Methods

Adult steelhead kelts for this investigation were transported from the Round Butte Fish Hatchery, Oregon, to Bonneville Dam. The kelts were tagged with HI-Z tags and a radio tag. A total of 200 treatment fish (100 at BON 1 ITS, 100 at BON 2 CC) and 37 control fish (downstream of BON 2 CC) were released. The total length of the treatment fish ranged from 475 to 800 mm with an average length of 633 mm. Control fish ranged from 540 to 760 mm with an average length of 644 mm.

Results/Management Action

The recapture rates (physical retrieval of alive and dead fish) were similar between BON 1 ITS and BON 2 CC and were 98 and 96 % respectively. Retrieval times at BON 1 ITS and BON 2 CC were 4 to 47 min and 4 to 57 min, respectively with an average recapture time of 11 min. The recapture times for the control group ranged from 2 to 81 min, with an average time of 10 min.

The 48 h survival estimates were calculated two ways including and excluding fish likely preyed on by seals. The 48 h survival estimates for the two release sites including predation were 98.0 and 97.9% for BON 1 ITS and BON 2 CC, respectively. Excluding three fish that were likely predation, the 48 h estimates for BON 1 ITS and BON 2 CC were 100.0 and 99.0%, respectively. Precision (ϵ) on survival estimates for BON 1 ITS and BON 2 CC was $\pm 2.3\%$, 90% of the time and met the prespecified criterion. Difference between the two survival estimates was not significant ($P > 0.10$).

One fish (1%) with a passage related visible injury was identified at each of the two release sites. The respective malady-free (free of visible injuries, scale loss $> 20\%$ per side, and loss of equilibrium) estimates were 99.0% for both BON 1 ITS and BON 2 CC passage routes. The desired precision on the malady-free estimates was achieved ($CI \pm 1.6\%$, 90% of the time), and the estimates were not significantly different ($P > 0.10$).

The two injuries consisted of a bruise on top of head above the left eye for the BON 1 ITS fish and a torn right operculum for the BON 2 CC fish. The probable source of the injury for BON 1 ITS was mechanical and for BON 2 CC was shear. The severity of these two maladies was classified as major. Two fish from BON 1 ITS and 1 from BON 2 CC were likely preyed on by seals.

Passage through both BON 1 ITS and BON 2 CC appears to be quite benign, and one route does not appear to be better than the other for passing adult steelhead kelt at the Bonneville Project.

How Spill Operations Affect Survival of Fish Passing McNary Dam: A Multi-Year Analysis of Survival Data Collected at McNary Dam, 2004-2009

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Background

The U.S. Geological Survey conducted radio and acoustic telemetry studies at McNary Dam between 2004 and 2009 to obtain approach, passage, and survival information about yearling and subyearling Chinook salmon and juvenile steelhead released 18 km upstream from the dam. We also collected fish passage and behavior data from acoustic-tagged fish released at dams in the Mid-Columbia River by Grant County and Chelan County public utility districts. Although the annual studies provided valuable information, studies conducted in any given year are subject to the environmental conditions that nature delivers, which often leads to a narrow range of study conditions. Multi-year analyses are better suited to developing quantitative relationships than annual studies.

Methods

We analyzed six years (2004–09) of passage and survival data collected at McNary Dam to examine how spillway operations affected survival of juvenile salmonids passing through McNary Dam. We also examined the relations between spillway operations and survival through the juvenile fish bypass in an attempt to determine if survival through the bypass was influenced by spillway operations. A Cormack-Jolly-Seber model was used for each juvenile salmonid species (spring and summer Chinook salmon, steelhead, and sockeye salmon) to express spillway survival as a function of various group and individual covariates used to describe dam operations and environmental conditions. Variables incorporated in the models included spillway discharge, project discharge, percent spill, spill pattern (north to south), spill bay type, and other covariates. Spillbay discharge formed an individual covariate that was incorporated into the analysis. Because the deployment of monitoring equipment changed from year to year we pooled across adjacent spillbays to form groups of two to seven bays and then averaged the discharge within the groups. To examine spill pattern across multiple years we created categories based on the proportion of spill discharged through the north, middle, and south portion of the spillway. Akaike's Information Criterion was used to rank and evaluate the resulting models.

Results/Management Action

The results of our analyses indicated that specific spill operations influenced spillway survival in addition to the effects of other factors such as water temperature, fish size, and project or spillway discharge. Depending on species, these factors included spill pattern, spill bay type, spill bay discharge, and percent spill. Spillway operations had less influence on the survival of fish that passed through the juvenile fish bypass.

Visualizing and Quantifying Fish Behavior at McNary Dam 2006-2009

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Background

Between 2006 and 2009, the U.S. Geological Survey conducted acoustic telemetry studies at McNary Dam to obtain approach, passage, and survival information about yearling and subyearling Chinook salmon and juvenile steelhead released 18 km upstream from the dam. We also collected fish passage and behavior data from acoustic-tagged fish released at dams in the Mid-Columbia River by Grant County and Chelan County public utility districts. In 2007, 2008, and 2009 Temporary Spillway Weirs (TSWs) were installed and evaluated. Conducting studies over multiple years allowed us to examine TSW performance in various locations and during different operating conditions and river flows. Although the annual studies provided valuable information, studies conducted in any given year must deal with the environmental conditions that nature delivers, which often leads to a narrow range of study conditions. Multi-year analyses are better suited to developing quantitative relationships than annual studies.

Methods

Much of the valuable information collected at McNary Dam was in the form of three-dimensional (3-D) tracks of fish movements in the forebay. In 2011, we constructed a Graphical User Interface (GUI) to work in conjunction with off-the-shelf visualization software (Eon Fusion) to construct user-defined “scenes” depicting fish movements in the forebay of McNary Dam. By selecting various parameters in the GUI, the user is able to easily depict the behavior of multiple species during different diel periods, spill conditions, powerhouse operations, and testing of the surface bypass structures (TSWs).

Results/Management Action

Although the GUI allows the user to visualize the behavior of fish during various operational and environmental conditions, one of the challenges is summarizing the behavior in a meaningful way. To accomplish this, we applied a Markov chain analysis to provide a mathematical way to characterize fish behavior in the forebay of McNary Dam and examine how fish movements were influenced by operational and structural changes at the dam. The numerical characterization of fish behavior can also be used to construct simulations to examine how proposed fish passage structures might influence passage of juvenile salmonids. To demonstrate this, we used the results of the Markov chain analysis to examine how a Virtual Fish Collector (VFC) located in the center of the powerhouse might influence passage of juvenile salmonids at McNary Dam.

McNary Dam Oregon Shore Fish Ladder Intake Screen Monitoring, 2011

RA Moursund

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Background

In the spring and summer of 2011, Moursund Research Group LLC conducted monitoring of juvenile fish at the Oregon shore adult fish ladder intake of McNary Dam. This intake supplies auxiliary water to the lower portion of the ladder as part of the adult collection system and also to irrigation and the nearby wildlife area. It's screened by two traveling screens that were designed as part of the original construction of the dam in the early 1950's, prior to the establishment of current National Marine Fisheries Service standards. In early 2011, both screens were replaced with in-kind machinery.

Methods

This study used several technologies and approaches deployed both in front of the intake and at the traveling screens. Splitbeam hydroacoustics was used to determine fish presence and potential for entrainment in the immediate forebay. Optical video equipment was used to monitor the number and diversity of fish at the screens with the potential for impingement. Debris washed from the screens was also monitored for any fish mortalities not directly observable with the other techniques.

Results/Management Action

We observed considerable activity in front of the intakes with splitbeam hydroacoustics; however, the fish tracked did not show a directional coherency. The majority of fish were not generally drawn or entrained into the intakes. An observed gradual increase in activity with temperature combined with video identification suggests the majority of hydroacoustically tracked fish were not salmonids, but were poikilothermic resident fish.

The majority of fish encountered in video observations at the screens were salmonids (72%), adult smallmouth bass (17%), and juvenile lamprey (10%). Juvenile lamprey were found exclusively in spring; smallmouth bass in summer. Smallmouth bass detections were closely associated with smolts, and active predation events were observed. Observations showed fish were not impinged using NMFS' injurious contact definition. Even though juvenile lamprey spent considerable time on the surface of the screen mesh, they were also observed swimming off the screen even after sustained contact.

The screen wash debris trap captured 28 fish that were not pre-injured for an overall catch rate of 0.4 fish/day from both screens combined. The proportion of the catch was three-spine stickleback (46%), salmonid (28%), yellow perch (11%), catfish (7%), peamouth (4%), and centrarchid (4%). This was an unusually high flow year and the fry caught may have been due to increased flow scouring within tributaries.

This study has shown that species of concern were present in both the immediate forebay and within the intake structure. Though representing only a single year under unusual flow conditions, the data to date suggest impingement is a less likely source of mortality or injury. Delay and/or predation may be more significant than impingement for this low velocity intake structure, and perhaps low velocity intakes in general. This information will be useful for resource management action agencies in making construction and operational decisions in regards to this intake structure for the benefit of anadromous fish.

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Current Status and Restoration Potential for Mainstem Spawning Fall Chinook in the McNary Tailrace and Upper John Day Reservoir

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Background

The purpose of the study was to assess current levels of fall Chinook spawning below both John Day and McNary Dams. The construction of John Day Dam created a reservoir 76 miles long and inundated one of the most prolific spawning sites for fall Chinook salmon in the Columbia Basin. However, tailrace habitats in the Columbia and Snake rivers can provide some level of suitable spawning habitat as evidenced by redd surveys. Documented spawning of fall Chinook salmon has occurred below both John Day and McNary Dams. From 2002 to 2005, four years of BPA-funded research resulted in an average estimate of 1,133 redds below John Day Dam. In 2004, a reconnaissance survey conducted below McNary Dam identified six redds even though less than 3% percent of the area was surveyed.

The U.S. v. Oregon Parties have recently proposed a new mitigation level to the COE relative to the long-term restructured John Day and The Dalles mitigation. The Parties concluded that the appropriate level of mitigation responsibility from both projects is the adult production level equivalent of a minimum of 65,000 natural spawners whereas the current level of mitigation is 30,000 adult fall Chinook. The identification and enumeration of existing fall Chinook redds and assessment of current and drawdown spawning habitats below both projects will be integral to future mitigation discussions.

Results/Management Actions

In FY2011 COE funded deep water fall Chinook redd surveys were conducted below John Day and McNary Dams resulting in counts of 221 and 4 redds, respectively and expanded estimates are currently being developed. Redds mapped below John Day Dam were distributed in clusters and located in the same locations as past observations. The 4 redds mapped below McNary Dam were located in cobble patches just upstream of the highway bridge with zero redd observations below the bridge. The count below John Day Dam is the highest on record while the count below McNary should be considered a minimum given the large survey area. Neither BRZ was accessible during the survey period. Throughout the McNary tailrace study site, substrates were assessed and large extents of bedrock were observed which are not suitable for spawning and totaled approximately 40% of the survey area. With the work completed in 2010, future surveys can now focus on areas where there is at least some probability of spawning occurring and will result in the first quantitative counts and estimates of spawning below McNary Dam.

To mitigate for hydrosystem related losses, remnant and newly discovered spawning populations can be protected through management actions. To this end, it is possible to increase both the quantity and quality of tailrace habitats by providing beneficial hydrosystem operations during the spawning season. This is the case in the Hanford Reach and below Bonneville Dam where mainstem spawning salmon benefit from specific hydrosystem operations.

Hydroacoustic Evaluation of Adult Steelhead Fallback and Kelt Passage at McNary Dam, Winter 2010-2011

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Background

In the winter of 2010-2011, Battelle Pacific Northwest Division conducted a hydroacoustic study at McNary Dam to evaluate the number and distributions of adult steelhead passing downstream through the powerhouse. The primary purpose of the study was to enumerate and determine the vertical and horizontal distribution of adult steelhead as they passed through the powerhouse.

Methods

Adult passage was monitored at eight of 12 operating turbine intakes from December 17, 2010, through April 13, 2011. Fixed-aspect hydroacoustics were used to estimate the number of adult fish-sized targets entering each turbine intake unit. A DIDSON acoustic imaging device was used to monitor the region just upstream of the trash rack at units 5C and 6A in order to verify the presence of adult steelhead and other similar-sized individuals of other species.

Results/Management Action

Downstream passage of adult steelhead through the monitored turbine intakes at the powerhouse of McNary Dam across the entire study period was estimated to be 946 individuals, with 95% confidence bounds extending from 750 to 1142 individuals. If a similar rate of passage through unmonitored turbine intakes is assumed, the estimate of total powerhouse passage would be 50% higher at 1419. Passage was greater at turbine units nearer the north or south ends of the powerhouse, and lower near the center of the powerhouse, but unmonitored units limit our ability to confirm and interpret horizontal distributions. Vertical distributions (depth) showed a trend of passage nearer the ceiling of the intake. This suggests that a high proportion of adult steelhead would encounter screens, if they were in place.

The unexpected occurrence of spill likely reduced turbine passage of adult steelhead and kelts. During periods with forced spill, rates of turbine passage appeared lower, but it is not possible to determine whether those differences are related to spill or to the occurrence of those periods later in the study. During periods of forced spill, passage was greater near the north end of the powerhouse, adjacent to the spillway. Turbine passage was distributed at greater depth during spill than during periods without spill. While these findings suggest that spill is influencing turbine passage, we cannot differentiate spill effects from trends in other factors through the passage season.

For similar periods in the spring, turbine passage at McNary Dam was intermediate to the two years of estimates of turbine passage at The Dalles Dam and lower than passage through the Corner Collector at Bonneville Dam powerhouse 2. The rate of passage into turbines in the present study during the winter, when other studies did not sample, was higher than during the spring. If spill does not occur during the winter of 2011-2012, we expect higher estimates of turbine passage for adult steelhead and kelts in the winter and spring.

Hydroacoustic Evaluation of Overwintering Summer Steelhead Fallback and Kelt Passage at The Dalles Dam, 2011

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Background

This abstract presents the results of an evaluation of overwintering summer steelhead (*Oncorhynchus mykiss*) fallback and out-migrating steelhead kelts downstream passage at The Dalles Dam (TDA) turbines during spring 2011. The study was conducted by the Pacific Northwest National Laboratory for the U.S. Army Corps of Engineers to investigate whether adult steelhead are passing through the powerhouse turbines during early spring before annual sluiceway operations typically begin. This study is a follow-up to similar studies of adult steelhead passage at the sluiceway and turbines we conducted in the fall/winter 2008, early spring 2009, fall/winter 2009, and early spring 2010.

The goal of the 2011 study was to characterize adult steelhead passage rates at the turbines while the sluiceway was closed so fisheries managers would have additional information to use in decision-making relative to sluiceway operations. Sluiceway operations were not scheduled to begin until April 10, 2011. However, based on a management decision in late February, sluiceway operations commenced on March 1, 2011. Therefore, this study provided estimates of fish passage rates through the turbines, and not the sluiceway, while the sluiceway was open.

The study period was from March 1 to April 10, 2011 (41 days total). The study objective was to estimate the number and distribution of adult steelhead and kelt-sized targets passing into turbine units.

Methods

We obtained fish passage data using fixed-location hydroacoustics with transducers deployed at all 22 main turbine units at The Dalles Dam.

Results/Management Action

Adult steelhead passage through the turbines occurred on nine days between March 1 and April 10, 2011. We estimated a total of 215 ± 98 (95% confidence interval) adult steelhead targets passed through the turbines during the study. Horizontal distribution data indicated Main Unit 18 passed the majority of fish. Fish passage occurred throughout the day. We conclude that adult steelhead passed through turbines during early spring 2011, while the sluiceway was in operation.

In our previous studies that included sluiceway operations, 3,556 adult steelhead targets passed the dam during November 1 through December 15, 2008, and March 1 through April 10, 2009, and 2,926 targets passed the dam during November 1, 2009, through April 10, 2010. During our 2009/2010 study that included a turbine-only evaluation of steelhead passage in winter months (Dec 16 – Mar 7), 62 ± 40 (95% CI) fish passed the turbine units over a period of 82 days. Collectively, the results of these studies and our early spring 2011 study indicate that overwintering summer steelhead fallbacks and kelts migrating downstream used the sluiceway with a passage efficiency of 91-99%, and total turbine passage increased as a function of average outflow ($R^2=0.95$).

The results of these studies strongly suggest operating the sluiceway for steelhead passage during winter and early spring to provide an optimal, non-turbine route for these fishes to pass the dam.

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PIT-Tag Reach Survival Estimates, 2011

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Background

NOAA Fisheries began using PIT tags to conduct reach survival studies in the Snake and Columbia Rivers in 1993. The primary objective is to provide managers the information needed to assess structural and operational improvements made within the hydropower system to decrease travel time and increase juvenile survival.

Methods

Seven of the eight mainstem dams that Snake River stocks pass during their downstream migration have PIT-tag detection systems within their juvenile fish bypass systems. Additionally, in the Lower Columbia River downstream of Bonneville Dam, NOAA Fisheries operates a 2-boat trawl with a PIT-tag detector in the cod end. We constructed a detection history for each tagged migrant (the record of whether or not detected at each detection site), and used statistical models for mark-recapture data ("Cormack-Jolly-Seber" models) to estimate survival probabilities of PIT-tagged juveniles through individual reaches (one reach is one reservoir and dam combination) and combined reaches. We also used PIT-tag detection data to calculate travel time statistics, estimate the proportion of fish transported from Lower Snake River dams, and other quantities, and investigate relationships among these estimates and environmental conditions and management operations.

Results/Management Action

During most of the 2011 spring migration, Snake River flow was higher than in recent years. Mean spill volume was on the high side of average until about 15 May when high flow forced very high spill volumes. As a percentage of flow, spill remained near 30% until mid-May, when average spill percentage increased to around 50%, higher than in recent years. Estimated survival through individual reaches averaged 91.3% for yearling Chinook salmon and 93.7% for steelhead. Average travel times for both species were among the shortest we have observed during the study. For both yearling Chinook salmon and steelhead, estimated survival through the entire 750 km hydropower system (Snake River trap to Bonneville Dam tailrace) was lower in 2011 than in 2009 and 2010 (though not statistically significantly lower). Through the entire hydropower system the estimates were 48.3% for yearling Chinook salmon and 59.2% for steelhead. These estimates are very near the long-term average for Chinook salmon and above the long-term average for steelhead. High spill rates coupled with surface passage structures at all 4 Snake River dams in 2011, and a delayed start to transportation resulted in transportation of about 38% of Chinook salmon and 37% of steelhead in the run at large, very near the average transported percentages since 2007. Consequently, there were more smolts in the Snake River than in earlier years when a higher proportion were transported. As a result, a lower proportion of steelhead was likely eaten by piscivorous birds near the confluence of the Snake and Columbia Rivers, resulting in increased survival through the Snake River.

Initial Results from the 2011 COAST Study: Lower River, Estuary, and Early Marine Survival and Movements of Yearling Chinook Salmon

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Background

The Coastal Ocean Acoustic Salmon Tracking (COAST) study tests critical uncertainties regarding juvenile salmon survival during their early marine migration. In 2011, we expanded our study to incorporate a wider range of Chinook stocks and tested whether delayed or differential-delayed mortality occurred in the lower river and estuary (LRE), or coastal ocean.

Methods

In 2011, sub-arrays were deployed at Astoria and Sand Island (“Columbia River mouth”), north of the river at Willapa Bay, WA, and Lippy Point, BC, and south at Cascade Head, OR. All coastal-ocean sub-arrays were extended offshore to 500 m depths. We used the array to track movements and estimate LRE and early marine survival of yearling Chinook smolts ≥ 130 mm FL surgically implanted with VEMCO V7 transmitters at Bonneville (B2J) and Lower Granite (GRJ) dams. In-river smolts tagged at B2J ($n=580$) were released into the tailrace in late-April, early-May, mid-May and late-May; smolts tagged at GRJ ($n=200$) were transported downstream and released below Bonneville Dam in early-May and mid-May. Stock of origin for each tagged individual was determined by genetic stock identification post-release. Thus, survival was estimated separately for in-river migrating mid/upper Columbia River spring Chinook (IR_{Col}) and Snake River spring Chinook (IR_{Snake}) captured at B2J, as well as Snake River spring Chinook smolts captured and transported (TR_{Snake}) from GRJ. 92% of tagged smolts were of hatchery origin.

Results/Management Action

Mean travel time to the river mouth (~220 km) was significantly longer for IR groups released in late-April when compared to all May release dates. Although travel time through the plume generally decreased throughout May for all groups, Transported smolts released in early-May took 9x longer to migrate through the plume than transported smolts released in mid-May (9.5 days vs. 1.05 days). From Willapa Bay to Lippy Point (NW Vancouver Island; 580 km) mean travel time was approximately 20 days for all groups.

Nearly all smolts migrated north upon ocean entry (only six smolts were detected south of the river mouth). Estimated survival in the LRE was high and similar for all groups (IR_{Col} : 84%, SE=4%; IR_{Snake} : 81%, SE=4%; TR_{Snake} : 78%, SE=5%). Plume survival (river mouth to Willapa Bay, ~50 km distant) was much lower (IR_{Col} : 27%, SE=4%; IR_{Snake} : 23%, SE=5%; TR_{Snake} : 14%, SE=4%). Minimum survival (i.e., % detected) from Willapa Bay to Lippy Point (485 km) for the release groups pooled was 25% for IR_{Col} , 22% for IR_{Snake} , and 9% for TR_{Snake} . Minimum survival from Bonneville Dam to Lippy Point (~750 km total) was 5.7% for IR_{Col} , 4.2% for IR_{Snake} , and 1.0% for TR_{Snake} .

Preliminary estimates of post-Bonneville Dam survival to Lippy Point were similar for both IR_{Col} and IR_{Snake} smolts, therefore delayed mortality due to Snake River dam passage was not evident 750 km and >1 month beyond Bonneville Dam. Transported smolts, however, had 1/4 the survival of IR_{Snake} smolts from Bonneville to Lippy Point. This reduced survival in 2011 may be evidence of differential-delayed mortality and is contrary our prior findings (2006 and later years) that transported smolts have higher survival in the plume and coastal ocean than in-river migrants.

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Snake River Basin Differential Delayed Mortality Synthesis

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Background

Differential delayed mortality (D) is the ratio of post-hydrosystem survival of barged fish relative to run-of-river (ROR) fish. Although the ratio of smolt-to-adult returns (SAR) of barged versus ROR fish, or transport to in-river ratio (T:I), is a better metric for evaluating whether transport increases adult returns, D is a useful metric for understanding how differential survival downstream of the release point influences the effectiveness of the fish transportation program. The goals of our report were to synthesize literature related to D, identify key uncertainties and data gaps, and develop a roadmap of potential future research.

Methods

We reviewed and compiled in a database over 200 studies on hatchery and wild spring/summer Chinook, steelhead, and fall Chinook from peer-reviewed journals and reports. In our synthesis, patterns of D were characterized and 12 potential factors relating to fish and environmental conditions were identified. A conceptual–mathematical model was developed to integrate factors and track interactions underlying D. Through a regional workshop, researchers provided additional information and perspectives on D. With the assistance of workshop participants, we categorized the 12 factors by their relative importance to D and degree of uncertainty in the data and conclusions. This categorization helped develop the roadmap of future research.

Results/Management Action

The 12 factors identified were: pre-hydrosystem conditions; hydrosystem arrival time and travel time; fish size; physiological condition; diseases; dam operations; barging conditions; lower river conditions and predation; estuarine conditions and predation; ocean conditions; straying; and tagging and estimation of survival. D varies across species, rearing type, hydrosystem arrival date and year because of the interactions between seasonally varying factors related to fish and environmental conditions. Three major hypotheses emerge to explain the seasonal and across-run differences in D:

1. Arrival time – ROR and barged fish passing BON at different times of the season experience different levels of predators, food, and environmental conditions in the estuary and ocean.
2. Length – ROR and barged fish entering the estuary at different lengths are susceptible to different levels of predation.
3. Fish condition – ROR and barged fish entering the estuary with different levels of smoltification, energetic status, disease, and stress are differentially susceptible to predators.

In general, post-hydrosystem survival depends on the interaction of the condition of fish after passing Bonneville Dam and the condition of the estuary and ocean environments; and these interactions are tractable in the conceptual–mathematical model.

In the roadmap of potential future research, an evaluation of the length and condition hypotheses is most warranted because of their relations to factors categorized as high/moderate importance to D and as high uncertainty. To better characterize the effect of fish and environment-specific factors to D, measures of length and condition of fish entering and exiting the hydrosystem by ROR and barge passage types coupled with information on the status of the estuary and ocean are needed. An improved understanding of this linkage will provide managers better information to decide which runs to transport and under what conditions.

A Study to Determine Seasonal Effects of Transporting Fish from the Snake River to Optimize a Transportation Strategy

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Background

Studies have shown that the benefit of smolt transportation varies within migration seasons. Typically, transportation has been less beneficial for earlier, smaller migrants. As a result, a later starting date for general transport from Snake River Dams was chosen in recent years, typically around 1 May at Lower Granite Dam and later at downstream sites. The objective of this study is to investigate within-season patterns in smolt-to-adult return rates (*SARs*) of transported (I) and in-river migrant (M) fish, and patterns in the *SAR* ratio (I:M).

Methods

We considered all PIT-tagged wild and hatchery yearling Chinook salmon and steelhead released upstream from Lower Granite Dam from 1998 through 2009, along with fish collected and PIT-tagged at Lower Granite Dam. To study within-season *SAR* patterns required known dates of juvenile passage. Therefore, in-river migrant groups were formed from PIT-tagged fish that were bypassed (i.e., detected and returned to the river) at Lower Granite Dam. Inference for the run-at-large requires an assumption regarding the relationship between *SARs* for detected and never-detected fish. We adjusted standards of comparison to account for lower *SARs* generally observed for detected fish. We used the statistical method of Poisson log-linear regression to model *SARs* for daily groups of transported and migrant fish, and used Information Theoretic methods (e.g., AIC-based model averaging) for multi-model inference. In a set of descriptive analyses, we modeled *SARs* strictly as a function of date. For another set of explanatory analyses, we compiled data on a large collection of freshwater and ocean factors that potentially influence *SARs*. We selected a few variables – flow, spill percentage, and water temperature during migration, smolt passage index, and ocean upwelling index -- to use as potential predictor variables in the regression models.

Results/Management Actions

We observed a wide variety of patterns in *SARs* and I:M ratios. A common pattern was that *SAR* decreased from the beginning of the season (earliest fish to arrive at LGR) until the end (latest to arrive). The latest arriving migrant fish (late May) almost always had the lowest *SARs* of the season. For transported groups, the lowest *SAR* of the season was often for those that were transported earliest. The relationship of *SARs* with explanatory covariates was not consistent across data sets. For about half of all data sets, models including at least one covariate were better than strictly descriptive models. For all species and rearing types, water temperature was most strongly associated with *SAR* among the covariates we investigated. Rankings among the other covariates varied between species and rearing types. Before 2006, the estimated I:M ratio almost always exceeded standards for fish that arrived at LGR on May 1 or later. Patterns did not change drastically in 2006-2009, but the earliest date on which I:M exceeded standards was more likely to be later in May (e.g., May 10), especially for steelhead. Additional years of data are required to determine the degree to which the changed transportation strategy has altered *SAR* and I:M patterns.

Snake River Sockeye Pilot Transportation Study 2009-2011

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Background

Snake River Sockeye salmon have been listed as endangered since 1991. With low numbers of returning adults each year there have not been sufficient numbers of juveniles to evaluate effects of transportation on Snake River sockeye salmon. The effect of the juvenile transportation program on sockeye salmon has been a critical uncertainty identified by the Independent Scientific Advisory Board (ISAB). Recent increases in adult returns and plans for additional hatchery production in Idaho will allow for a large-scale transportation evaluation. A pilot transportation evaluation was initiated to collect information to develop a robust transportation evaluation. The objectives of the pilot evaluation were to estimate: 1) reach survival probabilities (Release to Lower Granite Dam (LGR); LGR-McNary Dam (MCN)) 2) collection efficiencies and 3) overall SARs for Snake River sockeye salmon.

Methods

From 2009-2011 a total of 192,113 juvenile fish were PIT tagged by BioMark. Of these fish, 159,316 were reared at Sawtooth hatchery in Idaho and 32,797 were reared at Oxbow Hatchery in Oregon. All fish were released from the Sawtooth and Redfish Lake Creek trap sites in Idaho. Reach survival estimates, collection efficiencies, and SARs were calculated using the programs PitPro and Roster. Due to small sample sizes no age specific adult survival estimates were generated.

Results/Management Action

Fish reared at Sawtooth hatchery were smaller (mean fork length at tagging 2009-2011; 97 mm) than fish reared at Oxbow hatchery (144 mm). Release to LGR survival estimates for Sawtooth reared fish were 0.39, 0.15, and 0.74 for migration years 2009, 2010, and 2011, respectively. The LGR-MCN survival estimates for Sawtooth reared fish were 0.67, 0.68, and 0.56 for migration years 2009, 2010, and 2011. Reach survival estimates varied considerably across the study years, likely a result of different flow conditions. Collection efficiency at LGR averaged 22% for 2009-2011 (range 8.8-25.2%). Preliminary SARs were calculated for the 2009 release years and the Sawtooth reared fish returned at a lower rate than the larger Oxbow reared fish. The reach survival, collection efficiency, and SAR information will be useful for development of a large scale transportation evaluation and provide fish managers information for determining sample sizes necessary to achieve a desired level of statistical power.

Alternative Barging Strategies to Improve Survival of Transported Juvenile Salmonids

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Background

From 2006 through 2008, we released PIT-tagged smolts for a study to test the hypothesis that releasing transported juvenile salmonids in the lower Columbia River estuary would produce higher smolt-to-adult returns (SARs) than releasing them at the traditional release site just below Bonneville Dam. Adult returns from those releases are now complete.

Methods

Hatchery and wild spring/summer Chinook salmon and steelhead were PIT tagged on six consecutive Sundays each year with one group barged to the release site at Skamania Landing just below Bonneville Dam (river kilometer [rkm] 245) and the other group released at night on an outgoing tide at rkm 10, below Astoria, Oregon (AS). Pathogen levels, losses to avian predators in the Columbia River estuary, SARs, conversion rates, and straying were compared between the two release sites.

Results/Management Actions

Based on complete adult returns, release of yearling Chinook salmon below Astoria either provided no benefit (2007 and 2008) or was detrimental (2006) to SARs compared to the traditional release site at Skamania Landing, although no annual comparisons were significant. While release at rkm 10 did provide a significant reduction in losses to avian predators, predation on Skamania releases were already low, so there was little impact on SARs. Adult conversion rates and travel times between Bonneville and Lower Granite dams were similar for the two groups and stray rates were low.

For steelhead, estuarine release provided a significant increase in SARs for hatchery steelhead and for hatchery and wild steelhead combined from the 2006 study year. However, estuarine release of steelhead smolts provided no significant benefit to SARs in the other two years compared to Skamania releases. This was despite a very significant reduction in losses to avian predators for the Astoria released fish. Offsetting the potential gain to SARs from a reduction in avian predation, conversion rates of steelhead adults between Bonneville and Lower Granite dams were significantly lower for Astoria released fish, resulting in an average 20% fewer adults crossing Lower Granite Dam. Conversion rates are affected by rates of straying, differential susceptibility to harvest, and pre-spawning mortality. Straying was higher in Astoria released fish, but the difference wasn't significant in the majority of comparisons.

Identifying Overwintering Location and Natal Origin for Snake River Fall Chinook Salmon

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Background

Anthropogenic disturbances have clearly caused drastic shifts in the life history of Snake River fall Chinook salmon. Recently, Connor et al. (2005) described an additional life history for juvenile Snake River fall Chinook salmon, which they termed “reservoir type.” Fish that adopt the reservoir-type life history delay their subyearling seaward migration, and instead overwinter in reservoirs, resuming their seaward migration the following spring to enter the ocean as yearlings. Reservoir-type fall Chinook salmon make up a large contribution to the returning population of spawners, but most mitigation actions are directed at ocean-type juveniles. Further, many of these fish move downstream during the period when PIT-tag detectors are off line, resulting in a great deal of uncertainty about their migratory patterns. Otolith microchemistry offers a resource-efficient method of analyzing the movements of individual fish at a finer geographic scale than is possible with current tagging technology. The daily growth increments of fish otoliths record the chemical signatures of the environments through which a fish passes.

Methods

We analyzed otoliths from adults (collected from Lyons Ferry Hatchery) to reconstruct their life histories during the juvenile stage (hatching to ocean entry) by estimating residence times in segments along the migration route. In addition, we also analyzed otoliths derived from juveniles of known origin to validate the methods. In doing so, we addressed the following questions: where do reservoir-type fall Chinook overwinter in the Columbia River watershed? Where and for how long are fish of various life history strategies and natal origins residing during downstream migration, and when do they migrate out of the hydrosystem? When do fish enter the ocean and how much time do they spend in lower river habitats, including the estuary? How are the various life strategies represented across the populations and cohorts used in transportation studies?

Results/Management Action

Classification of known origin juveniles to rearing areas based on strontium isotopic ratios was very accurate. The vast majority of individuals that overwintered had an overwintering signature consistent with that of the lower Snake River. The relationship between fish length and otolith radius was strong, allowing for the reconstruction of growth trajectories. Trajectories across otoliths of strontium isotopic ratios and intensities, along with estimated growth trajectories, provide information about the size of fish as they migrated out of their rearing areas and size at ocean entry. The relative locations on the otolith trajectory of the time of ocean entry and the first annulus provides clear information on whether individuals entered the ocean as yearlings or subyearlings. Finally, the chemical trajectories revealed several distinct migratory patterns.

NOTES

NOTES

CAMPUS MAP



WHITMAN COLLEGE Campus Map

- 1 Admission and Financial Aid (Penrose House)
- 2 Alumni House
- 3 Amphitheatre
- 4 Anderson Hall (residence hall)
- 5 Asian Studies House (interest house)
- 6 Athletic Complex (outdoor fields)
- 7 Baker Faculty Center
- 8 Baker Ferguson Fitness Center/Harvey Pool
- 9 Beta Theta Pi (fraternity house)
- 10 Bortleske Stadium
- 11 Boyer House
- 12 Bracher Observatory (astronomy facility)
- 13 Bratton Tennis Center
- 14 College House (residence hall)
- 15 Community Service House (interest house)
- 16 Cordiner Hall (auditorium)
- 17 Dance Studio
- 18 Das Deutsche Haus (interest house)
- 19 Environmental House (interest house)
- 20 Fine Arts House (interest house)
- 21 Fouts Center for Visual Arts
- 22 Global Awareness House (interest house)
- 23 Glover Alston Center (intercultural resources and programs)
- 24 Hall of Music (includes Chism Recital Hall)
- 25 Hall of Science (includes Brattain and Gaiser auditoriums)
- 26 Harper Joy Theatre (includes Alexander and Freimann stages) – renovation 2010-11
- 27 Hunter Conservatory (rhetoric and film studies/ debate, Kimball Theatre)
- 28 Jewett Hall (residence/dining hall)
- 29 La Casa Hispana (interest house)
- 30 Lakum Duckum
- 31 La Maison Francaise (interest house)
- 32 Lyman House (residence/dining hall)
- 33 Marcus House (residence hall)
- 34 Maxey Hall (social sciences)
- 35 Memorial Building (administration)
- 36 Multi-Ethnic Center for Cultural Awareness (MECCA/interest house)
- 37 North Hall (residence hall)
- 38 Olin Hall (humanities and mathematics, technology services)
- 39 Organic Garden
- 40 Penrose Library
- 41 Phi Delta Theta (fraternity house)
- 42 Physical Plant Services
- 43 Prentiss Hall (residence/dining hall)
- 44 Reid Campus Center (student services/café)
- 45 Sheehan Art Gallery
- 46 Sherwood Athletic Center (climbing wall)
- 47 Sherwood House (president's residence)
- 48 Sigma Chi (fraternity house)
- 49 Tamarac House (residence hall)
- 50 Tau Kappa Epsilon (fraternity house)
- 51 Tekisuijuku (interest house)
- 52 Welty Center (counseling and health services)
- 53 William O. Douglas Hall (residence hall)
- 54 Writing House (interest house)

Key Locations

- 1 Penrose House**
Admission/Financial Aid Services
- 35 Memorial Building**
Business Office
Dean of Students
Development and College Relations
Human Resources
Off-Campus Studies
President
Provost/Dean of the Faculty
Registrar
Residence Life and Housing
Security
- Student Residences**
44 Reid Campus Center
Bookstore
Cafe
Career/Student Engagement Center
Community Service
Intercultural Center
Newspaper (The Pioneer)
Outdoor Program
Radio station (KWCV)
Student activities/organizations
Student employment
- Accessible Entrances**
● With power-operated doors
○ Without power-operated doors