ORAL ABSTRACTS (*presenter, **student presenter)

Abbott*, A. [1]. [1]U.S. Fish and Wildlife Service.

The Maine Model – Flexible Partnerships for Restoration

A broad public-private partnership in the state of Maine is celebrating its tenth year of working in a concerted effort to improve aquatic connectivity. As the last hope for restoring Atlantic salmon in the U.S., the last bastion of extensive intact wild Eastern brook trout habitat, with burgeoning populations of alewife and tremendous potential for other diadromous fish, Maine offers a landscape-scale laboratory for enhancing connectivity. The partners focused first on assessments encompassing nearly 17,000 stream crossings (almost 70% of the state's perennial crossings), as well as hundreds of dams and natural barriers. Site data is associated with habitat data, and accompanied by site photos, allowing evaluation of passage issues at many scales. This large dataset allows analysis to set priorities for restoration by town, landowner or watershed. Public outreach to encourage use of this valuable data by individuals and organizations became a second focus of the partners and has been a vital feature of our success. Outreach includes web-based information and videos of exemplary connectivity projects, introductory and field-survey workshops for road owners and managers, and advanced Stream Simulation trainings for restoration professionals. The third and ultimate focus of the partnership is to increase the pace of restoration to improve aquatic connectivity across the state. Funding opportunities for connectivity projects in Maine have expanded in recent years with a bond act passed to help finance municipal stream crossing replacements. Partners join together in simple or complex groups to meet the needs of restoration projects. Federal agencies provide technical assistance for site assessment and fish passage evaluation, state agencies provide vital habitat data and assessment work, large private landowners integrate connectivity priorities to their infrastructure maintenance plans, and NGOs cover funding gaps, help with funding and permit applications, and often lead and energize large and small restoration projects.

Alcott**, D. [1], and T. Castro-Santos[1,2]. [1]University of Massachusetts, Amherst, MA; [2]U.S. Geological Survey.

Migratory delay of anadromous river herring at anthropogenic obstacles on a small coastal stream

Restricted access to spawning habitat is one of the primary factors contributing to population declines of anadromous river herring (genus *Alosa*). Hydroelectric dams, tide gates, and road-crossing culverts often disrupt migrations of diadromous fishes. Acoustic (JSATS) and PIT telemetry were used to quantify migratory delay of river herring at a tide gate and an additional five consecutive road-crossing culverts on the Herring River in Wellfleet, MA. Data were collected for three seasons from 2014-2016. Return rates of repeat spawners exceeded 15% in 2015. Median upstream delay at the tide gates was seven days after first arrival. Both upstream and downstream groundspeed were reduced by an order of magnitude through road-crossing culverts compared to between culvert reaches. Passage success decreased and mortality increased for fish arriving later in the season. These data demonstrate the importance of considering movement rates in barrier assessments and evaluations.

Almeida*, P. [1], R. Oliveira[1], C. S. Mateus[1], C. M. Alexandre[1], A. F. Belo[1], E. Pereira[1], A. Telhado[2], M. F. Quadrado[2], and B. R. Quintella[1]. [1]MARE–Centro de Ciências do Mar e do Ambiente, Universidade de Évora, Portugal; [2]Departamento de Recursos Hídricos, Agência Portuguesa do Ambiente, I.P., Portugal.

Sea lamprey behavior during negotiation of technical and nature-like fish passes

A restoration plan was implemented on the River Mondego River, Portugal, to restore connectivity and increase available habitat for diadromous fish. This rehabilitation program started in 2011 with the construction of a technical fish pass at the Coimbra Açude-Ponte dam by the Portuguese Environmental Agency (APA). Since then, a monitoring program and additional restoration efforts were put in practice. In 2015, nature-like fish passes were installed in five small weirs previously identified as difficult obstacles to fish migration. Among methods applied to evaluate the efficiency and effectiveness of these fish passage solutions, radio-telemetry was used to study the behavior of target species when negotiating the new fish passes. Sea lamprey, an anadromous species for which there is some paucity of behavioral and physiological data related to obstacle negotiation, was the main target of these telemetry studies. Specifically, this component of the passes monitoring program aimed to evaluate and compare the behavior of sea lampreys downstream, during negotiation and after transposition of the different fish passage solutions installed in River Mondego. To evaluate their large-scale migratory behavior, 40 lampreys were tagged with conventional radio-transmitters and released downstream of the selected fish pass. Main results reveal a passage efficiency of 30% for the technical fish pass constructed in the Açude-Ponte dam, with lampreys surpassing this obstacle in less than 2 weeks. An additional 10 sea lampreys were tagged with EMG radio-transmitters to study fine-scale behavior and muscular activity during fish pass negotiation. Sea lampreys took 3 hours to completely negotiate the technical fish pass at the Açude-Ponte dam, during which high muscular effort was registered only during negotiation of the vertical slots that connect the pools. This study shows that the use of complementary telemetry methodologies provides a comprehensive passage evaluation that can be very important to validate the suitability of different fish passage solutions.

Amaral*, S.[1], E. Perry[2], L. Sullivan[3], M. Timko[3], D. Giza[1], and P. Jacobson[4]. [1]Alden Research Laboratory, Inc. Holden, MA; [2]Biostatistician Consultant; [3]Blue Leaf Environmental; [4]EPRI.

Evaluation of Behavioral Cues for Guiding Silver American Eel at Hydro Projects

During annual spawning migrations from freshwater to the marine environment, silver eels may experience high mortality rates if they pass through turbines at one or more hydro projects. Consequently, providing safe downstream passage for silver eels at power dams is a priority for fisheries managers and project owners. In response to this need, the collaboratively-funded Eel Passage Research Center (EPRC) was established by EPRI and U.S. and Canadian utilities and resource agencies to investigate technologies that can be used to reduce turbine entrainment at large hydro projects on the St. Lawrence River. As part of the EPRC's efforts, we completed a laboratory evaluation of behavioral cues designed to elicit avoidance reactions from silver eels and guide them towards a collection system. This study included tests conducted in a large flume with an electrical guidance system (EGS; Smith-Root, Inc.) and the Flow Velocity Enhancement System (FVES; Natural Solutions LLC) to determine the ability of each stimulus, alone and in combination, to repel and guide eels as they moved downstream. Acoustic telemetry techniques were used to track eel movements during stimulus exposure and control trials in order to determine responses to the two stimuli. Statistical analysis of eel movement direction and speed after they entered a stimulus field did not demonstrate any concise or consistent avoidance or guidance responses to the EGS or the FVES. However, several aspects of the study approach and test facility design may have influenced observed eel behaviors during testing with each stimulus or reduced our ability to detect avoidance or guidance. Additional analysis of the acoustic telemetry data is being considered to further evaluate eel responses and to determine whether one or both of the stimuli should be considered for additional testing.

Amaral, S. [1], T. Grant*[1], P. Jacobson[2], J. Pyatskowit[3], and S. Dearden[4]. [1]Alden Research Laboratory, Inc., Holden, MA; [2]EPRI; [3]Menominee Indian Tribe of Wisconsin; [4]Whooshh Innovations.

Evaluation of Lake Sturgeon Passed through the Whooshh Fish Transport System

The development of biologically efficient and cost effective fish passage technologies that can be applied at a wide range of hydropower projects with a variety of fish species has been a major challenge for project owners and resource agencies. A new technology that has garnered considerable interest for fish passage applications is a fish transport tube developed by Whooshh Innovations. The Whooshh system uses a pressure differential to move fish through air inside a flexible tube, using a nominal amount of water for lubrication. This technology is currently being investigated primarily for upstream passage of adult salmonids, but other applications with additional species are also being considered. In particular, there are nine sturgeon species that occur in North America, most of which have been impacted by dams that limit their upstream and downstream movements to varying degrees. To examine the potential for the Whooshh system as a sturgeon passage technology, we evaluated the ability of lake sturgeon to be successfully introduced into and pass through a Whooshh tube and whether passed fish suffered any discernable external injuries or mortality. Testing was conducted with 40 sturgeon ranging in length from 635 to 1,016 mm that were gillnetted from Legend Lake in Keshena, Wisconsin. Twenty fish were passed through the Whooshh system and 20 were used as controls. All were assessed for external injuries after passage through the Whooshh tube and collection from a receiving pool (treatment fish) or direct placement into and recovery from the receiving pool (control fish). There was no indication of external injury to treatment fish caused by passage through the Whooshh system and no mortalities occurred for treatment or control fish. Based on these results, the Whooshh system appears to have potential as a method for passing sturgeon upstream or downstream at dams.

Amaral*, S. [1], A. Popper[2], M. Birmann[3], J. Caumartin[4], T. Pratt[5], and P. Jacobson[6]. [1]Alden Research Laboratory, Inc., Holden, MA; [2]University of Maryland (retired); [3]Scientific Solutions, Inc.; [4]Hydro-Québec; [5]Fisheries and Oceans Canada; [6]Electric Power Research Institute.

Can vibration or electromagnetic fields guide downstream migrating silver eels?

We tested the response of silver American eels to vibration and electromagnetic fields (EMF) to determine if either stimulus could elicit directional avoidance behaviors that could be used to guide eels to collection facilities above hydropower projects. Both stimuli were evaluated in test enclosures in a small flume at low velocity, with stimulus sources positioned at each end of the enclosures. Three vibration signals were selected after initial testing: 1) 100 ms, 10 Hz tone burst, 2) 100 ms, 50 Hz tone burst, and (3) 10 ms, 50 Hz half sign impulse. EMF were generated using alternating current electromagnets designed to produce a detectable EMF approximately 0.6 m in all directions. Trials were conducted at night and lasted one hour (20 min pre-exposure, exposure, and post-exposure observation periods). Vibration tests used 15 eels/trial, and there were three trials per stimulus; EMF tests used 10 eels/trial over three trials. Both tests also included three control trials. Avoidance behavior was assessed using a center-of-school (COS) approach where the distribution of eels was characterized by calculating COS through time for each of the three observation periods. COS positions demonstrated a statistically significant, sustained movement of eels away from the stimulus source during the vibration trials with the two tone burst signals (100 ms pulse duration at 10 and 50 Hz), though the magnitude of the avoidance was reduced with the 50 Hz tone. A weaker response was observed for the 10 ms-50 Hz half sine impulse signal. No avoidance behavior was observed during EMF exposure trials. Earlier studies have found limited effects of infrasound on eel behavior, but the vibration signals evaluated herein were effective in moving eels away from the stimulus. We are considering further research to optimize frequencies and signal characteristics to maximize eel avoidance responses and assess the utility of this approach for guiding eels outside of a small flume environment.

Aponte Clarke*, G.[1] and L. R. Day[1]. [1]Penobscot River Restoration Trust.
Looking After the Leap: Reflections on the Penobscot River Restoration Project
Dams have impeded fish movement in Maine's Penobscot River for centuries, blocking vital connections between inland waters and the sea; people and the river. Populations of sea-run fish, once measured in millions, have plummeted to fractions of their historic counts. In 2004, an innovative agreement between the Penobscot Indian Nation, a dam owner, conservation groups, and resource agencies aimed to turn the trend by resolving decades of conflict over fisheries and hydropower. Novel in scale and scope, the Penobscot River Restoration Project aimed to restore self-sustaining populations of sea-run fish through the strategic removal of multiple barriers while also rebalancing hydropower. Through this collaborative initiative, Project partners have successfully completed three coordinated fish passage projects to achieve timely and cost-effective outcomes. The nonprofit Penobscot Restoration Trust, a non-profit working with partners to implement the project, purchased and decommissioned three dams; removed the lowermost two, and built a nature-like bypass channel around another upstream. Widely hailed as a restoration milestone, 11 species of native fishes will benefit from significantly improved access to critical habitat within nearly 1,000 miles (1609 km) of watershed. These include Atlantic salmon, short-nose and Atlantic sturgeon, American shad, alewives, and American eel. In 2015, already 727,000 alewives passed the former Veazie dam along with 1806 shad, a dramatic increase from pre-Project counts. In this presentation, we will examine selected lessons learned from implementing this large-scale, multi-faceted restoration project. Our discussion will provide guidance to those endeavoring future restoration projects of all sizes and scope. We propose this presentation as the "anchor" to a Penobscot Project Session highlighting some of the Project's major accomplishments. These may include the recently completed Howland nature-like fish bypass, the Veazie dam removal, offshoot connectivity projects throughout the watershed, and the unprecedented multi-parameter before-after monitoring program.

Arruda*, S. D.[1], N. S. Wiberg[1], S. Harold and S. Comings. [1]Fuss & O'Neill, Inc.; [2]The Nature Conservancy.
No longer caught up in that old race – successful velocity barrier elimination for anadromous fish
The Nature Conservancy of Rhode Island (TNC) received funding from the U.S Fish & Wildlife Service (USFWS) under the Hurricane Sandy Resiliency Competitive Grant Program to undertake flood mitigation and the restoration of fish passage on the Lower Pawcatuck River at the White Rock Dam (Dam) located on the border of Connecticut and Rhode Island. As the lowest remaining dam on the Pawcatuck River, and the only dam lacking any formal fish passage structure, the Dam impeded access by anadromous fish to approximately 31 miles of mainstem riverine habitat. The Dam diverted normal river flow through a breached remnant millrace channel consisting of rocky sections with excessive slopes and flow velocities. According to a 2014 USFWS study, suitable fish passage did not exist through the channel due to velocities which exceeded the swimming abilities of all but a small minority of fish during the upstream migration season. As a result, TNC undertook removal of the Dam in 2015 to improve flood resiliency while providing successful passage of anadromous and resident fish species as well as overall riverine continuity. The project faced a number of challenges, including development of a management strategy for accumulated sediment that had choked the natural river channel below the dam since the raceway breach, mitigating potential impacts to private drinking water wells, discovery of an historic legacy dam behind the existing dam, mediating the design to accommodate recreational boating interests, and coordinating permitting between two state wetlands agencies. Project elements included implementation of bioengineered riverbank stabilization measures to protect developed properties below the dam, and the use of innovative construction contracting/permitting strategies to expedite this project from field investigations through design to completion in 16 months.

Avalos*, C.[1], P. G. Heisey[1] and D. Mathur[1]. [1]Normandeau Associates.

European Eel Passage Survival and Injury Through Three Propeller Type Turbines in France

Survival (direct effects) and injury rates of European eel, *Anguilla anguilla* (600-1,040 mm) in passage through three propeller type turbines (two located on the Rhine River and one on the lower Rhone River in France) were estimated via controlled releases of HI-Z tagged specimens at multiple entrainment depths within each turbine. Survival rates differed between turbine types. The number of runner blades, eel length, and entrainment location individually or in combination affected survival and injury rates. The direct 48h survival was substantially higher for the 4 bladed Kaplan units at Fessenheim (92.4%) and Beaucaire (92.3%) than the five bladed Kaplan unit at Ottmarsheim (78.6%). The Kaplan unit at Beaucaire is a horizontal bulb turbine; the other units are vertically oriented. Generally, eels released near the tip of the turbine blades incurred diminished survival rates and higher injury rates as compared to other release points. High recapture rates enabled injury rates, types and mechanisms to be determined with greater certainty. Most observed injuries were mechanically induced, with the primary injuries observed being severed or nearly severed bodies, bruising and or scraped bodies. Injury rates at the four bladed Beaucaire and Fessenheim stations were 6.5 and 11.5%, respectively. The injury rate at Ottmarsheim was 26.5%.

Avalos*, C.[1], R. Bleistine[1], and K. Long[2]. [1]Normandeau Associates; [2]Exelon Power Corporation.

Biological Studies of American Eel at the Conowingo Project

As part of a broad bioengineering investigation at Conowingo Hydroelectric Dam, MD, we studied the distribution and abundance of juvenile American eel, *Anguilla rostrata*, downstream of the dam over two years. Results of our study were expected to provide potential location(s) for an eel fish way when and if deemed desirable for the migrating population. Elvers and yellow eels were sampled between 24 June and 6 September 2011 using elver ramps (with Enka Mat and Akwa Drain substrates) and eel pots (for yellow eels). A total of 1,159 eels (1,100 elvers collected from the elver ramps and 59 yellow eels in pots) were collected in the spillway side downstream of Conowingo Dam compared to 166 elvers and 92 yellow eels collected in 2010. Capture of elvers differed between substrate type and location of ramps. The East ramps (located farther from the powerhouse) collected 539 elvers, with 133 collected in the Enka Mat substrate, and 406 elvers collected in the Akwa Drain substrate. The West ramps (location near the powerhouse) collected 561 elvers, with 405 collected in the Enka Mat substrate, and 156 elvers collected in the Akwa Drain substrate. High elver collections on both sides occurred on ramps parallel to walls, suggesting that elvers orient themselves upstream to structure. The collection locations of elvers were subject to spillage, which caused extensive damage to the collection gear. It was observed that the integrity of any structure below the spillway could be at risk during spillage. Elver lengths ranged from 87 to 188 mm TL, with an average size of 124.9 mm. The study period encompassed three new moon periods and two full moon periods; no strong relationship was observed between the number of elvers captured and lunar phase. Elvers were observed in abundance below crest gate 30. Yellow eels harvested from the eel pots totaled 151 for both study years; with one exception, all yellow eels were collected near the powerhouse location. The length of eels ranged from 300 to 689 mm TL, with an average length of 515.4 mm. Most elvers 1 or 2, and 3 to 5 years of age were split at 30%, respectively. A large gap in age at year 6 to 8 was apparent; larger eels were aged 9 to 17, with one at 19 years of age.

Barber*, J. [1], P. Hrodey[2], and K. Mann[1]. [1]U.S. Fish and Wildlife Service; [2]Great Lakes Fishery Commission.
Balancing connectivity with sea lamprey control
The U.S. Fish and Wildlife Service, as an agent of the Great Lakes Fishery Commission (GLFC), deploys a sea lamprey barrier program as an effective alternative to the use of pesticides to control the invasive, parasitic sea lamprey (*Petromyzon marinus*) in the Great Lakes basin. Decades of use and research have demonstrated that pre-existing and purpose-built physical barriers successfully deny sea lamprey access to spawning habitat in Great Lakes tributaries. However, barriers also reduce passage of non-target fishes and growing interest in removing barriers is presenting new management and policy challenges. A number of tools can be used to evaluate the effects of barrier removals and other management actions focused on increasing connectivity. The GLFC has invested additional effort in creating an inventory of barrier structures throughout the Great Lakes, cataloging habitat and lamprey density upstream of blocking barriers, and more recently in a web mapping application that will aid decision makers as they weigh barrier removal scenarios against the objectives of the Sea Lamprey Control Program.

Beran*, B.[1], and L. Hollingsworth-Segedy[2]. [1]Beran Environmental Services. [2]American Rivers.
Large wood debris and dam removal, part 2: refining river restoration practice through field experience
Beran Environmental Services was the construction contractor for an American Rivers dam removal project which involved combining Large Wood Debris (LWD) with two dam removals to provide a stable stream channel configuration and incorporate in-stream habitat on a complex restoration site in Western Pennsylvania. Completing this phased project over two successive years provided a unique opportunity to integrate the prior year's restoration efforts and their outcome into the implementation of Phase II. Additionally, the project provided a unique opportunity to refine the practice of combining LWD and dam removal. Combining LWD construction techniques and utilizing on-site materials enabled the stabilization and reconstruction of a high gradient reproducing brook trout stream, in a remote location, with minimal disturbance to the adjacent upland area as well as the stream corridor. This paper, which builds on the previous one, will focus on knowledge gained during the construction of two dam removal/LWD projects, including:

- Training before doing;
- Communicating with the designer;
- Using available on-site materials;
- Observing and interpreting existing conditions;
- Anticipating site evolution;
- Interpreting plans;
- Accommodating construction cost changes;
- Strategies for incorporating the techniques to other sites.

Bernier*, M.[1,2]. [1]ERT Contractor; [2]NOAA Restoration Center.
When a Rising Tide Doesn't Pass All Fish
Barriers at head of tide are arguably the most critical for sea run fish since they represent checkpoints to migration and can limit populations over entire watersheds. Despite the importance of these barriers, guidance for fish passage at tidal sites is scarce, and seems burdened by two narratives that may have never been valid. The first narrative is that migrating fish always come in on a flood (incoming) tide, and therefore passage need not be provided throughout an entire tide cycle, especially at low tide. A second narrative is that some diadromous fish, such as rainbow smelt and striped bass, will not use fishways and therefore need not be included as target species in design, while other species such as the American eel and Atlantic sea lamprey have superpowers for swimming ability and can pass any structure. These narratives have created a legacy of passage at head-of-tide structures that completely blocks some species and severely limits others, so that new thinking about fish passage in dynamic tidal environments is overdue. Real-life examples of head-of-tide projects that have been recently improved, or are in the feasibility stage, suggest a new paradigm for evaluating fish passage at tidal sites. What's required is 1) identifying the full suite of species that would migrate upstream if given the opportunity, 2) understanding a barrier's impact not only on fish passage but also on historic habitat, water levels, hydraulics and water properties such as temperature and salinity, 3) understanding how fish approach a structure under different tide and freshwater flow levels, 4) monitoring water levels (especially tide levels) to design favorable attraction and passage around or through structures, 5) accounting for climate change (sea level rise), in hydraulic design, and 6) understanding how predators of migrating fish use head-of-tide infrastructure to their advantage.

Bhattacharya, T. [1], and K. Ray[1]*. [1]Katwa College, Burdwan University, India.
Environmental toxicology with special reference to the study of fish biodiversity and physiology
Untreated sewage discharged from municipal and agricultural activities adds high concentrations of carbon-rich organic material and heavy metals to pollutant loads. We attempted to study the biodiversity indices and effects of available pollutants on fish physiology in the Ajoy and Ganga Rivers, and at their confluence using the air-breathing teleost, *Channa punctatus.* Fish from these rivers, were exposed to sub-lethal concentrations of mercuric chloride, cadmium chloride, phenol, ammonia, and a mixture of these four chemicals for 48 hours to determine the effects of these pollutants on fish diversity indices, hypothalamo-pituitary–thyroid axes, and carbohydrate metabolism. Fish diversity is rich and consistent in all seasons in the Ganga and Ajoy, but decreased significantly in the confluence zone. Inhibition of head kidney peroxidase enzymes is usually associated with a decrease in iodide peroxidase activity and blood thyroxine and tri-iodothyronine levels. An alteration in head kidney acid phosphatase activity indicates changes in lysosomal membrane characteristics. Stabilization of the lysosomal membrane may be explained by the reduction of head kidney lysosomal protease activity, which is essential for thyroxine and tri-iodothyronine release from the follicular cells of the head kidney. Elevated guaiacol or non-iodide peroxidase activity has a role in the detoxification of pollutants. Fish were found to be hyperglycemic, with a concomitant depletion in hepatic glycogen content and an increase in glucose-6-phosphatase activity on the 1st and 2nd days of exposure to pollutants. Cellular damage in the inter-renal tissues, haemopoietic tissue necrosis, shrinkage of capillaries in the glomeruli and increase in Bowman's space were observed in the hepatopancreas, accompanied by karyolysis, apoptosis and necrosis, and derangement of the pancreatic acini. Analysis of the available data suggest that pollutants deplete energy resources and disturb the metabolic pathway of *Channa punctatus* by adversely affecting thyroid function, carbohydrate metabolism, and causing histopathological lesions in the hepatopancreas and kidney.

Bolland*, J. [1], R. Stanford[1], N. Lewin[2], C. Williams[2], N. Angelopoulos[1], N. Baker[1], L. Murphy[1], I. Cowx[1], J. Reeds[2], K. Jerrom[2], J. Hooker[2], and R. Wright[2]. [1]University of Hull International Fisheries Institute; [2]Environment Agency.

Survival and health of European eels, Anguilla anguilla, entrained in water pumps of varying size, design and specification

European eel, *Anguilla anguilla*, are critically endangered, and the EC Eel Regulation (1100/2007) aims to protect them from human-mediated activities. It is suspected that a major impact on European eels is the entrainment of downstream migrating adults in water pumping stations which regulate upstream water levels for flood control, agriculture, industry and navigation. In England, the European regulation is enacted through the Eels Regulations 2009 Statutory Instrument (the Eel SI), which includes authority to screen water intakes (including pumping stations) abstracting greater than 20 m^3 a day. There are 913 pumping stations in England, but evidence of eel injury and mortality during pumping station operation is limited to anecdotal reports. Robust site-specific assessments are required to confirm whether pumping stations are compliant under the Eels Regulations 2009, or require eel protection measures. A protocol for assessing survival, external and internal condition (including parasitology, virology and histopathology), behavior and delayed mortality of entrained eels was developed. Individual eels were captured, condition assessed before entrainment and tagged to enable them to be identified when recaptured after passing through pumps. Batches of eels representing "normal" condition in the catchment and control for net damage were also incorporated into the investigation. Five pumps of varying size, design and specification were investigated during the silver eel migration in 2015. The greatest level of mortality was found for the smallest axial flow pump with the most blades on the impeller and the highest rotation speed, whereas larger mixed flow pumps with fewer blades and slower rotation speed did not kill eels. Eels entrained at a site where an alleged 'fish-friendly' pump was installed within original pipework and outfall, also suffered some mortality after 48-hours. Key results will be presented, including types of internal and external injuries observed.

Boucher*, J. [1], and R. McBride[1]. [1]National Marine Fisheries Service, Northeast Fisheries Science Center.

Dynamics of the 2015 spawning migration of American shad (Alosa sapidissima) in the Connecticut River

Although great effort has been invested in restoring the Connecticut River Atlantic salmon population, with no sign of improvement, other anadromous species have rebounded greatly during this same period. American shad is one of the success stories, as passage at the first dam (Holyoke) has increased from 4899 to 370,506 between 1955 and 2014, with a high of 721,336 in 1992. Presumably, adult shad migrating past the dams are using this expanded range of habitat for spawning, but this has been poorly documented, and is the focus of this work. In 2015, adult shad were collected at four locations along the river: at the river mouth (Old Lyme, CT), at Holyoke Dam (Hadley, MA), at the Cabot Power Station (Turners Falls, MA), and the Vernon Power Station (Vernon, VT). Males and females entered the lower river in late April, while temperatures were still below 14 C. Females were consistently larger (both length and weight) and older than males. However, there was a higher ratio of males to females at all sites, except Holyoke. Sex-based ages were not different among locations or time periods, indicating a well-mixed population throughout the spawning season. Spawning-condition females, including running-ripe individuals, were collected at the most upstream sampling site (southern Vermont), indicating that increased fish passage at these dams has opened up nearly all of the potential historic spawning habitat for American shad. The age structure of downstream-migrating shad remained similar to upstream migration for both sexes, with no apparent age bias in survival to downstream passage. Truncated age distributions, combined with repeat spawners comprising only 2% of the population, indicate that American shad in the Connecticut River may no longer be robust to changes in their environment.

Bowden*, A.[1], D. Borggaard[2], and B. Gahagan[3]. [1]The Nature Conservancy; [2]National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office; [3]MA Division of Marine Fisheries, Annisquam River Marine Fisheries Station.

Linking Passage, Habitat Quality and Range-wide Survival, New Approaches for Conservation of River Herring

Over the past 15 years river herring populations have decreased in many watersheds and recovery has been sporadic across the species' range. In response, several states closed river herring harvest, and the Atlantic States Marine Fisheries Commission (ASMFC) mandated closures coastwide with exceptions for states with approved sustainable fishery plans. In August 2013, the National Marine Fisheries Service (NMFS) found that listing river herring under the Endangered Species Act was not warranted, but also committed to immediate action steps, including addressing information gaps and expanding collaborations. NMFS and ASMFC are leading diverse partners and utilizing their expertise in the development and implementation of a dynamic conservation plan for river herring that identifies key research needs and conservation efforts range-wide, tracks project implementation, and monitors the progress of restoring these important species. Given the many threats that river herring face across their complex life cycle, conservation must be holistic, and coordination is essential. In response to the data-poor status of river herring, new collaborations among state and federal agencies, academic researchers, NGOs, municipalities and others have arisen. These collaborations have led to numerous successes such as adoption of new technologies, increasing innovation in monitoring techniques, and development of new metrics to monitor or predict abundance. Collaborations are a critical component of improving river herring access to habitats and habitat quality, as well as important for range-wide survival.

Burke*, M.[1], L. Stiles[2], G. Aponte Clarke[3], B. Kulik[2], and S. Fuller[4]. [1]Inter-Fluve, Inc.; [2]Kleinschmidt Associates; [3]Penobscot River Restoration Trust; [4]SumCo Eco-Contracting.

Aspects of Design and Construction of the Howland Fish Bypass Channel, Piscataquis River, Maine

Last to be implemented of the three major fish passage enhancements forming the Penobscot River Restoration Project, the Howland bypass channel is a notably large nature-like fishway, the design and construction of which included several novel elements. The channel was designed to operate passively over fish passage operational flows ranging from 250 cfs to 1,800 cfs in the channel itself, with peak flood flows up to 13,000 cfs routed through the bypass. The design resulted in a 100-foot wide cross section with varying cross slope that includes a low flow channel and an over bank to progressively provide zones of passage opportunity within target velocity and depth criteria. Over the 1,000-foot channel length, pools and boulder refugia elements were spaced in consideration of the anticipated physical capacities and behavioral traits of the target fish community. The proportion of the overall Piscataquis River flow that is routed through the bypass within the operational range was maximized and carefully balanced with spillage over the remaining 400-foot long spillway to manage a potentially competing far-field attraction signal, while also maintaining a minimum impoundment level and providing channel stability during extreme floods. The remnant dam structure was also modified to provide supplemental downstream passage pathways, and flexibility to adapt facility operation based on future observations of fish utilization. Channel construction involved substantial bedrock removal and a novel approach to channel substrate installation. The bypass channel was substantially completed in 2015 and is presently being subjected to flow testing. The presentation will provide an overview of the design, construction and observations of the early performance of the channel.

Burrows*, J. [1]. [1]Atlantic Salmon Federation.
Reconnecting the Penobscot River with its Tributaries
Despite several important large dam removals, substantial habitat restoration and fish passage work remains to be done in order to get sea-run fish species to the majority of their historic habitat in the Gulf of Maine. In the Penobscot River watershed, the Atlantic Salmon Federation (ASF) has focused on opening-up key tributaries for Atlantic salmon, American shad, American eel, alewives, blueback herring, brook trout, and sea lamprey as part of their Maine Headwaters Project. Through numerous small dam removal, fishway construction, and culvert replacement projects, access has been restored to more than 200 miles of stream habitat and more than 8,000 acres of lake and pond habitat in the Penobscot in recent years. Examples of different projects will be shared in this presentation along with lessons learned from working with diverse constituencies and stakeholders in on-the-ground restoration projects.

Castro-Santos*, T. [1], and K. Sprankle[2]. [1]USGS-S.O. Conte Anadromous Fish Research Center; [2]U. S. Fish and Wildlife Service, Connecticut River Coordinator's Office.
Passage performance and migratory delay of American shad at the Holyoke Fishlift.
Holyoke Dam is the first barrier to American shad migrations on the Connecticut River. Passage is provided with dual fishlifts, and the perceived success of the structure has contributed to the promotion of lifts as a solution for passage for many 'non-leaping' species. During 2011 and 2012 we performed a large-scale telemetry study of shad, tagging them at the river mouth and monitoring passage throughout their migration. More than 65% of tagged migrants arrived at Holyoke in each year, and of these 74% passed in 2011 and 66% passed in 2012. This is comparable with some of the best passage percentages observed for this species at high-head dams. Delays were extensive, however, with many fish taking more than two weeks to pass. Migratory motivation was enhanced, but passage success was reduced at high flows, producing a mismatch in passage and migratory motivation. The extensive delays may affect migratory range, even for those fish that pass.

Chase*, B. [1], E. Clark[1], and B. Gahagan[1]. [1]Massachusetts Division of Marine Fisheries.
American Eel Passage Improvements at Coastal Rivers in Massachusetts
The Massachusetts Division of Marine Fisheries has worked with dam owners and partners to install structures designed to improve American eel passage in coastal Massachusetts since 2007. American eel had traditionally been considered a species that needed little passage assistance in coastal rivers as it exhibits behaviors outside of the limits of other migrating diadromous fish. Increasing awareness of the impact of various obstacles to eel passage, gained while working on river herring fishways, prompted efforts to evaluate requirements for eel passage. This effort has led to inclusion of eel passage in regional planning for diadromous fish passage restoration and the installation of nine eel passage structures since 2007. Three eel ramps are AC powered pumped-supply systems, two are solar powered pumped-supply systems, and four are customized gravity-fed systems. Most sites include standardized monitoring protocols adopted from the Atlantic States Marine Fisheries Commission's East Coast-wide effort to monitor the annual abundance of glass eels. Our approach to site selection, system design and monitoring will be described.

Chelminski*, M. [1], and R. MacEwan[1]. [1]Stantec Consulting Services Inc.
Amethyst Brook Restoration Project: Co-Evolution of a Project and a River with Two Dam Removals
This presentation addresses scoping, permitting and design, and implementation for the removal of two dams on Amethyst Brook in Pelham, Massachusetts, as part of the Amethyst Brook Restoration Project (Project) in Pelham, Massachusetts. The Project was developed and implemented with multiple partners, including the Massachusetts Division of Ecological Restoration and American Rivers, and stakeholders, and is the subject of ongoing geomorphic studies. This presentation is focused on permitting and design for removal of the dams as part of the Project. Project scoping was initiated in 2009 with a site reconnaissance study to evaluate removal of the Bartlett Rod Shop Company Dam (BRSCD). Primary motivators for removal of BRSCD included a dam safety order and potential for restoration of aquatic habitat and fish passage. Design and permitting for removal of BRSCD was initiated in 2010, and the dam was removed in 2012. Identified constraints to removal of this dam included accumulations of coarse-grained sediment to approximately 12 feet above the anticipated thalweg upstream from the dam. In lieu of attempting to construct a stable channel upstream from the dam, the design approach included onsite repositioning of sediment with the expectation that the upstream channel would evolve following dam removal. The channel upstream and downstream from BRSCD evolved rapidly following dam removal, and vertical degradation of the upstream channel resulted in exposure of a previously undocumented dam (Timber Dam) approximately 500 feet upstream from BRSCD in the spring of 2013. Assessment, permitting, and design for removal of Timber Dam were initiated in 2013, and Timber Dam was removed in January 2016. This presentation addresses a single chapter in the larger story of the Project and is focused on changes in the scope and extent of permitting and design for removal of Timber Dam in 2016 relative to work for removal of BRSCD in 2012.

Christensen*, P. [1]. [1]R2 Resource Consultants.
North Fork Floating Surface Collector Design, Operation, and Results
The North Fork Hydroelectric Development is part of the Clackamas River Hydroelectric Project in northwest Oregon, owned and operated by Portland General Electric (PGE). North Fork Dam was constructed in 1957, along with a 1.7-mile-long fish ladder for upstream anadromous fish passage around two dams, and a downstream migrant collector and bypass system incorporated into the ladder for passage downstream around three dams. Anadromous species present in the Clackamas River include Chinook and Coho salmon, Steelhead Trout, and Pacific Lamprey. Although the original bypass did attract and safely pass a portion of these species, results were inadequate to meet the current bypass standards, and as part of the relicensing settlement agreement PGE agreed to construct a 1,000-cfs Floating Surface Collector (FSC) and bypass improvements to supplement the existing collector. During design of the FSC a presentation was provided at the 2013 Fish Passage Conference highlighting the unique design features of the North Fork FSC relative to other floating collectors, including direct passage of fish from the FSC to a bypass pipeline, combining of fish from the new and existing collectors, and unique flow control features. Construction was completed in July of 2015 and the FSC is now operational. Hydraulic analysis of the operating FSC showed that no adjustments were required to meet federal design operating criteria. Official biological testing of the new facilities will begin in the spring of 2016 and initial results will be available by the time of the presentation. Unofficial testing occurred in the fall of 2015 and results were very promising. This presentation will provide an overview of as-constructed features of the design, lessons learned, project operations, and preliminary biological results of field studies.

Clingerman*, J.[1], J. T. Petty [2], F. Boettner [1], F. Orr [3], and M. Strager [2]. [1]Downstream Strategies; [2]West Virginia University; [3]Critigen.

A Multi-Scale Web-Based Fish Habitat Decision Support Tool

The technological advancements of the 21st century have revolutionized environmental science, granting planners and decision makers access to an enormous breadth and depth of revelatory data. Pair this with the ever present reality of limited funding and resources, and the task of maximizing the ecological "bang for your buck" of each aquatic habitat project can seem impossibly daunting. With an eye on solving this dilemma, we developed an approach that synthesizes complex, peer-reviewed science into an intuitive, map-based process designed to underpin the enterprise of putting science to work. The Fish Habitat Decision Support Tool (FHDST) is the first implementation of this framework. The FHDST provides resource managers and the public access to data, models, and prioritization tools within several fish habitat assessments across the Great Plains, Midwest, and Atlantic Coast. The mapping and analysis capabilities are akin to a lightweight GIS, but are accessible by any web browser. Datasets key to decision making efforts are included, such as landscape variables (both natural and anthropogenic), socioeconomic information, and predictive model results. Model results, which vary geographically, describe natural habitat quality, biological stress, and predicted habitat condition for distinct aquatic endpoints. These data can be explored at several scales through thematic mapping, and analyzed via two methods: ranking and futuring. Ranking allows resource managers to define their own selection criteria for prioritization while the futuring tool models the effects of user-defined habitat changes locally and downstream. Understanding baseline fish habitat conditions up and downstream from a specific barrier to fish passage will aid managers as new solutions are evaluated. Together, the data visualization, ranking, and futuring components of the FHDST offer a coherent approach to these and other resource planning decisions that can result in sustainable leveraging of finite resources.

Coe*, T. [1], P. Kibel[1], G. Morier-Genoud[2], M. Raeder[3], and P. Kemp[4]. [1]Fishtek Consulting; [2]Poyry; [3]Xayaburi Power Company Limited; [4]Southampton University.

The swimming ability of wild-caught Mekong fish species and implications for fish pass design in SE Asia

The Mekong River contains a very biodiverse fish fauna, of which some are endemic to the river and many are migratory. The Xayaburi Hydropower Plant is the first of many mainstream projects being constructed in the lower Mekong basin and a mandatory part of its construction is the inclusion of efficient fish pass facilities. Presented here are the results of a unique investigation into the swimming ability of Mekong fish species, carried out using wild-caught fish in a purpose-built large, open channel flume constructed on the banks of the Mekong. The burst speed of five representative species was tested, as well as the volitional swimming abilities of a large number of species, at three different water velocities (0.8, 1.2 and 1.6 m/s). Burst swimming speeds varied between 7.3 and >16 bodylengths/second depending on the species tested. For all five species tested, swimming duration was significantly affected by water velocity: higher velocity resulting in shorter swimming duration. For the majority of species there were more volitional movements in the flume at the lowest water velocity (0.8 m/s) and velocity had a significant impact on the maximum distance moved up the flume. At the highest velocity (1.6 m/s), movements within the flume were infrequent for most species. The results support the design at Xayaburi of a hybrid vertical-slot pass with four slots of different sizes and a maximum average velocity of 1.2 m/s (in the largest slot), with lower velocities in the smaller slots. This design ensures heterogeneity of flow and low velocities in the smaller slots to accommodate the widest range of fish species. Furthermore, this new knowledge helps to explain why some fish passes on tropical rivers are inefficient, and has implications for fish pass design in the Mekong basin and throughout SE Asia.

Collins*, M.[1,2], D. D. Tullos[3], J. R. Bellmore[4], J. A. Bountry[5], P. J. Connolly[6], P. B. Shafroth[7], and A. C. Wilcox[8]. [1]National Marine Fisheries Service, [2]NOAA; [3]Biological and Ecological Engineering, Oregon State University, Corvallis, OR, USA; [4]Pacific Northwest Research Station, USDA Forest Service, Juneau, AK, USA; [5]Sedimentation and River Hydraulics Group, Bureau of Reclamation, Denver, CO, USA; [6]Western Fisheries Research Center, Columbia River Research Laboratory, USGS, Cook, WA, USA; [7]Fort Collins Science Center, USGS, Fort Collins, CO, USA; [8]Department of Geosciences, University of Montana, Missoula, MT, USA.

Synthesis of common management concerns associated with dam removal

Practitioners must make dam removal decisions in spite of uncertainty about physical and ecological responses. This can result in implementing structural controls or other interventions at a site to avoid anticipated negative effects, sometimes even if a given concern is not warranted. We used a newly-available dam removal science database and other information sources to explore seven frequently-raised issues we call "Common Management Concerns" (CMCs), investigating their occurrence and the contributing biophysical controls. We describe these controls to enable managers to better assess if further analyses are warranted at their sites before interventions are planned and implemented. The CMCs addressed are: degree and rate of reservoir sediment erosion; prolonged or excessive channel incision upstream of dam sites; downstream sediment aggradation; elevated downstream turbidity; drawdown impacts on local water infrastructure; colonization of reservoir sediments by non-native plants; and expansion of non-native fish. The relative dearth of case studies available for many CMCs limited the generalizable conclusions we could draw about prevalence, but the available data and established understanding of relevant processes revealed important biophysical phenomena controlling the likelihood of CMC occurrence. To assess CMC risk, managers should concurrently evaluate if site conditions suggest the ecosystem, infrastructure, or other human uses will be negatively affected if the biophysical phenomenon producing the CMC occurs. We show how many CMCs have one or more controls in common, facilitating the identification of multiple risks at a site, and demonstrate why CMC risks should be considered in the context of other important factors like watershed disturbance history, natural variability, and dam removal tradeoffs. Better understanding CMCs and how to evaluate them will enable practitioners to avoid unnecessary interventions and thus maximize opportunities for working with natural processes to restore river function.

de Bie*, J. [1], and P. S. Kemp[1]. [1]University of Southampton.

Horizontal vs. vertical fish screens: efficacy in guiding fish schools

Although many fish species aggregate during certain periods of their lifecycle, rarely has this collective behavior been applied to fish passage studies. To aid downstream migrants, a variety of screening devices are implemented that block/divert them away from potentially harmful water turbines and intakes. Hydrodynamics associated with screens can substantially vary and possibly affect fish school cohesion, leading to delay and increased predation, and ultimately affecting successful passage. An understanding of how hydrodynamics near fish screens affect school cohesion and behavior is needed. Traditionally, bars in screens are oriented vertically, yet it is hypothesized that a horizontal orientation imposes a more beneficial cross-screen sweeping flow that could promote guidance towards and passage through downstream bypasses. Furthermore, as fish are usually higher than wide, it is thought they are less likely to pass through horizontal bars and are better able to free themselves when impinged. Both assumptions lack empirical testing. Studies were executed that assessed the response of fish schools to screens with horizontal and vertical oriented bars in an experimental setting. Chub (Squalius cephalus) were chosen as a representative for residential fish species that migrate within rivers. Schools were released under high and low discharge and video recorded as they moved downstream and encountered screens. ADV measurements were used to quantify hydraulic conditions associated with different screens. Results showed that chub initially reacted differently to horizontal screens than to vertical ones, and different efficiencies (total fish passed as proportion of total fish approached) emerged. Behavior was linked to flow conditions that varied for different horizontal screens and their vertical counterparts. Findings suggest horizontal screens have advantages over traditional vertical ones in terms of hydraulics and behavior. The presented data could aid in improving future fish screen efficiency to accommodate a range of species.

de Bruijne*, W. [1, 2]. [1]LINKit Consult; [2]Wanningen water consult.

The fish migration project at the Gabčíkovo Dam, Slovakia

In the Danube river basin, up to 500 priority fish migration barriers have been identified. The three largest dams, which were also farthest downstream on the Danube's main stem, Iron Gate Dams 1 & 2 and the Gabčíkovo Dam, were listed as of 'utmost priority' in the ICPDR (International Commission for the Protection of the Danube River basin) Danube River Basin Management Plan. In 2011, at the request of Romania and Serbia (and encouraged by the ICPDR), the FAO conducted a scoping mission to explore general fish migration solutions at Iron Gate Dams I and II. Subsequent to the FAO scoping mission (2013) a consortium of Dutch companies and a Romanian research institute (DDNI) performed a prefeasibility study for fish migration restoration measures at the Iron Gates site (presented in Madison – Fish Passage Conference, 2014). Following these projects, a consortium of Dutch companies and the World Fish Migration Foundation conducted a scoping mission at the next barrier upstream from the Iron Gates: the Gabčíkovo dam on the border of Slovakia and Hungary. This dam is in Slovakian territory, therefore a number of Slovakian organizations and international experts were informed, and invited to attend an on-site workshop. They included WWF Slovakia, the ICPDR, Universities of Vienna and Bratislava, relevant ministries and NGOs. The Gabčíkovo Dam Project consisted of a field visit, data collection and analysis (including dam structure, bathymetry, hydrology, ecology), predesign of the most feasible fish migration solutions, rough cost estimate, stakeholder mapping and meeting. Finally, a roadmap for following steps was developed. This presentation will focus on the main outcomes of the scoping mission, the project's process, key questions remaining and following steps on the roadmap.

de Bruijne*, W. [1, 2], and R. Mulder[3]. [1]LINKit Consult; [2]Wanningen water consult; [3]Province of Fryslan, The Netherlands.

Fish Migration River – Monitoring and evaluation after construction

The Afsluitdijk Dam that separates the Wadden Sea from Lake Ijsselmeer is a large fish migration barrier in the Dutch Delta. To restore connectivity and thereby allow fish to pass there is an initiative to build the largest fishway in the world, the Fish Migration River (FMR), at the Kornwerderz and sluice complex. Construction is foreseen in 2019-2021 and part of the project is an extensive and integral monitoring program in conjunction with a number of organizations, among which are governmental organizations, universities and NGOs. At present several aspect of the monitoring program have been detailed. The goals of the monitoring plan are to evaluate: 1) overall passage past the Afsluitdijk Dam to and from Lake Ijsselmeer over the entire Kornwerderz and sluice complex, 2) attraction efficiency of the FMR, 3) passage efficiency of the FMR, and 4) use of the FMR as habitat and for acclimatization during transition into freshwater. We are also exploring the possibilities of including facilities to do fundamental research on fish behavior in fish ways in tidal areas. The presentation includes an overview of previous and ongoing monitoring in the area to describe the current state of knowledge. The monitoring plan to evaluate points 1-4, as described above, is also presented. This includes suitable methods and locations for a monitoring program which addresses a broad spectrum of target species that vary in abundance. Furthermore, the possibilities to perform research in the FMR are discussed.

Deligan*, T. [1], and J. McKnight[1]. [1]Whooshh Innovations, LLC.

Advances in Fish Passage Technology – How to Move Migratory Species Safer, Farther, Faster

Whooshh Innovations™ has developed a proprietary water-sparing device that moves fish through soft flexible tubes using pressure differentials and light water mist. Over the past two+ years, Whooshh has successfully demonstrated that it is indeed possible to "Whooshh" live migratory fish gently, safely, and efficiently over/around barriers, to/from rivers, and within a hatchery setting. In 2014, the Washington Department of Fish & Wildlife purchased a mobile Whooshh system, successfully transporting 10,000+ live Chinook salmon; in 2015, WDFW successfully "Whooshhed" 16,000+ live Chinook. The agency plans to use the system again in 2016, and is considering expanding the system's use at other installations. Safety and efficacy studies were also completed in this time frame. In 2014, the Yakama Nation compared the mortality rates and egg survival of salmon using the Whooshh system versus traditional methods of fish transport. Researchers concluded that the condition of "Whooshhed" fish proved equal to or better than moving via traditional methods. In late 2014, under a U.S. Department of Energy grant, the Pacific Northwest National Laboratory (PNNL) compared spawning rates and egg survivability of fish that were sent through two separate lengths of Whooshh tube with traditional trap & haul fish. PNNL concluded that the Whooshh system proved equal to or better than trap & haul, and recommended further in-field study. Whooshh also conducted two studies of volitional entry systems in 2015. For the City of Newport, OR, Whooshh successfully moved live rainbow trout using a volitional system. On the White River in Washington, Whooshh built a volitional entry system for pink salmon. This project showed convincingly that salmon, attracted to water flow, could enter the Whooshh system without human intervention. In 2015, Alden Labs and the Electric Power Research Institute used the Whooshh system to test live sturgeon transport; moving invasive carp was also successfully completed.

Duguay**, J.[1], J. Lacey[1], and J. Gaucher[2]. [1]Université de Sherbrooke, Sherbrooke, Québec; [2]Hydraulic Engineering, Hydro Québec, Production Group.

Experimental validation of an open-sourced and a commercial numerical model for simulating flows within a large scale pool and weir fishway in Québec, Canada

The ability of OpenFOAM's free and open-source interFoam solver to model the complex three-dimensional flow field of a large weir and pool fish passage located in Eastern Québec, Canada, is validated. The predicted flow field within a typical pool of the fishway are compared to velocity and turbulence data obtained through acoustic Doppler velocimetry (ADV), measured water surface profiles and results produced with a leading commercial computational fluid dynamics code (FLOW-3D). OpenFOAM showed much agreement with the depths, flow rates, pool volumes and general flow structure predicted by FLOW-3D. Both models suggest the presence of a large horizontal roller in the pool, however ADV measurements do not support its presence, indicating the standard k-epsilon model may not sufficiently capture the levels of turbulent induced momentum diffusion within the pool. Nevertheless, OpenFOAM accurately predicted maximum velocities and water surface levels to within an average of 5% of measured values. The general agreement between modeled and measured values suggests the outlined OpenFOAM modeling approach is acceptable for modeling similar free surface three dimensional ecohydraulic applications.

Duncan*, W., J. Henning[1], J. Hogrefe, D. Ratcliff, W. Rice, and S. Wells. U.S. Fish and Wildlife Service.
Landscape Approaches to Aquatic Connectivity Improvement: A review and panel discussion of fish passage prioritization tools and watershed scale biological outcomes
Prioritization tools intended to facilitate fish passage project selection have proliferated over the past 5-10 years. Each tool is different, with unique objectives, input datasets, outputs, and functionality. The preceding talks have spanned multiple geographies, taxonomic groups, and disciplines. During this review and panel discussion, we will discuss strengths, potential improvements, and future directions for the development of fish passage prioritization tools. We will discuss opportunities and impediments to implementing scoring and ranking techniques, optimization models, and watershed scale biological monitoring. Topics of interest will be solicited from the audience to ensure a lively discussion.

Druschke C.G. University of Rhode Island
The Future of Dams: Developing a stakeholder-engaged, solutions-focused framework for decision-making
Hydropower is a major source of renewable, low-carbon energy in New England. More than 50 hydropower dams in the region are scheduled for relicensing in the next decade, requiring communities to make critical decisions about the future of this infrastructure. Beyond hydropower dams, iconic mill dams are an integral part of New England's industrial history and continue to provide some recreational, water supply, and aesthetic benefits for many communities. Yet they block ecologically and economically important fish migrations and many pose safety and liability risks. With so many competing interests over the presence and function of dams, decisions about their future must be made thoughtfully, integrating environmental, social, and economic tradeoffs. This presentation introduces the Future of Dams project, a multi-state, interdisciplinary research initiative supported in part by a $6 million National Science Foundation EPSCoR grant that is working to develop a methodology for making these important decisions about the future of dams. Using a multidisciplinary approach that integrates fish biologists, engineers, landscape designers, economists, ecologists, hydrologists, and communication researchers through the use of innovative stakeholder-based modeling efforts, we work to strengthen the connection between scientists and decision-makers by creating tools to support governments, communities, and dam owners as they make decisions about the future of New England dams.

Ecret*, J. U.S. Fish and Wildlife Service.
A Three Component Mitigation Approach for Fish Passage in St. Lawrence River Tributaries
The U.S. Fish and Wildlife Service's New York Field Office (NYFO), through funding provided by the Fish Enhancement, Mitigation, and Research Fund (FEMRF), has been implementing a multi-component approach to evaluate tributaries to the St. Lawrence River for potential fish passage concerns. During 2009-2014, over 200 potential fish barriers within 24 tributaries in Jefferson and St. Lawrence Counties have been evaluated. In order to prioritize mitigation efforts, the NYFO has also been conducting in-stream habitat, as well as migratory and resident fish community surveys within these systems since 2012. These combined data sets allow for a more efficient approach in identifying fish barriers within tributaries with greater habitat potential; thus allowing for a more effective approach to prioritize these ongoing mitigation efforts. Through collaborative efforts with the Partners for Fish and Wildlife Program, the NYFO has completed two successful fish barrier removal projects restoring 28 miles of stream for riverine spawning fish.

Ekren*, M. G.[1], Ağıralioğlu, N.[1] and H. G. Coşkun[2]. [1]Department of Hydraulics and Water Resources Engineering, Istanbul Technical University, Turkey; [2]Department of Geomatics Engineering, Istanbul Technical University, Turkey.

Secure Fish Passage Design for Sustainable Fish Populations: A Case Study in the Vereinigte Weißeritz River

Fish passage can be defined as any form of conduit, channel, lift, other device or structure which facilitates the free passage of migrating fish over, through or around any dam or other obstruction, whether natural or man-made, in either an upstream or a downstream direction. Fish passage is considered a necessity where a dam or hydropower plant separates a target species from needed habitat. Small hydropower project development has been, for the last decade, one of the sectors in the energy field that has been very active. One of the main environmental challenges of small hydropower development is related to both upstream and downstream fish passage. The quantity, quality, and accessibility of up and downstream fish habitat and fish migration can play an important role in population sustainability. Fish populations may be blocked, delayed, injured, killed or otherwise lessened by hydropower facilities. Existing disfunctional fish passage structures represent a systematic failure due to inadequate interdisciplinary cooperation on this subject. In order to tackle such challenges and insure secure fish passages, an ecohydraulics approach should be adopted for projects where hydropower and fish passage are both necessities. This investigation seeks to develop an innovative design for a currently disfunctional fish passage near the WKA Bienertmühle weir on the Vereinigte Weißeritz River (Dresden, Germany) to help target fish species make their way on both upstream and downstream migrations and promote sustainable fish populations.

Frick*, K. [1], S. Corbett[1], M. Hanks[1], and M. Moser[1]. National Marine Fisheries Service; Ocean Associates.

Passage Options for Climbing Lamprey: If You Build it They Will Come

Dams are an impediment to the spawning migration of many species of lamprey worldwide. Methods such as velocity reduction, lamprey-friendly structural modifications, and lamprey-specific fishways have been implemented to improve fishway passage for these species. We investigated climbing behavior of adult Pacific lamprey (*Entosphenus tridentatus*) in an effort to understand and improve their passage performance in the Columbia River basin. The ability of adult Pacific lamprey to climb has enabled development of targeted passage structures; vertical elements with a smaller footprint are needed for these structures in areas where space is limited. We designed an experimental vertical climbing structure that could collect and pass lamprey without impacting co-occurring salmonid species. The 1.6-m aluminum wetted wall was outfitted with three regulated water delivery mechanisms (overflow, upwelling, and sidewelling), allowing us to test Pacific lamprey vertical climbing ability in relation to flow and delivery type. Passage success and climbing time were recorded for individual Pacific lamprey (n=122). For those that interacted with the structure within the 2.5 h observation period (n=104), 94% successfully ascended the wall. Average time from first interaction with the structure to exit ranged from 19.5 to 47.0 minutes. Success rates and passage times were not significantly affected by either flow or water delivery treatments. This indicates that vertical elements can facilitate lamprey passage in the flow range we tested (6 – 180 liter·min-1). Behavioral observations suggest some refinements to the climbing structure.

Gahagan*, B. [1], and Scott Elzey[1]. [1]Massachusetts Division of Marine Fisheries.

Adaptive Management of Fish Passage at a Weir-Pool Fishway

In 2013, the Massachusetts Division of Marine Fisheries (MDMF) initiated a program to revive the impacted river herring (Alewife *Alosa pseudoharnegus* and Blueback Herring *A. aestivalis*) run on the Parker River, in northeastern Massachusetts, USA. As part of this effort, repairs and modifications were planned to an aged pool-weir fishway at the Woolen Mill Dam, just above the head of tide. Passive integrated transponder (PIT) technology has served as a powerful tool that allows a number of passage metrics to be accurately quantified, but most studies have not taken advantage of the long lifespan of this tag type. Instead they offer snapshots of passage in one or two years. Unfortunately, fish passage structures are seldom static, and passage can fluctuate based on a number of conditions, including maintenance and management (or lack thereof). To monitor the response of river herring to perceived improvements at the Woolen Mill Dam fishway in the fall of 2013, more than 325 river herring were PIT tagged per spring from 2013 to 2015. Tagging occurred below the dam and passage through the fishway was monitored using four antennae in the ladder and one on the spillway. We employed PIT technology in an adaptive management framework to assess how steps in the repair and flow management at the fishway impacted passage. Passage at Woolen Mill Dam was affected by repair to the downstream area and fishway entrance and some modifications produced negative effects. Alewife were more likely to successfully pass the ladder than Blueback herring and passage rates appeared lower for river herring immediately after tagging compared to fish tagged in prior years.

Gisen*, D. [1], P. Heneka[1], and C. Schütz[2]. [1]Federal Waterways Engineering and Research Institute, Germany; [2]Federal Institute of Hydrology, Germany

Fish-size-based criteria for assessing attraction flow

Effective fishway entrance attraction is crucial for supporting upstream fish migration at dams. One way of investigating attraction flow plumes is to generate hydraulic data through 3D CFD models or physical models. Currently these data are interpreted in a qualitative manner based on expert knowledge and verbalized criteria. To increase transparency and comparability, we propose a quantitative evaluation framework for attraction flows using a checklist of numerical criteria. Given a set of steady flow fields resulting from, e.g., alternative entrance geometries or discharges, the procedure is as follows. First, the flow field is classified by mean velocity magnitudes into areas of stagnation, sustained swimming speed, prolonged swimming speed, and burst swimming speed. The ranges are computed by means of a simple relationship based on fish total length, TL. Different TL represent relevant species and their swimming capacities. Second, possible migration corridors are identified dependent on the spatial extent of the velocity areas. Third, a checklist of criteria based on fish sizes and a speed-fatigue relation is processed. For each criterion, the model value is compared to an evaluation value, resulting in one of the three grades 1 (success likely), 2 (success unsure), or 3 (success unlikely). German technical guidelines are taken as a basis for the evaluation values. The framework allows estimating the functionality of alternative designs. We recommend to either compare the grades for each criterion individually or to develop weights for a mean value. For the future, fish investigations are needed to support our assumptions, to refine the evaluation values, and to identify important additional criteria. Eventually the framework will increase objectivity and lessen individual expertise necessary for evaluating model results. Thus it will become easier to discuss results between parties involved and to develop common standards for planning fishway attraction.

Gleason*, N. [1], and R. Mesko[1]. [1]U.S. Army Corps of Engineers.
Skokomish River Basin Ecosystem Restoration

The U.S. Army Corps of Engineers has finalized a Feasibility Report and Environmental Impact Statement for the Skokomish River Basin Ecosystem Restoration Project. The Skokomish River is located on Hood Canal, a natural fjord-like arm of Puget Sound identified by the U.S. Environmental Protection Agency as a watershed of national significance. The river basin hosts four salmonid species listed under the Endangered Species Act. Priority objectives for the study were providing year-round fish passage near the confluence of the North Fork and South Fork of the Skokomish River as well as improving the quantity, quality, and complexity of pool habitat. The Corps and non-federal sponsors, the Skokomish Indian Tribe and Mason County, selected a recommended restoration plan that includes over a mile of levee removal, a side channel reconnection to the river, riparian wetland restoration at two sites, and placement of large woody debris. The recommended plan provides significant benefits for upstream fish passage to an approximate additional 40 miles of habitat in the South Fork Skokomish River that is periodically inaccessible due to the lack of water in the river channel adjacent to the confluence. The plan also provides fish passage through a wetland to salmon rearing habitat. The total area of the proposed sites included in the recommended plan is approximately 277 acres at a restoration cost of approximately $20 million.

Goetz*, F. [1]. [1]U.S. Army Corps of Engineers.
Upstream Migrant Trapping Solutions for a Puget Sound Glacial-fed River and Abundant Pink Salmon Runs

The Seattle District (USACE) is beginning the design phase for a large upstream trapping system. The facility is a replacement trap at a 75-year-old site at Mud Mountain Dam (MMD), a 450-foot-tall flood control facility on the White River near Seattle, WA. The site is characterized by conditions that are unusual or unique to upstream fish traps. The White River is a glacial fed river system flowing from Mt. Rainier that carries up to 50,000 tons of bedload per year. The White River and other rivers in Puget Sound have seen establishment of pink salmon runs since 2001 that can exceed 1,000,000 in a year. The MMD trap, also known as a Buckley Style trap, is one of the oldest trapping systems in the Pacific Northwest. It was designed to pass 4,000 fish in a year and utilizes a 100-yr old wood-flash board barrier to keep salmon from reaching the base of the MMD. In 2009, the trap passed over 540,000 pink salmon while 450,000 remained in the river within 1-mile of the facility. USACE is designing a new trap and haul facility in collaboration with NMFS, USFWS, tribes, and regional stakeholders. The design objective is to pass a maximum of 60,000 fish in a day, 1.25 million fish in a year, and to manage the large bedload and woody debris with a moveable gate system. The presentation will discuss these unique design problems, with potential solutions for sediment management, and facility features necessary to pass 60,000 pink salmon in a day.

Gordos*, M.[1], M. Mallen-Cooper[2], H. Robinson[3], S. Slarke[4], and C. Copeland[1]. [1]NSW Department of Primary Industries (Fisheries); [2]Fishway Consulting Services; [3]NSW Public Works; [4]URS Australia Pty Ltd.
Designing a cost effective vertical-slot fishway

Walgett Weir is located on the Barwon River in the Murray-Darling Basin, Australia. A proposal to raise the weir by 1.0 m will increase the maximum differential head to 5.1 m, resulting in further impacts to native fish passage. To mitigate these impacts, a vertical-slot fishway was proposed at a cost of AUD $5.8 M, which was consistent with recent fishway costs. However, limited funding was available, which necessitated re-evaluating the original ecological, hydrological, and hydrodynamic criteria for the fishway to reduce capital cost whilst minimizing compromises in fishway effectiveness. Following a detailed analysis, a revised vertical-slot concept design was produced with an estimated construction cost of $3.1 M. A key step was refining the ecological objectives, with fish migration guilds being used to prioritise declining species or species with annual cyclic migrations, over common species that have generalised dispersal movements. Additionally, the broad ecological target was varied from passing all species and size classes of fish up to 1500 mm, to excluding large-bodied fish > 800 mm based on an assessment of species' migration scales and the available aquatic habitat upstream and downstream of the weir. The minimum operational range of the fishway was changed from cease-to-flow (i.e. 0 m3s) to greater than 0.3 m3s, which reduced the overall length of the fishway with minimal loss to the duration of fishway operation. Design measures to reduce material costs include reducing the design life from 100 years to 50 years, limiting construction risk by altering the proposed location of the fishway, and reconfiguring internal cell dimensions to reduce overall fishway length while maintaining suitable internal hydraulic conditions for fish passage. Refining ecological objectives and migration biology, and challenging long-held engineering assumptions, has enabled a less expensive design that still meets the fish passage objectives.

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Are fishways cost beneficial?

Over the past decade, capital costs for technical fishways in Australia have increased considerably to the point where asset owners and governments are openly questioning whether they are a cost-beneficial remediation option. In reviewing the literature, the New South Wales Department of Primary Industries (Fisheries) could find no record of a cost-benefit-analysis (CBA) being completed in Australia, and no applicable examples from overseas. As such, the Investment Appraisal Unit within the NSW Department of Industry was engaged to conduct a detailed CBA on two fishway options within the Macquarie River, NSW. The first fishway option involved constructing a high level fish lift at the 72 m high Burrendong Dam at a cost of $79 million. The fishway was deemed necessary under the NSW Fisheries Management Act 1994 due to recently completed dam safety upgrade works. However, due to the perceived high cost, three alternative vertical-slot fishway offsets were collaboratively agreed upon at downstream low-level weirs at a cost of $19 M, or a savings of $60 M. Despite these savings, the Fishway Offsets Program was halted in 2014 due to concerns by the asset owner about their cost-benefit. The Investment Appraisal Unit used a contingent valuation technique to estimate the consumer surplus associated with the Burrendong Dam Fishway and the Fishways Offsets Program. Both fishway options represent an estimated Net Present Value (NPV) benefit to NSW of $39.0 million and $63.0 million, respectively. Of the two options, the Fishways Offsets Program represents the best return to NSW based on its favorable social welfare NPV, Benefit Cost Ratio (BCR = 4.48) and NPV/Investment (NPV/I = 3.56) metrics. Importantly, the findings demonstrate that fishways can be cost beneficial, and are viewed by the NSW public as a viable remediation option for native fish.

Gregory*, J. [1], E. Washburn[1], and J. Hateley[1]. [1]Environment Agency UK.

Producing European guidance for assessing the efficiency and related metrics of fish passage solutions

Improving Fish Passage Solutions: This paper is intended to update progress on developing a European standard to assess the efficiency of fish passes. At Fish Passage 2015 in Groningen, a parallel session on

Standardizing Fish Pass Evaluation generated significant support for the development of a European Standard for evaluating fish passage solutions. Representatives from more than 20 countries committed to helping take this forward. Following this meeting we submitted a proposal to CEN for the creation of a European standard: Guidelines for assessing the efficiency and related metrics of fish passage solutions. CEN is the European Committee for Standardization, an association that brings together the National Standardization Bodies of 33 European countries. CEN supported the proposal, which was also given strong backing from EIFAAC (European Inland Fisheries and Aquaculture Advisory Commission). We therefore organized a European workshop to start the process of developing a standard. This took place in November 2015 in the UK. Practitioners and academics from sixteen countries were represented at the workshop, which sought a common consensus to focus the scope of the standard so that it can best deliver improvements to the design of fish passage solutions. This paper will outline the key areas of consensus and those where discussion is ongoing and give a clear indication of the direction of travel for the European standard on evaluating fish pass performance.

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Assessment of Three Sonars to Evaluate the Downstream Migration of American Eel in the St. Lawrence River

The Electric Power Research Institute (EPRI) facilitated the collaboratively funded Eel Passage Research Center (EPRC) to develop methods for providing effective downstream passage of out-migrating adult American eels at hydroelectric facilities. Based on previous studies, EPRC's preferred strategy to provide safe downstream eel passage is to guide out-migrating eels to a collection point, transport them downstream, and release them back into the St. Lawrence below Beauharnois Generating Station. To evaluate eel behavioral responses to stimuli for guidance to a collection point, a suitable sampling technique is essential to effectively monitor eel abundance and movements. This study assessed the feasibility of three sonar technologies to estimate eel abundance, determine distribution, and describe approach behavior. A Simrad EK60 split-beam echosounder (120 kHz), Sound Metrics ARIS Explorer multibeam sonar (1100/1800 kHz), and Mesotech M3 multi-mode multibeam sonar (500 kHz) were deployed at Iroquois Dam for experimentally testing their capabilities in detecting and identifying known numbers and sizes of live adult eels tethered to surface floats released upstream of the sonar beams and allowed to swim through at known locations and times. In addition, sonars collected data continuously to monitor wild, out-migrating eels during July 15-22 and September 17-19, 2015. Results highlight several challenges in acoustically monitoring eels in a large, fast-moving river with a few orders of magnitude higher abundance of other targets that can lead to a high false positive error rate. The ARIS multibeam sonar, operating with 48 beams, holds the most promise for correctly identifying eels out to 16-20 m in range, but the M3 multibeam sonar has some value for tracking previously identified targets over larger areas.

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Temporal and Spatial Distributions of Out-migrating Juvenile Blueback Herring in the Presence of an Ultrasonic Fish Guidance System at a Hydroelectric Project

At the Crescent Hydroelectric Project (Crescent) on the Mohawk River, New York, ultrasound was produced to deter Blueback Herring adults and juveniles out-migrating to sea from entering the intake channel to the Crescent headrace and turbines where mortality may occur. To increase the previously reported deterrence rate of 31%, the sound field was extended further upriver to expose juvenile Blueback Herring to an increasing sound gradient as they migrate downriver and allow them more time to avoid the intake channel. During the peak migration period of 20 September through 14 October 2012, data from continuous fixed-location horizontal echosounding indicated 77% of the net downstream passage of juvenile Blueback Herring at the upriver site bypassed the intake channel with peak downstream activity occurring during daylight morning hours. Repeated pelagic trawling and mobile echosounder surveys corroborated these results by showing Blueback Herring density was significantly higher in the main channel than in the intake channel. Echograms indicated juveniles were most abundant in the upper water column and exhibited stronger schooling behavior during the day than at night. This study demonstrated that pulsed ultrasound, when properly directed, can be used effectively as a fish guidance system to provide safe downstream passage of juvenile Blueback Herring at hydropower dams.

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Fish passage across a large dam in the Amazon basin: the case of the Belo Monte Megadam, in northern Brazil

The Amazon River basin, the largest and one of the most biodiverse in the world, is currently suffering an unprecedented boom in hydropower dam construction, along with other river basins in tropical regions. Migratory fish species are profoundly affected by impoundments and it is of fundamental importance to assess the feasibility of installing fish passages, since they can be ineffective or even harmful to the fish assemblages. Located on the Xingu River within a unique ecosystem featuring long distance migratory fish species, the Belo Monte hydropower complex consists of two dams and a shunt channel, and will be the third largest in the world in installed capacity (11,233 MW). A series of studies investigating fish movements and the efficiency of recently opened fishway are being conducted. To assess if migratory fish species could cross the Volta Grande (Big Bend), a natural barrier of 100 km of rapids and waterfalls, 400 fish were tagged with combined acoustic and radio telemetry (CART) before the dam closure, and 400 will tagged in 2016 after the reservoir is filled. The moement of these fish will be monitored along an 800 km stretch of river. Here we discuss challenges involved in studying a harsh environment such as the Amazon, and present preliminary results from the first period of monitoring the 1.2 km long, up to 15 m deep fishway, which started operation in early February, 2016. Questions regarding attractiveness, efficiency and selectivity are investigated using Radio Frequency Identification (4,000 fish will be PIT tagged in 2016), video recording, fish sampled downstream and inside the fishway, and fish tagged with hydrostatic tags. Moreover, in a region where lack of knowledge is as great as fish diversity, evaluation and monitoring of fishways are essential support for measures to improve fish conservation.

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MaineDOT Stream Crossings – learning from ten years of experience to improve stream connectivity through transportation structures

MaineDOT completed fish passage monitoring in 2014 and 2015 at culvert rehabilitation project in Northern Maine. The fish passage study was completed using ~100 tagged Brook trout (*Salvelinus fontinalis*) and multiple other resident fish species. Results showed fish passage conditions remained favorable for fish making stream movements throughout the surveyed period. Data revealed differential patterns of tagged brook trout movement. In addition to PIT tag fish passage monitoring, MaineDOT has also completed short duration mark-recapture monitoring at many structures over the last ~10 years. Mark-recapture data show that particular crossing design scopes fit into ecological solutions dictated by regulations. MaineDOT uses this past monitoring data to inform decisions on future projects.

Haraldstad*, T. [1], E. Höglund[1], F. Kroglund[2], and T. O. Haugen[3]. [1]Norwegian Institute for Water Research; [2]County Governor of Aust- and Vest-Agder; [3]Norwegian University of Life Sciences.

Long-term effects on Atlantic salmon (Salmo salar) and brown trout (Salmo trutta) smolts of downstream migration through hydropower turbines

By hindering upstream spawning migration and through direct turbine mortality during downstream migration, hydropower is regarded as one of the most serious threats to anadromous salmonids. However, knowledge of long-term turbine-induced effects on survival is needed for successful management of salmonid populations. This work investigates post-turbine survival of wild Atlantic salmon and brown trout smolts. Fish were PIT-tagged upstream of a power plant. By use of multiple downstream PIT-antennas and traps, we were able to estimate river-section-delineated survival rates, sea survival, and compare survival rates between smolts that had migrated through the turbine with smolts that bypassed the turbine. In general, total river-descent survival of turbine migrants of both species was significantly lower than survival of bypass migrants. Sea survival was positively related to smolt size, and was lower for turbine migrant sea trout. For Atlantic salmon smolts, however, sea survival was not smolt-size dependent and was highest for turbine migrants. These findings demonstrate a differential between the post-turbine mortality of two anadromous salmonids. The higher sea survival of turbine-migrating Atlantic salmon smolts indicates turbine-induced selection processes promoting sea survival in this species.

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Comparison of Attraction and Passage of Downstream Migrant American Eels for Airlift and Siphon Deep Entrance Bypass Systems

Deep bypass entrance structures with bottom entrances hold some promise for increased effectiveness as protection measures for this species. Two deep entrance bypass designs; an airlift (the Conte Airlift) and a conventional gravity siphon, were hydraulically and biologically tested in a simulated forebay environment under controlled laboratory conditions. Migratory silver-phase American eels (Anguilla rostrata) tested at night under dark conditions readily located, entered, and passed both types of bypasses at an entrance velocity of 1.2 m/sec. Attraction and passage rates were not significantly different between bypass designs. Passage through the riser pipe of the airlift and the siphon pipe appeared to be largely passive, although eels appeared to swim against the flow while in both pipes. No mortality or injury of bypassed eels was observed in either the airlift or siphon design. Critical functional elements of airlift and siphon bypass designs are discussed.

Haro*, A.[1], T. Castro-Santos[1], and M. Grader[2]. [1]S. O. Conte Anadromous Fish Research Laboratory, U. S. Geological Survey; [2]Ecological Services, Region 5, U. S. Fish and Wildlife Service.

Telemetry study of downstream passage of silver phase eels at three small hydroelectric projects on the Shetucket River, Connecticut

Recent management plans for American eel call for minimizing mortality of adult silver eels leaving rivers to spawn in the Sargasso Sea, including protection of downstream migrants at hydropower projects, where eels are at risk of migratory delays, impingement, and turbine injury and mortality. Some hydropower projects in the northeast region are equipped with downstream bypass structures designed primarily for juvenile anadromous salmonids and clupeids (i.e., reduced bar racks, bypass conduits, opened spill sluices), but the effectiveness of these structures for adult migrant eels has not been well studied. We describe data

from a radio telemetry study of downstream migrant eels at three consecutive small (0.8 to 2.2 MW) hydropower projects on the Shetucket River, Connecticut. Telemetered eels passed the projects via several types of bypass structures, but the use of the structures was variable and dependent on river flows and project operations. Movement rates and overall passage at each project were variable; approximately 43% of eels passed all three projects.

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The fish-lifting trough - a combined trash cleaner and fish passage device

In Germany the most utilized concept for downstream fish passage is the guidance of fish to bywashes via inclined or angled trash screens. The cost of these screens is high due to their large area and expensive concrete structure in the headrace of hydropower plants. Until now there has been no evidence that their efficiency is high enough and disadvantages exist, such as poor guiding effect, water demand, etc. A completely different concept developed at Kassel University is the fish lifting trough. The concept is based on the idea of collecting fish swimming in front of a protection screen with a special screen cleaner. Laboratory tests with living fish showed a high efficiency with salmon smolts, silver eels and other fish species. By smoothly lifting a trough in front of the screen, fish are included in the cleaning system and collected together with debris wiped off the screen. A fish protection comb helps fish get into the system, protects them from current and predators, and collects debris in the trough. When the water level is reached, the trough drains to a bypass that conveys water, fish and debris to the downstream side. A first pilot project is under construction in Interlaken/Switzerland. The presentation explains the concept, and illustrates its function with lab fishes and construction examples.

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The drifting dead: drift of dead fish in three German rivers

Hydropower stations influence migrating fish species in many ways. Besides a delay in migration, turbines and other installations at power stations may cause physical injury and mortality in downstream migrating fish. Telemetry is a useful tool to monitor the behavior of fish in front of hydropower stations and during passage. However, mortality is difficult to document as fish that died during passage through the hydropower station may drift further downstream and their movements cannot easily be distinguished from the migration of living fish. To examine how far a dead fish can drift and to gain insights into the patterns of this movement, we radio-tagged dead smolt and eel and released them into the tailrace of three German hydropower stations. 20 dead smolt and 5 to 30 eel were treated in this way at each study site. After release, fish were repeatedly tracked from boats using a 3-element Yagi antenna. About one third of dead smolt disappeared from the rivers, several showing strong signs of predation. In the case of eel, about 20% of released fish disappeared during the study. Eel drifted much farther than smolt, with maximal drift of up to 30 km and 2.4 km, respectively, before becoming stationary. The maximal drift distance of dead fishes may now be used as a baseline for deciding between dead and living fish, where individuals which have passed the farthest drift of dead fish are considered to be alive. Thus, dead fish can be used as a control group in telemetry studies to help evaluate passage mortality at a hydropower station.

Heisey, P. G. [1], and J. C. Avalos*[1]. [1]Normandeau Associates.

Assessment of Fish Condition Passed Through Conventional and Environmentally Enhanced Hydro Turbines with the HI-Z Tag Recapture Technique

The ability to examine fish after turbine passage provides valuable information on how fish friendly turbine designs, passage locations, and operating conditions are on captured fish. Prior to the development of the HI-Z Tag, the fish recapture technique of netting turbine discharge was the primary method to assess post passage condition of turbine passed fish. However, net deployment is often feasible only at low discharge units and has the following significant shortcomings: capture of non turbine passed fish; selective capture of turbine passed fish (i.e. injured fish captured at higher rate); and net-induced injuries. The principal objective of this presentation is to show how the HI-Z Tag recapture technique has been used to assess the direct effects (mortality and injury) of conventional and environmentally advanced turbines on entrained

fish during the last 20 years. Assessing the rate, type, severity, and cause of injuries and mortality rates has proven to be beneficial in developing fish friendlier units. The ability to examine turbine passed fish within minutes of turbine passage has assisted the development of fish friendly turbine designs and operating conditions in the following ways: closing gaps at the turbine hub and blade tip; reducing the number of blades, designing rounder and thicker leading blade edges for use in larger and slower rotating units, and operating beyond peak efficiency. Concurrent tests at conventional and advanced turbines have proven to be the best protocol for assessing fish friendly features. Some recent tests indicate that shape and thickness of the blade leading edge may have a considerable effect on the severity of injuries to fish that contact a blade during passage; however more field tests are needed. Our studies have indicated that minimizing gaps between turbine blade and hub and between blade tip and discharge ring can make turbine's fish friendlier. Decreasing the number of blades and increasing distance between blades generally provides the greatest benefits to turbine entrained fish by reducing the probability of encountering a turbine blade. Recent laboratory and field studies indicate that blade shape and thickness, particularly the leading edge can also markedly affect injury and survival. Additionally, field tests should be conducted with a range of blade shapes to ascertain what design best minimizes injury to fish while still providing efficient turbine operations. If practical, it would be beneficial to develop a full size turbine where different interchangeable blade shapes that could be tested.

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The Southeast Aquatic Connectivity Program: A Landscape Approach to Connecting Rivers in the Southeast

Fragmentation of river habitats by anthropogenic barriers is one of the primary threats to aquatic species in the United States. To help address this problem, the Southeast Aquatic Resources Partnership (SARP) has developed the Southeast Aquatic Connectivity Program, focusing on a landscape approach to reconnecting rivers. This program is in partnership with American Rivers and consists of three parts:

1) A GIS-based fish barrier inventory, with assessments.
2) On the ground partner interaction: Providing technical support and training for assessment tools to facilitate on the ground restoration from assessment results.
3) Initiation of Connectivity Teams in the 14 SARP states, bringing these teams together to initiate and develop working relationships.

To date, SARP, together with the Nature Conservancy (TNC), USFWS and other partners have completed a large-scale barrier inventory and various prioritization scenarios of dams, ranking them based on their potential ecological benefits if removed or bypassed. With the completion of these assessments and the barriers in-hand, SARP, together with American Rivers, performs desktop and on the ground reconnaissance of top ranking dams to provide high quality potential projects to statewide connectivity teams and local project managers. In addition to these efforts, SARP is working to develop and assist new "Connectivity Teams" or dam removal partnerships in other SARP states. In October, multiple partners came together to hold a Georgia Dam Removal Workshop, and to initiate the first Georgia Aquatic Connectivity Team, a statewide group of resource managers that will build capacity for dam removal throughout the State of Georgia.

Hollingsworth-Segedy*, L.[1]., and B. Beran[2]. [1]American Rivers; [2]Beran Environmental Services.

Large Wood Debris and Dam Removal, Part 1: Elevating Practice Through Complementary Techniques

Large Wood Debris (LWD) has been proven to be an effective technique for stream stabilization and habitat enhancement, particularly in remote locations with access to trees. However, when combined with dam removal, LWD can also be a cost-effective solution to challenging restoration conditions. American Rivers combined LWD with the removal of two dams on a wild brook trout stream to provide a stable stream channel in the impounded reach of the downstream dam. The upstream end of this impoundment had been over-excavated, creating a 50-foot length of 17% gradient, which posed a fish passage barrier if not restored. During the design phase, we evaluated several methods of eliminating the steep gradient at the top of the impoundment, including the associated risk of stream channel entrenchment and unacceptable sediment release into the stream. We decided to incorporate LWD into the site plan although it had never been applied

on a dam removal project in Pennsylvania. Utilizing restoration materials derived on the site, including large trees with root wads, concrete dam debris, clay core, impounded sediment, and native soils, the construction team cost-effectively and successfully restored a stream channel that replicated the riffle-pool/step-pool system in the watershed, provided effective fish passage, and enhanced habitat for native brook trout. At a second dam removal site upstream, we combined LWD and dam removal to reconnect the stream and re-establish a stable, fish-passable channel in an area of shallow sheet flow on the former impoundment floor. This paper will examine site conditions that are most appropriate for LWD, the decision points during design, and the evolution of the site since project completion. It will also set the stage for the following paper which focuses on the construction experience for this phased project.

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Design criteria and Culvert Fish Baffle comparisons

Culvert fish baffles are recognized as an effective way of improving fish passage through culverts. There are a number of variants available, however there has generally been little uptake. Therefore we undertook a comparison using a range of elements over and above basic fish requirements. The project kick-stared a redevelopment of baffles based on a broad list of criteria to better meet the needs of most fish in most conditions, while taking into account concerns of engineers and removing barriers to implementation.

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15 Years of MIGROMAT® - An Early Warning System Protecting Migrant Eels

Eels migrating downstream face countless barriers on their way into the ocean. Hydroelectric dams are particularly dangerous since eels can become impinged at the rakes, damaged or killed by turbine blades and during passage over the weir. There was no functional and cost-efficient solution to this problem when development of the MIGROMAT® system commenced in 1998. An initial prototype was installed at the Dorlar Hydroelectric Power Plant on the River Fulda in Germany. In the years thereafter, the system was thoroughly tested and evaluated, and improved versions were set up at several locations in Europe. Fifteen years later, nine MIGROMAT® systems operate on a routine basis and help reduce mortality rates. A recent telemetry study tracking eel migration in the River Main has further confirmed the proficiency of the system. The MIGROMAT® system is based on the principle of detecting premigratory restlessness in captive eels. When pre-defined threshold levels are exceeded, an alarm is sent to the power plant, which then switches its operation to an eel-protective mode. Potential measures include opening weir sections, reducing approach velocities at the rakes, altering turbine blade pitch angles, and - ultimately - shutting down turbines for the duration of a migration event. Due to intensive research efforts, the system's reliability and the concordance of predicted and actual migration events has steadily increased to exceedingly high levels. The MIGROMAT® system has proven to be a valuable tool assisting the protection of endangered eel populations, giving us a timely advantage until even more sophisticated systems will be available in the future.

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Critical Linkages: A Landscape-based Modeling Approach for Evaluating the Restoration Potential of Dam Removal and Culvert Replacement Projects

The Critical Linkages project is an application of the Conservation Assessment and Prioritization System (CAPS), a computer model that incorporates biophysical and anthropogenic data to compute an index of ecological integrity (IEI). Because CAPS provides a quantitative assessment for IEI as well as each metric used in ecological integrity models, it can be used for comparing management scenarios. Scenario analysis involves running CAPS separately for each scenario, and comparing results to determine the loss (or gain) in IEI or in specific metric units. We used the scenario testing capabilities of CAPS to assess changes in the aquatic connectedness metric for dam removal and culvert/bridge replacement projects in 13 states in the northeastern United States. A baseline assessment of aquatic connectedness provided a base scenario for comparison of restoration options. Scenario-testing software was developed to efficiently assess

restoration potential for large numbers of possible restoration projects and then applied to dams and road-stream crossings. Results of these analyses indicate that a relatively small proportion of possible culvert replacements or dam removals would result in substantial improvements in aquatic connectivity. We recently used the Critical Linkages methodology to address connectivity for cold-water fish habitat. In addition to assessing the potential for restoring connectivity for cold-water streams under current conditions, we evaluated how dam removal and culvert replacement priorities change when taking into account the impacts of climate change on stream temperatures. The results can inform efforts by resource managers to create and implement climate change adaptation plans for cold-water streams and fisheries.

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The North Atlantic Aquatic Connectivity Collaborative: A Coordinated Effort to Evaluate the Effects of Road-Stream Crossings on Aquatic Connectivity

Road-stream crossings are receiving increased attention for their role in fragmenting stream networks and the potential for restoring aquatic connectivity through culvert replacement. Given the large number of road-stream crossings that could potentially affect aquatic connectivity it is essential to carefully evaluate opportunities and set priorities for culvert replacement projects. Although dams can generally be viewed as near complete barriers to fish and aquatic organism passage, culverts and bridges vary greatly in the degree to which they disrupt aquatic connectivity. Landscape modeling tools are now available that can account for the degree to which particular stream crossings represents a barrier when assessing their impacts on aquatic connectivity. To take advantage of these modeling approaches we need field-based information about the degree to which individual crossings represent barriers to aquatic organism passage. Without this information landscape models produce results with a high level of uncertainty, which limits their usefulness for evaluating restoration potential and setting priorities for culvert replacement. A number of agencies, NGOs and academic institutions recently formed the North Atlantic Aquatic Connectivity Collaborative (NAACC) to address these data needs. The NAACC has developed a unified protocol for assessing stream crossings as well as programmatic infrastructure to support crossing assessments: a universal coding system for crossings, online training and certification, an online database with a map interface, digital collection and bulk uploading of data, scoring systems for aquatic organism passage, modeling to assist in the prioritization of crossings for assessment or replacement, and a system of distributed coordination to facilitate local involvement in data collection. Over the course of its first field season (2015) the NAACC has collected data from over 8,500 road-stream crossing assessments.

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The Eel Passage Research Center: Bi-National Collaboration at the Interface of Research, Resource Management, and Regulatory Compliance

American eel morphology, life history characteristics, and behavior, combined with the physical attributes of the upper St. Lawrence River and its hydropower projects, create an exceptional fish passage challenge. Ladders at the Beauharnois Generating Station (Quebec) and the Moses-Saunders Power Dam (New York and Ontario) provide juveniles upstream passage at these dams; however, except for a small, experimental trap and transport program, turbine passage is the only pathway for downstream migration of adults which exposes them to risk of turbine mortality. Virtually all downstream migrants are large females thought to be important contributors to the spawning stock of this panmictic species. The species is listed as endangered by the Province of Ontario and it is a species of concern across the rest of its range. The Electric Power Research Institute formed the Eel Passage Research Center (EPRC) in 2013 to address the challenge of safe passage for outmigrating American eel at hydropower projects on the St. Lawrence River. This

virtual center is a bi-national collaborative encompassing non-profit organizations; state, provincial, and federal (Canadian and U.S.) resource management agency representatives; and hydropower generating companies. With a minimum 5-year commitment and multi-million-dollar funding, the EPRC is investigating and developing technologies for guiding eels to collection points for transfer around hydropower projects. As physical screening has been deemed infeasible for the St. Lawrence River hydropower projects, the research focuses on behavioral stimuli (e.g., electricity, light, flow fields, sound and vibration) to guide the fish. The EPRC employs a collaborative process that includes adaptive R&D planning; explicit specification of research goals and objectives, research questions, and decision path; and collaborative decision-making. The process, organizational structure, and regulatory context of this collaborative enterprise, as well as results to date, provide lessons for other programs operating at the interface of research, resource management, and regulatory compliance.

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Citizen science on the move: detailing the spawning migration of alewife and blueback herring in a coastal Massachusetts watershed.

The annual return of anadromous river herring to New England's coastal streams and lakes to spawn is a phenomenon that is both culturally and ecologically important to the region. In response to declining river herring numbers, Massachusetts has enlisted citizen scientists to help enumerate the runs of these spawning fish. Volunteer efforts are an effective way to monitor many discrete runs, however, they leave many questions about herring migration, interactions with barriers, and basic biology unanswered. As a result, the nuanced movement patterns of these species are still poorly understood. Herein we detail a recent volunteer-based PIT tagging effort to describe patterns of movement exhibited by river herring in the Coonamessett River, a small coastal river in southeastern Massachusetts. Key findings from this multi-year effort include 1) Movement primarily occurred under cover of darkness, with peak periods of movement occurring immediately after sunset and just before sunrise. 2) Staging times and movement through the river were variable but often rapid, with many fish covering the 8 km stream length in a single night. 3) Spawning locations and times of the two species appeared to overlap. 4) Even small barriers in the watershed slowed migration and likely increased mortality from predation and/or exhaustion. 5) The period of residence in freshwater was protracted for most fish, with a mean of ~ 30 days. We discuss the implications of these finding for visual count-based estimates of herring returns, as well as how the application of these methods could enhance stock assessment and rehabilitation efforts more broadly. We also discuss outreach efforts associated with the project, and how this type of project can help catalyze restoration efforts.

Jordan*, M. [1], and R. Gubernick[2]. [1]Jordan Environmental Engineering; [2]U.S. Forest Service, Region 9, Duluth, MN.

Spreadsheets for Stream Simulation Design

Jordan Environmental Engineering (JEE) and the US Forest Service will present a set of interactive spreadsheets that JEE developed to support the USFS's Stream Simulation design methodology. To help ensure safe passage of aquatic organisms at road-stream crossings, structures with natural stream bottoms have become the design of choice for many conservation oriented organizations and government agencies. The USFS's "Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings, 2008" design methodology is a well-established approach for designing road-stream crossings with natural bottoms, but to date, there has been limited software available to assist designers with the implementation of this design methodology. As a package, the interactive spreadsheets will reduce design time by allowing the user to:

- Quickly check for data errors for key features such as the stream thawleg, stream cross-sections, etc., and qualitatively determine if sufficient stream feature data has been collected.
- Conduct a quick on-site analysis of the data to qualitatively determine if the data set contains a suitable reference reach for the road-stream crossing.

• Graphically determine the appropriate elevation and slope that the replacement structure should be set at and analyze various stream segments (long-profile analysis) to determine which one is best suited as a reference reach.
• Graphically determine lower and upper vertical adjustment potential lines for the stream bed, and the overall long profile shape of the stream.
• Create a "to scale" schematic drawing of the stream macro-roughness elements (shore lines, individual large rocks, large wood, rock steps, and wood jambs).
• Use the long profile analysis, cross-section analysis and macro-roughness elements spreadsheet components with either transit (total-station) data or "stream-wise tape and offset survey" data.
• Plot and compare multiple cumulative frequency distribution curves based on streambed pebble counts.

Keefe*, M. [1], P. Hilgert[1], A. Shelly[1], and T. Sullivan[1]. [1]R2 Resource Consultants, Inc.
What's in your tool box? Analytical tools for fish passage alternatives analyses.
Effective fish passage solutions are dependent upon understanding the biology and ecology of local fish populations, along with the hydrology and operations of the site. Baseline studies can provide site-specific data; but, in many cases there is insufficient data to accurately predict effects. More study is not always the answer, especially when target fish are not present for study or are present in low numbers. Fisheries technology is not advanced enough to monitor important lifestages or timelines, and budgets conflict with data collection requirements. Alternatively, there may be an abundance of existing data collected for different purposes that need to be put in the context of passage. In all cases, a biological effects analysis is critical for selecting the best passage alternative(s). R2 has developed and used relatively simple mathematical models for evaluating effects across alternatives and/or for different species and life stages. The models are built with existing data when available, but also can run as theoretical simulations in the absence of data specific to a location, species, or life stage. One of these originally developed as a cost effective means to address uncertainty in downstream fish mortality is the Biological Performance Tool (BPT). The BPT supports the evaluation of downstream passage alternatives and provides a platform for integrating parameters such as daily hydrology, daily reservoir fluctuations, project operations, facility design features, and fish migration behavior into relative estimates of passage success. We also have applied Bayesian belief networks to address sources of uncertainty (annual flow, migration timing, multiple species/life stages, operational flow, etc.) around predictive estimates of successful passage. This graphical model calculates process and parameter uncertainty and demonstrates how this uncertainty impacts decision criteria. Application of these models has allowed for transparency of the decision process and has facilitated stakeholder consensus during fish passage studies.

Kerr*, A. [1]. [1]Sustainable Eel Group.
European Eel Recovery - it is all about collaboration
Listed as critically endangered, the European eel,is regarded as one population over its entire range covering 30 or so countries in Europe and North Africa. Its complex and little understood life cycle, and the huge and diverse cultural traditions that have surrounded it have contributed to a boiling pot of competing and contradictory forces. The Sustainable Eel Group (SEG) was formed in 2010 in London by scientists, conservationists and commercial leaders who were prepared to work together under the common banner of Sustainability. The presentation will tell the story of the first 5 years of SEG's evolution from a concept to a functioning and influential organization inspiring and delivering effective action on a European scale. Scientific programs are now lead by Willem Dekker from SLU Sweden, Conservation through ZSL and Wetlands International and the Commercial side through DUPAN in the Netherlands. The presentation will focus on the importance of collaboration not only between countries but also between the forces of science, conservation and fishery/industry. Evidence of progress on many fronts, as well as disappointments, will be shared in an open and transparent way, which is a founding principle of the organization. Its great successes have been both the unblocking of migration pathways,

particularly in the UK, and the continuing development and implementation of the Sustainable Eel Standard and its progress to ISEAL membership. The conclusion will be the need for total commitment from a dedicated leadership team.

Khan*, F.[1] .[1]US Army Corps of Engineers - Portland District.
Challenges of Downstream Fish Passage at High Head Dams
High-head dams present immense challenges for fishery managers, engineering design teams, and stakeholders when considering downstream fish passage. The height of these dams, changes in river flows, and drastic seasonal changes in reservoir elevations (sometimes greater than 35 m annually) are some of the most common challenges. Downstream migrants must pass these high-head dams volitionally by way of turbines, where injury and mortality may be high, or by regulating outlets and spillways. Some high-head dams have surface collectors that utilize either transport or a system of bypass pipes as a means of passing fish, while others have none. This presentation will introduce challenges of downstream fish passage at high-head dams and results of a juvenile salmon and steelhead injury and survival study conducted at an abandoned bypass system at Green Peter Dam, Oregon.

Kirn*, R. [1]. [1]Vermont Fish and Wildlife Department.
Stream Sim Lite - Incorporating stream simulation concepts into Vermont statewide culvert design and construction standards.
Stream Sim Lite - Incorporating stream simulation concepts into Vermont statewide culvert design and construction standards. As in many states, Stream Simulation was adopted as the preferred design method within Vermont's 2009 stream crossing guidelines for aquatic organism passage (AOP). Vemont is a small state and it conducted a series of training workshops on this methodology for state and consulting engineers, regulators and river and fisheries scientists. Nevertheless, it was difficult to build adequate expertise in this approach to meet the high volume and diverse nature of state, municipal and private stream crossing projects. Stream simulation is an elegant, interdisciplinary approach that works best when the project designer can follow the project through to construction. This does not fit the model of project development and construction for most state, municipal and private endeavors in Vermont, where design expertise may be very limited or far removed from project implementation. To more effectively attain AOP compliance across the broad range of stream crossing projects, Vermont incorporated specific performance and design standards into the statewide Stream Alteration General Permit, which regulates these activities. These standards are based upon the principles and practices found within the stream simulation design method. We have found this to be an effective, straightforward and accepted approach to meeting AOP objectives at stream crossings in Vermont.

Kozarek*, J. [1], S. Mielke[1], M. Hernick[1], B. Mosey[1], and J. Hatch[1]. [1]University of Minnesota.
Experiments on Box Culvert Design for Fish Passage
Culverts can act as barriers to fish and other aquatic organism movement in streams due to insufficient water depth, excess velocity, excess turbulence, or insufficient roughness. In addition, aquatic organisms may encounter a behavioral barrier due to different conditions (such as light) within the culvert. This presentation will cover a series of experiments conducted in the field and at St. Anthony Falls Laboratory (SAFL) to examine the physical performance of fish passage culvert designs and fish behavior in dark culverts. While significant research efforts have been made to understand individual fish swimming abilities, our projects examine other aspects of fish and aquatic organism passage through culverts: a) culvert performance in terms of sediment transport into and through embedded culverts (a key component to predict habitat conditions within the culvert), b) potential behavioral barriers (light), and c) novel methods to add roughness along the boundaries of concrete box culverts. These experiments provide guidance to culvert designers on a) the need for sediment placement within embedded culverts to maintain natural stream bed roughness, b) the necessity for light mitigation strategies in long, dark culverts, and c) the ability to utilize inexpensive methods to retrofit culverts with additional boundary roughness.

Kreische*, F. [1], J. Borcherding[1], T. Havn[2], L. Heermann[1], M. Teichert[1], E. Thorstad[2], F. Økland[2]. [1]University of Cologne; [2]Norwegian Institute for Nature Research.

Analyzing small-scale movements in the downstream migration of European eel: a radio telemetry study

Whilst downstream migration of silver eel has been the subject of many publications, information on small-scale behavioral patterns is sparse. Here, we repeatedly tracked radio-tagged eel by boat and bike to give a high-resolution account of their movement patterns. Further, we wanted to assess whether individuals judged to be silver eel could be confirmed as such based on later behavior and silvering indices. Using this method of active monitoring, we were able to provide, among other data, migration time, speed and information on individual behavior, such as resting places and home range size. In addition, we could differentiate between live and dead, but drifting fish. Silver eels (N=134) were selected by experienced scientists according to visual criteria. They were tagged with intraabdominal radio transmitters and released about 9 km upstream of the power station in October 2015. Tracking lasted with varying intensities until late January 2016. In total, 96% (N=126) of tagged fish were detected at one or more of 27 total tracking events. Results showed that, upon release in low water conditions, silver eels remained stationary within close proximity to the release site. Only a few individuals showed migration activity from the start. However, once water levels increased, a majority of fish switched from stationary to migratory behavior. In contrast, upstream migration activity was recorded for some individuals, most of which were later identified as yellow eels based upon silvering indices. Several eels exhibited discontinuous downstream migration with stationary phases of varying lengths in between movement activity. Using this approach, we were able to gather precise, high resolution data on the whereabouts and movements of eel in freshwater habitats.

Kucukali*, S. [1]. [1]Cankaya University.

Flow and turbulence structure in a brush fish pass

The flow and turbulence characteristics (turbulence intensity and turbulent kinetic energy) of a brush type fish pass were investigated experimentally in a 0.4 m wide rectangular flume which has a variable bed slope in the range of 2-12% for discharges ranging between 10-30 L/s. The MicroADV was used to measure the three-dimensional instantaneous velocity fields and collect turbulence quantities. The drag created by brush bristles increases flow depth sufficiently to maintain flow in the subcritical range. It is shown that the brush fish pass ensures continuous low velocity migration corridors where acceleration zones can be negligible. In a brush fish pass, flow distribution is so homogenous that reduced flow velocities are nearly constant for the entire flow depth and the brush section has some zones with velocities below the minimum velocity for rheotaxis (umin<0.30 m/s). In the experiments, turbulent kinetic energy per unit mass ranged between 0.005-0.02 m2/s2, in which the lateral component of the turbulence intensity is an important contributor of the turbulence. Although energy dissipation is high, the turbulent kinetic energy has considerably lower values. This can be explained due to the fact that, in the brush zone, energy dissipation is related with the flow-induced vibrations of the bristles. Thus the main energy dissipation takes places via bristle oscillation rather than by the viscosity of the water in an energy cascade process. In most international standards it is

recommended that ΔP not exceed 200 W/m3, but it is argued that energy dissipation density is not suitable for use as a relevant parameter for a brush fish pass because the energy dissipation rate per unit volume cannot be an indicator of turbulence level. In the brush fish pass there is no need to build resting pools because it already contains reduced velocity zones (u<0.8 m/s) and low turbulent kinetic energy regions.

Kumar, B. G. [1]. [1]Govt. Science College, Ministry of Education, Dhaka-1000. Bangladesh.
Hydraulic impact on fish migration in the Sariakandhi fish pass of Bangladesh.
Recently, the importance of open water fish in our socio-economic regime has drawn the attention of Bangladesh's policy makers. FCD/FCDI projects mainly serve agricultural interests, but they also interfere with fish migration. This inevitably affects the open water fisheries sector as the migratory routes of many fish species are blocked, and their nursery grounds are disturbed. In order to permit fish migration in rivers, it is necessary to maintain conditions that help migrants reach their spawning grounds. To overcome obstacles such as hydraulic structures placed in the path of migrating fish, structures must be designed to assist fish passage. Fish passes constructed to allow normal breeding migration and to ensure natural routes of fish movement are a relatively new concept in Bangladesh. At present, two fish passes and two fish-friendly structures have been constructed. These are the fish pass from the Jamuna to the Bangali River at Sariakandi in Bogra, the fish pass at Kawadighi Haor on the Monu River in Moulovibazar, the fish friendly structure on the Lohajong River in Tangail, and the fish friendly structure at Morichardanra in Chapainawabganj. Movement of spawning adults, fish fry and fingerlings from the Jamuna to the Bangali River was the main objective of the Sariakandi Fish Pass Project. This Fish Pass is necessary for the development of dominant fishes like catfish as well as smaller fishes. It will also aid in efficient development of carp. During the monsoon carp are the dominant migratory species. Carp migrate at a higher velocity than the slower catfish. The spawning migration of carp in the study area was found to begin during the 2nd week of May and continue until the 3rd week of July. Catfish migration began during the last week of March and continued to the 2nd week of June. The study found seven major categories of migratory species in the project area and confirmed that the Fish Pass is contributing positively to the growth of fishery resources, despite some problems found in its operation and management.

Kynard*, B. [1,2], B. Kynard[1], and C. Morgan[1, 2]. [1]BK-Riverfish, LLC; [2]Department of Environmental Conservation, University of Massachusetts, Amherst.
Evaluation of the Owens Pond Fishway, Amherst, MA
Fish passage that connects a pond or lake to an inland freshwater drainage is uncommon and poorly studied. In 2015, we evaluated the Owens Pond Fishway, Amherst, MA, for providing fish habitat and fish passage. The fishway is an artificial stream, step-pool design, with a 4% slope, and rubble-boulder substrate that connects the pond to the Fort River drainage. The fishway successfully provides riffle and pool habitat during spring-fall for diverse fish species (485 fish representing 10 species and six Families were captured during May-November). The fishway provides a downstream movement route for year-0 juvenile Pumpkinseed Sunfish (P) and for year-0 Largemouth Bass (LMB) to leave the pond. The tens to hundreds of P and LMB we captured on a sample day in May-July likely represent thousands of fish during their total movement period. This suggests the fishway provides a major source of P and LMB to the Fort River, and perhaps, to the Connecticut River. Only 20 fish (four species) ascended the fishway during 9 d and 131.5 h of observations from April to November (75% or 15 fish total were year-0 P (nine fish) plus year-0 LMB (six fish). The few ascending fish may be related to a lack of behavioral drive by fish to ascend or to elements of stream design. When the fishway was designed, there was no information on species or size of fish that would be present. We found mostly small fish (50-70 mm TL) in the fishway. Swimming ability

of small fish is limited and several design features of the stream may create hydraulic or structural conditions difficult for small fish to ascend. The fishway is a great improvement for fish and wildlife (snakes & frogs) compared to the previous drainage pipe.

Lambert*, B. [1], K. Ferry[1], and T. Chorey[1]. [1]MA Division of Ecological Restoration.

Building municipal capacity for road-stream crossing replacement: Exploring a new model for habitat restoration

Undersized and improperly placed road-stream crossings are a major stressor on aquatic ecosystems in Massachusetts. Significant resources have gone into assessing and prioritizing culverts for replacement for ecological reasons. Massachusetts also has road-stream crossing standards for aquatic organism passage (AOP) that have been codified in regulations. Yet, to date, few crossings have been replaced to provide AOP, and few projects are in planning. The traditional habitat restoration model involves a single organization, such as a state agency or NGO, bringing partners and funders together to complete a high-priority restoration project. In Massachusetts, the traditional model results in the completion of 2 – 7 habitat restoration projects per year statewide. With more than 40,000 road-stream crossings in Massachusetts, the traditional habitat restoration model is not effective at reaching ecological goals. To increase the pace and scale at which road-stream crossings are being replaced, DER is exploring an alternate model for habitat restoration. The alternate model focuses on building municipal capacity for culvert replacement, with project leadership maintained at the municipal level. Municipalities own and maintain the majority of road-stream crossings. Municipalities have a vested interest in culverts that provide greater safety to the travelling public. With 351 municipalities in the state, if 10% began a culvert replacement project that meets AOP standards each year, the Commonwealth's streams would achieve greater connectivity than is likely under the traditional habitat restoration model. DER's new municipal assistance program began with a statewide needs assessment to identify barriers that municipalities face in replacing culverts with improved structures. This presentation outlines the results (some unexpected) of the needs assessment, describes how DER is structuring its new program to meet the identified needs, and shares the pilot effort now underway to build capacity in multiple municipalities in two regions of the state.

MacBroom*, J. [1], and R. Schiff[1]. [1]Milone & MacBroom, Inc.

Stream Power Thresholds and Applications

Stream power is the rate at which flowing water expends energy along a channel's perimeter, and can be used to quantify the geomorphic work available for erosion, sediment transport, and channel evolution. The concept of stream power has expanded in recent years from an abstract idea to an everyday tool to help classify channel patterns and resulting aquatic habitats, in addition to predicting watershed responses to extreme events and screening channels, culverts, and bridges for flood resiliency. Stream power data, including data from Hurricane Irene and Tropical Storm Lee, has been collected since 2010 for numerous northeastern rivers, and compared to European and American research literature. It is presented as a function of the riverbed grain size and channel condition, suggesting preliminary relationships that are being tested for predicting channel adjustments, such as deposition, local scour, and general degradation. Specific applications include forecasting channel patterns across former impoundments after dam removal, planning and design of stream restoration projects, naturalistic bypass channels, screening culverts, and bridge scour. Stream power can also be used to assess long-term channel equilibrium and the potential impacts of climate change.

Macdonald*, G. [1], M. Chelminski[2], and L. Wildman[3]. [1]Save the Sound; [2]Stantec; [3]Princeton Hydro.

Listen to the River: Flexibility and Resiliency in Dam Removal Project Management, Design and Construction

The state of Connecticut removed 7 dams in 2015, and was second in dam removal only to Pennsylvania. Save the Sound operated as the project administrator for two of these dam removal and river restoration projects through all phases including: fundraising, design, permitting, public engagement, construction and restoration planting. Both projects were funded in part by the Hurricane Sandy Restoration and Resiliency Grant Program, and required project partners to think on their feet and make design modifications in order to comply with regulatory requirements and complete the restoration projects on time and on budget. This session will use two recent dam removal case studies: one on the urban West River in New Haven, CT, and another on the rural Whitford Brook/Mystic River in Mystic, CT, to illustrate how incorporating flexibility and resiliency in project management, design and construction is critical to ensuring a successful restoration project**.**

Mader*, H. [1], S. Käfer[2], and F. Kratzert[1]. [1]University of Natural Resources and Life Sciences, Vienna; [2]VERBUND Hydro PowerGmbH.

Fishcam – a video-based monitoring system for fish passes

The FishCam migration monitoring system, which records high resolution video clips of migrating fish and drifting particles, was developed to avoid the time- and cost-consuming field work of fish pass monitoring and to record the migration of fish without contact and stress. Objects passing the detection tunnel with a size covering more than 1 – 3% of the number of pixels in the image are recorded by a high resolution camera based on security camera technology. A robust image classification algorithm is able to detect and track moving objects from the recorded videos. Passing fish are separated from non-fish moving objects, counted, measured and classified. Fully automated fish length determination performed successfully in tests, but still is under construction. Currently, 12 FishCam units are being used in Austria in the Federal States of Salzburg, Upper and Lower Austria and Carinthia. Compared with standard trap monitoring, the use of staff resources was reduced from emptying and cleaning the traps twice a day to FishCam maintenance and data backup once every 2 weeks.

Mahan*, L. [1], and R. Taylor[2]. [1]NOAA Restoration Center; [2]Ross Taylor and Associates.

Watershed-level physical and biological response to dam removal in Glenbrook Gulch, a small coastal stream in Mendocino County California

In 2010 a dam was removed on Glenbrook Gulch, a tributary to the Albion River in coastal Mendocino County, CA. The project footprint also included the installation of large wood and boulder habitat structures downstream of the former Glenbrook Gulch dam location. Stored sediment upstream of the dam was allowed to redistribute naturally downstream after the dam was removed. Two years of pre-project monitoring, and 6 years of post-project monitoring was conducted throughout the entire 1.5 mile Glenbrook Gulch watershed to characterize biological, substrate and habitat changes associated with the dam removal. Specific physical measurements included channel longitudinal profiles and cross sections, pebble counts and habitat assessments. Biological monitoring included pre-and post-project winter salmonid spawner surveys and summer juvenile salmonid surveys. Habitat quality for salmonids was improved both upstream and downstream of the dam as a result of allowing stored sediments to naturally evacuate upstream and

move downstream of the former dam. Spawning substrate suitability improved throughout the watershed both upstream and downstream of the dam removal project. Summer rearing and habitat quality increased as a result of the project. Passage conditions through bedrock areas of the stream were greatly improved downstream of the dam removal. Coho salmon and steelhead/coastal rainbow trout were not present upstream of the dam site prior to project implementation. Immediately after dam removal, juvenile steelhead/coastal rainbow trout were found upstream of the former dam location. Subsequent biological monitoring events documented utilization of the upstream and downstream habitat by juvenile and adult coho salmon and steelhead/ coastal rainbow trout, both federally listed species under the Endangered Species Act. Life history strategies such as non-natal rearing and lengthened juvenile freshwater residence time were documented throughout the study. Observed Spawning locations were directly related to the release and sorting of stored sediments upstream and downstream of the project.

Martin*, E. [1], J. Levine[1], S. Jackson[2]. [1]The Nature Conservancy; [2]University of Massachusetts, Amherst, MA.

Prioritizing Barriers

The fragmentation of aquatic habitats by dams and road-stream crossings is a primary threat to aquatic species. Road-stream crossings also limit the ability of water to flow freely during extreme storm events which can result in culvert failures and road washouts. Strategic removal of dams and upgrade of road-stream crossings can both increase habitat connectivity and enhance resiliency of road infrastructure. With support from the North Atlantic Landscape Conservation Cooperative and DOI Hurricane Sandy Mitigation funds, the University of Massachusetts-Amherst, The Nature Conservancy (TNC), and expert partners throughout thirteen states have formed the North Atlantic Aquatic Connectivity Collaborative (NAACC). Among other products, the NAACC will build on TNC's previous dam prioritizations in the Eastern U.S. including the Northeast Aquatic Connectivity project, Chesapeake Fish Passage Prioritization and Southeast Aquatic Connectivity Assessment projects and will produce a prioritization to help focus dam removals and culvert upgrades in places where they can have the most impact. This presentation will review the NAACC, the prioritization methods used in these projects, provide an overview of the strengths and weaknesses of this prioritization approach, and examples of how they have been used.

Martin*, K. [1], and K. Maloney[2]. [1]Kleinschmidt; [2]Brookfield - Black Bear Hydro Partners.

Fish Passage Enhancements on the Lower Penobscot River

The Penobscot River Restoration Project is a basin-wide, multi-dam, ecosystem restoration project which involves dam removals, enhancements of existing fish passage, and hydroelectric energy increases. The removals of Veazie and Great Works dams were a lynchpin in the restoration project, and another key component in the success of the endeavor was the installation of state-of-the-art fish passage facilities at the remaining dams. This involved four separate and simultaneous design and construction projects at three different dams. Upstream fish elevators and downstream passage enhancements were installed at both Milford and Orono, and downstream passage was expanded at new and existing Stillwater powerhouses. Integral to these improvements are two trapping, sorting, and trucking facilities that support Maine Department of Marine Resources (MDMR) stocking and hatchery programs. This presentation will describe the interrelation of the Stillwater branch and the main stem of the lower Penobscot River, and how this led to the selection of upstream and downstream passage solutions at each site. An overview will be given of all of the upstream and downstream facilities ultimately installed, including American eel passage. A brief summary of the hydro-electric generation increases at all three sites will also be presented.

Martin*, E. [1], J. Royte[1], and J. Bell[1]. [1]The Nature Conservancy.

Penobscot Habitat Blueprint Barrier Prioritization

The Penobscot River watershed, the largest in Maine and second largest in New England, was designated a Habitat Focus Area by NOAA in 2014. In addition to the many on-the-ground activities that will take place within the Penobscot Habitat Focus Area, a project is underway to identify priority areas for fish passage improvements. The Nature Conservancy (TNC), with funding from NOAA, has developed a barrier prioritization and an associated online decision support tool (DST) that helps planners identify those stream barriers whose removal or upgrade could have the greatest potential ecological benefit. Following the conceptual approach used by TNC in other geographies in the Eastern U.S., a suite of relevant metrics was calculated for barriers in the watershed and these metrics were subset and weighted by a multi-stakeholder workgroup to produce prioritizations for both diadromous fish and resident fish. The online DST includes functionality that allows users to modify the prioritization based on their objectives and also to assess the impacts of a proposed connectivity project on the surrounding barriers in the watershed. This presentation will provide an overview of the methods of the project and include a brief demonstration of the DST.

Mast*, N. [1]. [1]Institute of Applied Ecology.

A 5-Year Pit-Tag Survey tracking migrating fish in the River Elbe, at the Geesthacht Dam, Germany

Spanning 1,094 km from its source in the Czech Giant Mountains to its mouth on the North Sea, the River Elbe is Central Europe's fourth-largest river. The only obstacle for migrating fish, a dam built in 1960 for navigational purposes, is located near the town of Geesthacht, 35 km upstream from Hamburg, Germany. To allow passage, a nature-like fish pass situated on the left bank of the river was built in 1998. In addition, Europe's largest fish pass, constructed as a vertical double slot pass, went into operation on the right bank in August 2010. Simultaneously, a large-scale, long-term fish ecological monitoring program was established. Using PIT-tag technology, up to 10.000 specimens of anadromous and potamodromous species, e.g. Atlantic salmon (*Salmo salar*) and ide (*Leuciscus idus*), have been individually tagged with PIT-tags each year and released in the river up to 3 km downstream of the weir. Redetection of individuals migrating upstream was conducted using frame antennas positioned in the migration corridors at both fish passes. Eight antennas located on the left-bank and 23 on the right-bank fish pass automatically and continuously record the time and site of detections, and thus migration behavior. Additional information on migration distances has been obtained from PIT-tags returned by fishermen in the mail from all over Germany. Due to our very sophisticated survey design that includes above-average numbers of tagged individuals, it has been possible to receive unique, detailed information on the behavioral patterns of fish

migrating through the two fish passes. This includes new information on the duration of travel from the entrance of a fish pass to its upstream exit. Our results show that a fish pass is not a one-way road, and that fish migration behavior also depends highly on complex species-specific and individual behavioral patterns.

McCarthy*, T. K. [1], D. Nowak[1], and C. Lawton[1]. [1]National University of Ireland Galway.
Silver eel (Anguilla anguilla) production, spawner escapement biomass and mitigation of hydropwer mortalities in the River Erne, Ireland.
The trans-boundary eel management plan (required by EU Regulation EC 1100/2007) for the River Erne (mean annual discharge 92m3s-1) specifies that adverse effects of two hydropower dams on downstream migrating silver-phase eels must be mitigated annually by a trap and transport (T&T) program. The annual T&T target is 50% of the river systems silver eel production and the rolling target is monitored on a 3-year basis. However, following a juvenile eel fish kill (112kg) in elver traps at the lowermost dam in 2014 the mitigation requirement was increased. This was done by estimating the potential loss of future silver eel contribution to the spawning stock that the recruitment loss might have produced. Additional conservation measures were therefore initiated by Electricity Ireland, the hydropower dam operator, and conservation fishing effort was increased in the 2015/2016 silver eel migration season. Analysis of spawner biomass escapement to the estuary was enabled by: Monitoring the conservation fishery; mark-recapture experiments and data on mortality rates at the hydropower dams. This showed that in the 2015/2016 season the conservation fishing sites collectively contributed 54.7t to the trap and transport action and this represented 70.1% of the river systems silver eel (78.0t) production. Spawner escapement biomass was estimated to have been 71.7t which represented 91.8% of silver eel production. Increased fishing efficiency and effort were facilitated by unusually high discharge. Release of additional silver eels (8.5t) from a commercial fishery in Northern Ireland, resulted in both the annual mitigation target and the special compensatory requirement being reached. The methodology used in the silver eel trapping, transport and release will be outlined. The scientific monitoring of the River Erne eel populations will also be described.

McCaw*, D. [1]. [1]Penobscot Indian Nation.
Stream Connectivity Projects on Tribal Lands
The Penobscot Indian Nation has inhabited the Penobscot River drainage since time immemorial. The abundant diadromous fisheries resources of the Penobscot River sustained the Penobscot people for thousands of years. Currently, the Penobscot Nation owns large tracts of land in the drainage held in Trust status with the federal government. One piece of their trust lands contains nearly all of the Mattamiscontis stream drainage, a sub-watershed in the Penobscot River system. The Penobscot Nation, in collaboration with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Maine Dept. of Marine Resources, U.S. Dept. of Agriculture Natural Resource Conservation Service, the Atlantic Salmon Federation and the Nature Conservancy has been active in completing stream connectivity projects at lake outlets and road stream crossings. Recent projects have been opportunistic in nature, but a catalog has been developed of impacted sites to be addressed in 2016 and future years. It is the goal of the Penobscot Nation to reconnect the entire Mattamiscontis Stream drainage to the Penobscot River for the benefit of all species, which could be used as an example to other connectivity practitioners of a focused effort achieving long range benefits for the entire river system.

McLaughlin*, R. [1], E. Smyth[2], M. Koops[3], T. Pratt[3], and L. Ve´lez-Espino[3]. [1]University of Guelph; [2]ECOFISH Research; [3]Fisheries and Oceans Canada.

When Enough is Enough: Assessing How the Effectiveness of Fish Passage Can Influence the Recovery a Fish Population

The effectiveness of fishways is routinely assessed using proportions or rates of fish passed, where failing to pass all available fish is often considered to be evidence of poor performance. However, it is also important to assess the consequences of fish passage in light of broader management objectives for the watershed. We describe insights from a simulation study examining the population consequences of trap-and-sort fish passage for Walleye (*Sander vitreus*). Our simulated study system had features similar to the Black Sturgeon River, Lake Superior, Canada, where a dam used for control of invasive Sea Lampreys (*Petromyzon marinus*) is believed to be preventing the recovery of a once significant Walleye fishery. Two important insights emerged from our simulation study. First, only a fraction of migrating adult Walleye would need to be passed each year to reach the management target for Walleye recovery. The magnitude of that fraction will depend on the desired population size of Walleye (the management target) and the magnitude of any mortality of larval or juvenile Walleye passing downstream over the dam. Failing to pass all of the adult Walleye migrating upstream is expected slow the rate of Walleye recovery, but not prevent recovery or affect equilibrium population size. Mortality of juvenile Walleye passing downstream over the dam is expected to reduce equilibrium population size. Second, highly effective passage of migrating adult Walleye past the dam could create an ecological trap if there is spawning habitat downstream of the dam and if juvenile mortality associated with passing over the dam is high. Our study highlights the importance of interpreting fish passage effectiveness in terms of larger-scale management objectives. It further highlights how passing only a fraction of migrating adults could be adequate for circumstances involving recovery of fishes of commercial, recreational, and conservation interest.

McLean*, J. [1], G. Aponte-Clark[2], and L. Rose-Day[2]. [1]Wright-Pierce; [2]Penobscot River Restoration Trust.

Removal of the Veazie Dam – Improving Habitat Access for Sea-run Fish, Uncovering History, and Unharnessing the Penobscot River

The Penobscot River's native diadromous fish species (DFS) populations exist today at only a small fraction of their historic numbers. In an unprecedented collaboration, the Penobscot Indian Nation, seven conservation groups, hydropower companies, and state, federal, and tribal agencies, worked together to seize the opportunity to recover the DFS through the Penobscot River Restoration Project. One of the key components of the project was the decommissioning of the hydropower facility and removal of the dam in Veazie. Since the turn of the 18th century log drivers and saw mill operators have been building structures within and along the Penobscot River. By the late 1800s, the Penobscot River in Veazie was fully harnessed with river-spanning rock filled cribs. In 1912, substantive upgrades and construction occurred, which created the more recently familiar 30 foot tall and 500 foot long concrete Amberson-type dam structure. For more than one hundred years, the dam in Veazie stood at the mouth of the Penobscot River just upstream of tidal waters. However, in July of 2013, the Veazie Dam was breached and demolition activities commenced. Over the course of the next two years, the dam was fully removed and shorelines were restored. Like peeling the skin from an onion, it was important to unravel the structure slowly and methodically; each step of the way uncovering a piece of history. Working in the middle of the mighty Penobscot was not a task to be taken lightly. There were several key phases of demolition activity and steps

taken to dismantle the dam structure; all while safely and effectively managing river flows. This presentation will bring attendees on a journey through the removal and restoration process that occurred in 2013 thru 2015.

Modjeski[1]*, A., J. Krug[1] and K. Conrad[2]. [1]American Littoral Society, [2]US Fish and Wildlife Service
Restoring connectivity to Wreck Pond, Monmouth County, New Jersey
Historically, Wreck Pond, a 73-acre coastal pond located at the eastern end of the 12-square mile Wreck Pond Brook Watershed, was a place for recreational fishing, boating and swimming. Today, the Pond suffers from sedimentation, water quality issues, and lack of connectivity to the ocean. The American Littoral Society and Partners including United States Fish and Wildlife Service, New Jersey Department of Environmental Protection, Monmouth County and the Borough of Spring Lake are working to restore that connectivity in order to increase fish passage opportunity, improve water quality and habitat within the watershed, and reduce risk of flooding in the adjacent area. The planning stage of the project began in early 2014. Construction began in December 2015 and will be completed in Fall 2016. In summer 2015, the project expanded to include an additional dredging component as well as installation of 6000 feet of elevated berm and living shorelines to further improve water quality, habitat resource value, and reduce flooding risk. Pre-construction monitoring for river herring (alewife: *Alosa pseudoharengus* and blueback herring: *Alosa aestivalis*) and American eel (*Anguilla rostrata*) occurred in 2006, 2007, 2008, 2014 and 2015. 2016 monitoring includes a more robust fish survey coupled with PIT tagging of river herring. Post-construction monitoring will include spring and fall fish surveys with focus on river herring, PIT tagging, water flow and water quality studies, tidal surveys, and habitat assessments. An overview of the project as well as results from pre-construction monitoring of river herring and habitat will be discussed.

Monk*, S. [1], and D. Christensen[1]. [1]WEST Consultants.
Using 2D HEC-RAS to Determine Fish Passability and Habitat Quality
Assessing the ability of fish to pass through newly constructed stream restoration sites, as well as existing sites that may need rehabilitation in the future, has become an increasingly important part of hydraulic studies. Typically, one-dimensional models have been used to achieve this by estimating parameters such as depth, velocities, and water surface elevations. However, these parameters are computed as cross-sectional averages and thus may present misleading results when used to design and evaluate fish passage. Two-dimensional models have become more regularly utilized in engineering communities and it has been suggested by some that two-dimensional models become the standard for fish passage design. To support the use of two-dimensional models in fish passage and restoration studies, several different modeling techniques and analysis methods were tested to determine the habitat suitability and quality of a theoretical restored stream section in two-dimensional HEC-RAS (v.5.0) and compared to traditional one-dimensional modeling techniques. Results showing habitat diversity, fish passability, and other pertinent metrics were compared using the different modeling techniques for several different scenarios. In particular, velocity maps were developed for the area to determine if there were spaces for habitat and paths that fish could take to move upstream at many different flows and with different added hydraulic structures, such as riffles, pools, rock weirs, and j-hook vanes. Additionally, velocities at different depths were also estimated to determine if species other than mid-column swimmers would be able to find upstream passage paths. Some existing tools and regulations used in these analyses were FishXing, HEC-EFM, SLOPES, and ArcGIS.

Mosey*, B. [1], J. Kozarek[2], and J. Hatch[1]. [1]University of Minnesota; [2]St. Anthony Falls Laboratory.

Do low light levels in long box culverts affect the movement of Topeka Shiner and other prairie stream fishes?

Like many small streams, prairie streams in the central US are riddled with road crossings. If built incorrectly, road crossings can physically impede fish movement by altering velocity, depth, substrate, and gradient of the stream. Many bridges and short culverts are currently being replaced by longer box culverts due to road safety alterations and their financial easement. Longer culverts reduce ambient light levels across their length, which may act as a behavioral barrier to fish movement. Fish movement is necessary for populations to access key seasonal habitats (e.g., spawning or nursery areas, drought or predator refugia, off-channel habitats) and to maintain genetic diversity. The Topeka Shiner *Notropis topeka* is a federally endangered headwater species that may be encountering reduced movements. Other studies have measured impeded road crossing movement among fishes, including the Topeka Shiner, but none has considered the role of reduced light levels. We evaluated light levels and fish movement in three long box culverts and natural stream reaches in Topeka Shiner habitat in Southwestern Minnesota. Using a multiple mark and recapture scheme with visible elastomer implants, we marked 18,963 fish, including 456 Topeka Shiner and recaptured 1,874, including 46 Topeka Shiner. While many fishes, including Topeka Shiner, passed through all three culverts, the probability of movement decreased with increasing culvert length and ambient light reduction. The probability of movement was also significantly less for two culverts with higher ambient light reduction than for their corresponding natural stream reaches. Further statistical analyses will determine if these overall results apply to various guilds, species, and sizes of fish. Controlled laboratory flume studies of pond-reared Topeka Shiner and other wild-caught species are underway to determine if reduced light level by itself acts as a behavioral barrier to movement and to inform the need for light mitigation strategies including skylights or artificial lighting within culvert barrels.

Muir*, A. [1], R. McLaughlin[2], and T. Pratt[3]. [1]Great Lakes Fishery Commission; [2]University of Guelph; [3]Fisheries and Oceans.

Selective, bi-directional fish passage to balance tensions between management actions affecting fish movement

Selective, bi-directional fish passage can balance tensions between management actions altering connectivity to benefit fish production. Dam removal and fish passage can enhance fish production by increasing connectivity between tributaries and lakes or oceans. Conversely, in-stream barriers to movement can benefit native fishes by limiting the spread and reproduction of invasive species. Tensions between these options are recognized globally, although their importance can vary across river systems. Historically, fish passage research has devoted limited attention to blocking or removing undesirable fishes. Efforts to deliberately pass desirable fishes, while blocking or removing undesirable fishes, have often focused on single factor solutions examined independently and typically for single taxa or guilds (e.g. jumping vs. non-jumping fishes). While these efforts have considered a diversity of potential technological solutions, they have achieved limited success, or were labour intensive if success was high (e.g. trap-and-sort passage). Practical, successful methods of selective fish passage will require the integration, redundancy, and automation of technologies that both exploit and overcome the decision-making abilities and behaviors of fishes. Development of these integrated solutions for selective passage will need experimental facilities that provide conditions consistent with the scale and conditions of natural rivers. Further, selective passage does not need be 100% effective at sorting desirable and undesirable fishes to be valuable for restoration efforts. Despite significant uncertainties, the potential to integrate technologies offers hope that solutions for selective, bi-directional fish passage are possible.

Mulder*, R. [1], and W. de Bruijne[2]. [1]Province Fryslân, The Netherlands; [2]LINKit Consult.

Fish Migration River - project update

Fish Migration River – project update. The Netherlands literally means “the low countries”; almost half of the country lies below sea level. Water management has played a crucial role in the history and development of the country. The Afsluitdijk was constructed in 1932 and protects a large part of the Netherlands against flooding. But the dam closed off a unique tidal estuary; the salinity gradient disappeared and an important swimway in the Rhine-delta was blocked. The Fish Migration River is an innovative project designed to break this barrier. The planned construction of a brackish tidal river will reconnect the sea with upstream lakes and rivers. The project is in the phase of final preparations; construction works are planned from next year onwards. In the presentation, I will give an update on the current status, target species, system and design, external conditions and permitting. We are willing to share our knowledge and look forward to make connections to groups confronting similar migration barriers and to developing joint projects. This abstract precedes the presentation of Mr. Wilco de Bruijne (monitoring and evaluation of the Fish Migration River).

Mulligan[1], K., A. Haro[1], B. Towler[2] J. Noreika[1] and B. Sojkowski[2]. [1]United States Geological Survey, [2]United States Fish and Wildlife Service

The effect of fishway entrance gate orientation on upstream migrating adult American shad (Alosa sapidissima)

Increasing fishway attraction efficiency (i.e. the percentage of the motivated fish population that enters the fishway) and entry rates is recognized as an important research need within fish passage engineering. The design of a properly functioning entrance relies on knowledge of target species behavior and swimming performance. Nevertheless, a paucity of information exists regarding the correlation between a number of entranceway design parameters and the behavioral response of common target species. Typically, a fishway entrance consists of a fully submerged hydraulic control (e.g. flap gate) located at the downstream end of a rectangular channel that leads fish to the main body of the fishway (e.g. lift, pool-and-weir). Changes to the hydraulic control design and tailwater levels can influence the hydraulics (e.g. entrance jet velocity, flow pattern) and thus attraction and entry performance. The aim of this research is to understand how American Shad (*Alosa sapidissima*) respond to a variety of fishway entrance gate orientations (i.e. angle of the gate to the channel floor) and hydraulic conditions (e.g. water surface elevation, velocity) both upstream and downstream of the gate. The results will provide guidance on methods to improve fishway attraction and entry rates, and overall fish passage structure performance, to numerous state and federal resource agencies and the hydropower industry.

Murphy*, M. H. [1], and L. Wildman[2]. [1]Integrated Aquatic Sciences, LLC; [2]Princeton Hydro.

Use of unmanned aerial vehicles for monitoring habitat restoration and dam removals

Numerous dam removals and habitat restoration projects have been implemented to improve fish passage. New technologies are available to improve and better inform projects during design. Unmanned aerial vehicles (UAV) are a useful tool for obtaining aerial views of an entire river section at various flows and to assess substrate types in shallower waters. Recently, we used a UAV to observe flow dynamics and river patterns, resulting in more informed restoration designs in a section of river washed out during a flood of record. This technology also will be useful to monitor rivers following restoration. Many dam removal projects would have benefitted from this technology. Investigating wide shallow impoundments prior to dam removal can be challenging by boat, especially if there are large quantities of soft sediment within the impoundment or excessive submerged aquatic vegetation, e.g., the Hyde Pond Dam removal in CT. In some cases, conditions at a dam site are too dangerous to comprehensively assess under a variety of flows by any method, such as the Spoonville Dam removal project where multiple deaths had already occurred. Post dam removal conditions can be equally as challenging. Assessing stream formation and the migration of a headcut post dam removal can be limited by access in newly dewatered impoundments with wide, excessively soft sediments. In these cases, and others, a UAV would have provided valuable information by allowing visual observations of inaccessible areas. Using specific software programs also allows the drone operator to program repeatable flight patterns that can be used in long term monitoring of a site. The field of video photography with the use of UAVs is rapidly developing and we, as river restoration professionals, will benefit from these developments on future projects.

Murphy*, B. D. [1], and S. R. Gephard[1]. [1]Connecticut Department of Energy and Environmental Protection, Inland Fisheries Division.

Engineering and Design Approaches to Provide Fish Passage at Culvert Slipline Projects in Connecticut

Many aging culverts that convey streams under Connecticut highways are being rehabilitated with “sliplining”, a technique that involves placement of a smaller diameter culvert within the larger failing culvert. Sliplining increases water velocities and may exacerbate outlet perch conditions, making upstream fish passage challenging. In 2015, Inland Fisheries staff worked with the Connecticut Department of Transportation to design and implement fish passage solutions at three sliplined culvert projects. Projects were primarily designed to provide passage for fragmented native Brook Trout populations. The Tributary to Lyman Brook (TLB) project involved sliplining twin 5 ft. diameter culverts that were: 262 feet in length, slope of 4.5% and outlet perch of 1.5 feet. A concrete pool/weir fishway was constructed at the outlet. The fishway culvert was retrofitted with an angled corner baffle system. Mean daily flows are directed into the baffled culvert via a low flow diversion wall. The Tributary to Hubbard Brook project involved sliplining a 5.5 x 8 ft. culvert: 165 feet in length, slope of 4.0% and outlet perch of 3.1 feet. To compensate for the significant outlet drop and steep downstream grade of 8%, a prefabricated concrete fishway was installed. The culvert was retrofitted with alternating v-notch baffles. The Great Brook project involved concrete-lining an 11 ft. diameter culvert: 144 feet in length, slope of 0.5 % and outlet perch 0.75 ft. Rock weirs were installed downstream of the outlet to allow fish to enter the culvert. Culvert baffles were not required due to shallow slope; however, a series of weirs were installed at the inlet to allow fish to pass a concrete sill. Brook Trout movements will be monitored via stationary PIT-tag antennae at TLB from 2016-2018 to

determine fish passage efficiency and project design features. Lessons learned from these sliplining projects will help guide the development and design of fish passage features at future sliplining projects.

Nau**, G. [1], I. Spooner[1], M. Mallory[1], N. McLellan[2], C. White[3], and M. Stokesbury[1]. [1]Acadia University; [2]Ducks Unlimited Canada; [3]Nova Scotia Department of Natural Resources.

Using Sediment Core Analyses to Attempt to Quantify the Historical Abundance of Alewife (Alosa pseudoharengus) in Three Modified River Systems in the Maritime Provinces of Canada

Marine derived nutrients (MDN) transported by spawning runs of alewife in northeast North America can contribute as much biomass to aquatic and terrestrial ecosystems as Pacific salmon do in the northwest. Given the value of this energy input, interest in the effects of man-made riverine obstructions has increased, as have the removal and modification of dams. Due to the lack of accurate records, it is difficult to estimate the abundance of anadromous fish populations from before the installation of dams. This study will attempt to identify an abiotic proxy for the presence of anadromous fish in sediment cores collected from three lakes in Nova Scotia and New Brunswick that support alewife spawning runs, and have undergone extensive anthropogenic modifications. A core from Gaspereau Lake in Nova Scotia is being analyzed for trace metal content, as well as C, N and S stable isotope ratios. Results will be compared to recorded alewife landings over the past half-century, and the effects of the installation of a dam and fishway on the river. This may allow for the identification of one or more abiotic proxies of alewife presence and spawning density, and reveal an effect of dam and fishway installations on MDN input. Cores from two lakes in separate watersheds with no commercial fishing records will be analyzed using the same techniques, and the proxy identified in Gaspereau Lake will be used to identify alewife spawning migrations and effects of dam and fishway installations on MDN and lake productivity. This technique may allow managers of freshwater systems and dams to assess historical anadromous fish abundance, and the effects that dams and fishways have had on anadromous fish populations.

Nislow*, K. [1], F. J. Magilligan[2], B. Kynard[3], A. Hackman[4], and P. Damkot[3]. [1]USDA Forest Service; [2]Dartmouth College; [3]University of Massachusetts; [4]Massachusetts Department of Environmental Conservation.

Geomorphic and ecological adjustments following dam removal

Although more than 1,100 dams have been removed nationally, < 3% have pre- and post- removal assessments that formally combine geomorphic and ecological analyses. We used a combination of geomorphic measurements (channel planform and dimension, longitudinal profile, particle size distribution and embeddedness) with quantitative electrofishing surveys of stream fish richness and abundance, and visual surveys of native anadromous sea lamprey (*Petromyzon marinus*) nest sites to assess the effects of removing the Bartlett Dam on Amethyst Brook in central Massachusetts. Post-removal assessments were complicated by 2 events: upstream knickpoint migration exhumed an older wooden crib dam 120 m upstream of the former dam, and the occurrence of a significant flood 6 months after removal. Upstream of the dam, process-based erosion dominated in the initial post-removal months with significant bed erosion and knickpoint migration occurring through the former reservoir and upstream to the exhumed crib dam that now acts as a grade control, while the bed aggraded (20 cm) and fined (~50%) downstream in the initial year (with a small percentage of subsequent coarsening). Ecologically, and associated with the availability of suitable gravel, we observed sea lamprey spawning in previously unoccupied below-dam sections. Further, after dam removal, sea lamprey and three other fish species were found above the removed dam, but not above the exhumed dam. The recent removal of the observed dam will allow us to assess additional geomorphic and ecological changes at the site, which will in turn contribute to our overall understanding of ecological and geomorphic continuity in river systems.

O'Farrell*, M. [1], J. Kent[1], and C. Burger[1]. [1]Smith-Root Inc.
Fish passage philosophy on European rivers fueling hydropower installations in the 21st century
The first half of the 20th century saw hydropower development in most European countries designed to fuel industrial development, rural electrification and a general improvement in the living standards of people. The inevitable impact on migratory fish species was an accepted collateral damage to be mitigated by the operation of hatcheries for anadromous species e.g Atlantic salmon, and the collection and upstream transport of the juveniles of catadromous species e.g. European eel. This philosophy was testament to the existing poor understanding of the requirements of migratory fish species. Recent decades have witnessed a review of this philosophy. Upstream and downstream fish passage solutions are being researched and implemented. In recent years, feasibility studies have been carried out in several European countries (Norway, Sweden, Scotland, Ireland) on the suitability of graduated field fish barriers (GFFBs) to block and guide upstream migrating anadromous adult salmonid and lamprey species. This paper reviews relevant aspects of these feasibility studies (GFFB site selection, electrode array design, electric field modelling, electric power requirements and safety considerations) and also provides a commentary on the effectiveness of recent GFFB installations at hydroelectric installations in Europe. For example, a GFFB installation on the Nidelva in Norway has achieved 99% exclusion of adult Atlantic salmon from a tailrace tunnel and has also facilitated generating protocols which were not possible before the GFFB installation.

Panahon*, M. L.[1], and P. P. Ocampo[2]. [1]City Government of Calapan, Oriental Mindoro, Philippines; [2]Limnological research station, UPLB, Brgy. Mayondon, Los banos, Laguna.
Butas River, Naujan, Oriental Mindoro, Philippines Fish Assessment: Issues and Challenges
The state of health of the Butas River in Naujan, Oriental Mindoro, was determined with measurements using physico-chemical parameters and through assessment of fish abundance and composition in terms of Catch Per Unit Effort (CPUE). Results showed that dissolved oxygen (DO) and temperature did not differ markedly at three identified sampling stations within the 6-kilometer study area. However, the pH level varied slightly across the stations, each of which was a sampling point for one of three 2-kilometer intervals. A cast net measuring 4.5 by 5 meters was used during sampling, wherein twenty-five individual fish belonging to six families were caught. This study suggests that a more thorough and comprehensive assessment of riparian biodiversity and river water quality and quantity (discharge) over the entire Butas River is needed. Such research would generate benchmark information and provide inputs useful for developing protocols for basic system monitoring and environmental management.

Payne Wynne, M.[1], G. Aponte Clarke[2], R. Saunders[3], T. Sheehan[3], M. Collins[3], and J. Royte[1]. [1]The Nature Conservancy; [2]Penobscot River Restoration Trust; [3]NOAA Fisheries Service.
Monitoring the Penobscot River Restoration Project: baseline data to inform ecosystem response
Recognized as a model for cooperative conservation, the Penobscot River Restoration Project (PRRP) is an innovative, ecosystem-scale restoration project aimed at restoring self-sustaining populations of sea-run fish through increased connectivity in Maine’s largest river while also rebalancing hydropower. The project has strategically removed two mainstem dams, constructed a nature-like bypass at a third, and improved passage at four other dams. The completed project provides 11 species of native diadromous fishes with

significantly improved access to freshwater habitat, thousands of kilometers for “upper river” species and 100% of historic habitat for “lower river” species. The project provided a valuable opportunity to implement an expansive monitoring program, initiated in 2009, to document baseline conditions and project outcomes using a before-after study design. A collaborative effort evaluating changes in geomorphology, water quality, fish community, fish passage, fish migration and habitat use, wetlands, and nutrient transfer, the program provides an objective basis for evaluating ecosystem response and restoration outcomes. Among the early findings, five patterns emerged from pre dam-removal baseline results; 1) all native diadromous species of fish are present in the Penobscot River, many of which are successfully reproducing on their own; 2) diadromous species persist despite having access to only a small percentage of their historic habitat; 3) the former lowermost dam represented a near complete barrier to migration of most species of diadromous fishes; 4) large changes to flow, sediment regime, and habitat (except in the immediate vicinity of the former dam sites) were unexpected and did not occur; and 5) water quality does not appear to be limiting for most diadromous species. These patterns confirm the value of restoration efforts in a system that was well situated to respond. As post dam-removal results unfold, restoration planners, scientists, and managers now have an objective basis for evaluating project outcomes via long-term monitoring.

Peters*, A. [1]. [1]Pacific Netting Products.

Technical Developments in Fish Exclusion, Guidance, Barrier and Collection Systems

Application of materials and technology can enhance fish passage and prevent entrainment or impingement at hydroelectric facilities. This presentation will review developments in materials and technology that have led to successful installations of fish guidance and collection systems, temperature and algae control curtains, and debris control systems at high head dams, run of the river facilities and pumped storage facilities at sites in the Northwest, as well across the country and in Canada. In this presentation, we will discuss different designs, various components and the planning, materials, engineering, operations and maintenance considerations that all successful projects require. We will provide an introduction to three projects that illustrate these points. At Puget Sound Energy, Baker Lakes, Concrete, Washington in 1985, only 99 adult sockeye salmon returned to the Skagit River, imperiling the stock. PSE enacted a number of strategies to support the watershed's fish populations. Following PSE's investment in a full barrier netting and collection system built of a high molecular weight polyethylene fiber with 1/8 and ¼ inch square mesh, by 2014 over 1,000,000 downstream migrating salmon were collected and counted, with returns of 60,000 to 100,000 adult fish expected in 2016. We’ll discuss the design, materials, and construction of this flexible barrier. At PacifiCorp, Swift Reservoir, Lewis River, Washington, a catastrophic failure of a multimillion dollar barrier net, (manufactured by a supplier no longer active in the industry), occurred within weeks of its installation and deployment. We will discuss the reasons for the application failure, and the first of its kind, in-water renovation that resulted in redeployment of a 2400-foot-long, 500,000 square foot flexible barrier. With the latest addition of a lead net, the barrier is now poised to drastically improve downstream collection of salmon smolts. PGE, North Fork Clackamas, Clackamas Oregon PGE installed a floating surface collector, a partial exclusion, fish guidance flexible barrier and an innovative debris control system. We will provide a review of the installation and explain how a debris barrier operates in a run of the river facility.

Philippart*, C.[1], M. Baptist[1], E. Folmer[2], and A. Zuur[3]. [1]Waddenacademie; [2]Ecospace; [3]Highland Statistics.

Potential measures to strengthen diadromous fish stocks in the Wadden Sea

The strong decline in Wadden Sea fish since the 1980s has called for action to strengthen local diadromous fish stocks. A recent explanatory study showed that most promising potential measures to strengthen local fish stocks and other natural values of this region include reduction of fishing efforts, provisioning of suitable habitats (such as brackish zones) and facilitation of fish migration. Reduction of shrimp fishing in the Wadden Sea would decrease mortality of diadromous fish (4 million per year), and be beneficial for additional natural values of the Wadden Sea (e.g. mussel beds, birds, seals). Reduction of fishing activities for eel and smelt in the adjacent Lake IJssel would favor local fish stocks, and also enhance the supply of fish (e.g. smelt) to Wadden Sea stocks. Estuarine gradients in the Wadden Sea vary from small tidal creeks at the islands to large freshwater sluices along the mainland coast. Present natural estuarine gradients should be safeguarded and, if necessary (e.g. Ems estuary), be improved for provisioning suitable habitats for migratory fish. Furthermore, several areas are potentially suited for turning into large brackish habitats, but actual suitability still needs to be checked by feasibility studies. Fish migration could be facilitated by means of improving the connectivity within freshwater systems, and between freshwater systems and the sea. Potential measures include fish-friendly discharge management and fish passages, ranging from relatively simple (e.g. fish ladder) to very complex (e.g. Fish Migration River) solutions. At present, however, the attraction and passing efficiencies of such fish passages cannot be quantified due to a lack of data. Setting up a Migratory Fish Testing Facility and an integrated monitoring program will not only lead to more efficient and effective investments in fish passages in the Wadden Sea, but could be of international interest as well.

Phipps*, J.[1], P. Heisey[1], C. Avalos[1], and R. Koenigs[2]. [1]Normandeau Associates; [2]WDNR.
Estimates of turbine passage of fingerling and yearling lake sturgeon passing the Shawano project, Wolf River, Wisconsin
Controlled investigations of the turbine passage survival of emigrating Lake Sturgeon are lacking in published literature. We estimated survival of fingerling (N =150, average length 199 mm TL) and yearling sized (N =160, average length 260 mm TL) Lake Sturgeon using the HI-Z tag-recapture method in passage through a vertical Leffel-Z (Francis type) turbine at the Shawano Paper Mill Dam, Wolf River, WI. The turbine was relatively small (42 - 74-inch diameter) with 18 blades, a rotation rate of 100 rpm, a discharge of 260 cfs, and 10 ft operational head. Recapture rates were 88.7% for fingerlings, 90.6% for yearlings, and 98 and 95% for the respective control groups released downstream of the dam. Only the HI-Z tags were recovered on another 7.3 and 8.8% of the fingerlings and yearlings, respectively. The 48 h survival estimate was estimated at 92.7% ± 3.5%, 90% of the time for the fingerling sized fish, and was estimated at 90.6% ±3.8% 90% of the time for the yearling sized fish. Only one fish recovered was injured and observed dead at 48 h. Based on the fact that only one recaptured fish was injured and this is the only fish that died, survival estimates are likely higher than estimated. Entrainment survival estimates are important to understanding the effects that hydropower generating facilities have on fish populations, and these results will have international implications for sturgeon restoration efforts.

Ratcliff*, D.[1], J. O'Hanley[2], and L. DeBruyckere[3]. [1]U.S. Fish and Wildlife Service; [2]Kent Business School, University of Kent; [3]California Fish Passage Forum.
FISHPass: A Decision Support Tool for Optimizing Barrier Mitigation
FISHPass is a user friendly software that allows optimization of potential fish passage barrier removal scenarios. The California Fish Passage Forum has collaborated with leading experts in combining optimization methodologies and natural resource decision making to develop and refine the tool, which helps strategically prioritize and efficiently implement fish passage barrier remediation throughout the anadromous waters of California. FISHPass incorporates existing barrier data (e.g., California Fish Passage Assessment Database) to develop optimal barrier remediation solutions (versus ranking and scoring) based on a wide variety of desired outcomes and potential constraints. The software also integrates information

on barrier passability, potential habitat, and mitigation cost. Additionally, FISHPass accounts for spatial structure of barrier networks and the interactive effects of mitigation decisions on longitudinal connectivity. The Forum is currently working on strengthening the ability to estimate and balance factors, such as quality of habitat gained, cost constraints, differential species preferences and regionally unique priorities to attain the most efficient fish passage remediation at local, watershed, regional, and state scales. FISHPass, with additional refinements, is expected to prove useful in fish passage barrier planning and remediation throughout the United States.

Raz*, Y. [1]. [1]Yarqon River Authority.

Rehabilitation of the Yarqon River, a polluted Mediterranean climate ecosystem and reintroduction of the Yarqon bleak, an endangered endemic freshwater cyprinid fish

The Yarqon River is a 28 km long meandering perennial stream in the coastal plain of Israel with a catchment area of 1,800 km^2. The river's estuary flows through the Tel Aviv metropolitan region into the Mediterranean Sea. Diversion of its former annual 200 million m^3 of spring flow, second only to the Jordan River, has reduced the base flow to less than 4% and discharge of effluents kept the Yarqon an intermittent stream. As in other coastal streams, the fish of the Yarqon underwent major changes as a result of habitat destruction, pollution and fish introductions. Seasonal flooding events wash in contaminants from the watershed that often result in stress on the ecosystem and fish-kills. Rehabilitation efforts have partially improved the stream's water quantity, quality and habitats. The Yarqon River Master Plan calls for allocation of at least 10% of the original natural base flow, i.e. 2,500 m^3/hour. Currently the upper, relatively undisturbed 7 km section, receives 1,350 m^3/hr source water from wells in the aquifer. The rehabilitation of the ecosystem in this section has enabled the reintroduction of the Yarqon bleak – an endemic, endangered, red listed, freshwater cyprinid fish. The middle section, 16 km long, receives flow from upstream and tertiary effluents from a WWTP, 1,500 m^3/hr, that are pumped into a vertical subsurface tidal wetland VFTW before entering the river. Downstream, most of the water will be diverted to irrigation projects. The perennial nature of the 4 km estuary is maintained by allocating water from upper sections of the river. Together with intermittent winter flooding, these actions are expected to reinstate a Mediterranean-type flow regime.

Ryan*, E. R.[1], T. A. Stephens[1], and B. P. Bledsoe[1]. [1]Colorado State University.

Effects of Hydraulic Structures on Fish Passage: An Evaluation of 2D vs 3D Hydraulic Analysis Methods

Channel-spanning hydraulic structures can act as barriers to upstream fish movement. Negative consequences associated with this disruption of longitudinal habitat connectivity highlight the need for accurate and practicable assessment techniques. Three-dimensional evaluation methods have been shown to resolve the complex flow at in-stream structures and accurately predict fish movement; yet three-dimensional modeling can be impractical due to time and resource requirements. This study investigates

using a two-dimensional computational fluid dynamics model to describe the hydraulic conditions at a whitewater park structure in Lyons, Colorado. Hydraulic variables are defined along spatially explicit, continuous paths, which represent potential swimming paths, and paired with fish movement observations in statistical models. Logistic regression analyses indicate that flow depth and velocity are strongly associated with fish passage; a combined depth and velocity variable accurately predicts 92% of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) movement observations at this hydraulic structure. The results of this study suggest that two-dimensional analysis methods can provide a cost-effective approach to assessing the effects of similar hydraulic structures on fish passage when three-dimensional analysis is not feasible. Further, conclusions from this study can be used to guide management and design decisions for both trout and fishes with comparatively lower swimming performance.

Santos*, J. M. [1], P. Branco[1], S. Amaral[1], A. Silva[2], C. Katopodis[3], T. Ferreira[1], A. Pinheiro[4], and T. Viseu[5].
[1]Instituto Superior de Agronomia, Universidade de Lisboa; [2]Norwegian Institute for Nature Research; [3]Katopodis Ecohydraulics Ltd.; [4]Instituto Superior Técnico, Universidade de Lisboa; [5]Laboratório Nacional de Engenharia Civil.
The FISHMOVE project - Development of mitigation measures for small instream obstacles to fish migration in Portuguese streams
A great number of studies have reported significant changes in the structure, diversity and persistence of fish populations as a result of river fragmentation by large man-made structures. The effects of small instream obstacles, such as small weirs, have received much less attention, yet they are likely to be 2–4 orders of magnitude more numerous than large structures. These obstacles alter the patterns of current velocity, water depth and create vertical drops at outflows that change the hydraulic regimes of aquatic systems and impede the movement of fish species. The FISHMOVE project - Development of mitigation measures for small instream obstacles to fish migration in Portuguese streams – had as major goals the assessment of the effects of small instream structures on the migratory movements of Iberian cyprinid freshwater species, particularly their ability to negotiate distinct physical and hydraulic obstacles, as well as to determine the performance of fish movements through fish passage devices (pool-type fishways) with different flow regimes and retrofitting (i.e. boulder placement) designs. This study aims to report the different tasks carried out during the project, the main results achieved and respective implications for the improvement of longitudinal connectivity of rivers.

Schiff*, R. [1], and J. Macbroom[1]. [1]Milone & Macbroom.
Bridges, Culverts, and Flood Resilience
Over the past several years' large databases with thousands of records of bridge and culvert information have been assembled in the region, and this information needs to be screened to identify problem areas and possible locations for retrofit or preplacement. This talk summarizes the knowledge gained during several screening projects where tools were developed to see how well a structure matches the channel (i.e., geomorphic compatibility), if the channel reach is prone to excessive erosion or deposition (i.e., approximating stream power and bed resistance), and identifying the level of aquatic organism passage. This information is used to identify and prioritize projects for field verification, and guide the initiation of the design process.

Shupe, K., Heiner, B. and J. Wagner. U.S. Bureau of Reclamation.
Fish Screening and Passage at the St. Mary Diversion Dam near Babb, MT
After 100 years of service, the St. Mary Diversion Dam is being replaced with a new design that will provide more effective fish passage and protection. The diversion is located in northern Montana, adjacent to the east side of Glacier National Park. It diverts water from the St. Mary River 1 mile downstream of Lower St. Mary Lake. The existing 198-foot-long and 6-foot-high concrete weir diverts up to 850 cubic feet per second design flow from the St. Mary River into a 29-mile long irrigation canal. The existing facility, which is maintained and operated by the U.S. Bureau of Reclamation (Reclamation), was completed in 1915 and is in need of replacement. Endangered Species Act (ESA) listed species have been adversely affected by seasonal passage and entrainment into the canal. The St. Mary Diversion and Milk River Irrigation project have been identified as the primary threat to Bull Trout habitat in the St. Mary River drainage. Recovery efforts to restore Bull Trout habitat in the St. Mary River drainage requires that Reclamation provide effective Bull Trout passage and protection at the St. Mary Diversion. This paper presents a short history of the St. Mary Diversion and Milk River Irrigation project, and includes collaborations with all interested parties as well as physical and numerical modeling efforts that were used to enhance the design of the replacement structure to provide the best situation for Bull Trout recovery without limiting diversion capability.

Schuetz*, C. [1], and M. Herbst[1]. [1]German Federal Institute of Hydrology.
Reducing sample size in an open flume experiment by using a crossover design
Flume experiments with fish can be used to optimize the construction of fishway components. The necessary sample size in such experiments should be large enough to guarantee statistically sound results. Likewise, the number of fish should be as small as possible to reduce research time and meet ethical and legal demands for animal protection. In clinical trials, crossover designs are used because fewer patients are required in order to attain the same level of statistical power as in parallel designs. We use a 2x2 crossover design for a flume experiment where we investigate fish reactions towards different ways of adding auxiliary discharge into a fishway. Two construction types (A and B) are compared. The fish are randomly assigned to one of two experimental groups of equal size, AB and BA. Each fish is "treated" with both construction types. Fish assigned to group AB are first exposed to type A and then to type B. In group BA the sequence is vice versa. Since both construction types are investigated with the same fish, variance (intraspecific) is low, which yields a much smaller sample size than a parallel design where variance (interspecific) is much higher. In our case we calculated a minimum of 37 data points for each construction type which equals 37 fish. A parallel design calculated for the same power, significance and effect size would need 64 measurements per type and 128 fish. Problems can arise from carry over effects (e.g. training effects) or from sequence effects. To minimize training effects, we keep a minimum interval of 5 days between both "treatments". To avoid sequence effects we keep the fish in constant conditions (temperature, water quality, food). In such a way crossover designs can be a suitable statistical basis for flume experiments.

Scott*, S. [1]. [1]S. Scott & Associates LLC.
Survey of two Behavioral Fish Guidance Systems designed to improve safe downstream passage of anadromous salmonids
Many anadromous fish species, such as Pacific and Atlantic salmon (*Onchorhynchus spp*., *Salmo salar*), the shads and river herring (*Alosa spp*.), and catadromous species including the American eel (*Anguilla rostrata*), are in danger of extinction throughout some or all of their range. Impacts to these populations include entrainment at hydroelectric dams and other water conveyance facilities. State and federal laws now mandate protection of these and other fish populations. Facility operators must often implement physical or operational modifications to reduce fish entrainment. This presentation will document two Behavioral Fish Guidance Systems (FGSs) recently installed in California, USA, to improve survival of downstream migrating anadromous salmonids. The FGS is an effective technology for routing downstream

migrating fish to safer routes of egress. The FGS is composed of a series of floating panels anchored across the river channel. Many fish species migrate downstream in the thalweg, taking advantage of higher water velocities. The FGS is designed to exploit this migratory behavior and guide fish to a safer point of egress. The design and configuration of the FGS varies at each site according to hydraulic conditions and species present. A FGS was installed and tested in a tidal area in the Sacramento River in 2014. The purpose of the project was to reduce juvenile fish entrainment into Georgiana Slough an area of high predation. Results indicate that the FGS provided measurable guidance improvements. A second FGS was installed in 2015 at the Los Padres Dam, Carmel River, in conjunction with a Floating Surface Collector. The purpose of the system is to guide fish to the collector where they would then be conveyed safely through a pipe downstream below the dam. We will describe the unique design requirements at this site.

Sečnik*, M. [1], M. Brilly[1], K. Zabret[1], K. Sapač[1], and A. Vidmar[1]. [1]Faculty of Civil and Geodetic Engineering, University of Ljubljana, Jamova 2, SI-1000 Ljubljana, Slovenia.

A stereo vision camera system for monitoring fish migration

Within the European LIFE project, Ljubljanica Connects (LIFE10 NAT/SI/000142), we have developed a solution for monitoring fish migration through fish passes by using an underwater camera. In the fish passes at Ambrožev trg and near Fužine Castle we installed a video camera called "Fishcam" in order to monitor the migration of fish through the fish passes and evaluate the success of its reconstruction. Live stream from fishcams installed in these fish passes is available on our project website (http://ksh.fgg.uni-lj.si/ljubljanicaconnects/ang/12_camera). One disadvantage of monitoring fish migrations with a camera is that you cannot determine the size of the fish in the fish passes. In order to solve this problem, we decided to upgrade the fish monitoring system by installing two additional high-resolution digital cameras. Cameras are placed on opposite walls near the exit at Ambrožev trg fish pass. When a fish is detected, both cameras capture a picture of the fish from two different angles at the same time. From these two pictures, we then calculate fish size and estimated weight. This system of monitoring fish migration has turned out to work very well. From the beginning of monitoring in June 2015 to end of the year, more than 100,000 photographs were taken. The first analysis has already identified fish species in the pass and estimated their frequency of passage.

Shively*, D. [1], G. Apke[2], D. Heller[3], J. Capurso[1], and A. Moore[4]. [1]U.S. Forest Service; [2]Oregon Department of Fish and Wildlife; [3]Oregon Fish Passage Task Force; [4]Trout Unlimited.

Salmon SuperHwy: Strategic Fish Passage Barrier Prioritization and Community Engagement in the Tillamook-Nestucca Subbasin, Oregon.

Anthropogenic barriers to fish movement continue to have significant negative impacts on fish populations and other aquatic organisms world-wide. In the Pacific Northwest, these barriers are typically dams, culverts, or tide gates. Most typically, passage restoration occurs in an ad-hoc, opportunistic fashion across the landscape without benefit of using a strategic focus to identify which combination of projects might yield the greatest benefit at the fish population level. In response to this, a cooperative pilot project known as the Salmon SuperHwy was developed to provide a comprehensive and strategic approach to passage restoration. This was accomplished using a full assessment of passage barriers; estimates of restoration cost and the amount of blocked habitat, by species, for each site; and optimization models to arrive at the best barrier removal solution given limited resources. The Salmon SuperHwy is a landscape-scale program to expeditiously reconnect fish passage and watershed functionality, provide major economic benefits for local communities and upgrade important transportation infrastructure in the Tillamook sub-basin.

Significant restoration accomplishments result from implementation of a strategic, community-based blueprint for reconnecting the most biologically important stream networks and selecting the most cost efficient combination of restoration projects for implementation. Using traditional methods, restoring passage at all 270+ barriers, at average current spending of $2 million/year, would take 70 years and $140 million. The Salmon SuperHwy approach provides an investment portfolio and construction blueprint to achieve similar benefits in a fraction of the time and for less total cost by strategically selecting the most biologically important and cost efficient suite of projects. Community focus and team work, job creation and related economic benefits, increased flood resilience, a reduced public works maintenance burden and healthier fisheries and ecosystems are important outcomes from this investment in the future.

Silva*, S. [1], B. Byatt[2], M. Lowry[1], C. Macaya[1], E. T. Silva[1], and M. C. Lucas[1]. [1]School of Biological and Biomedical Sciences, Durham University, UK; [2]Environmental Agency, UK.

European River Lamprey Lampetra fluviatilis *passage efficacy at a tidal barrage using a navigation lock as a novel fish pass*

Tidal barrages, navigation locks, and sluices are abundant in estuaries and are important restrictions for the migration of diadromous species, especially anguilliform morphotype species, such as lampreys and eels, due to their poor swimming performance. This study aimed to test the efficacy of using a navigation lock under ebb tide conditions to facilitate upstream passage of adult European river lamprey at a tidal barrage located in the mouth of the River Derwent, which separates it from the tidal river Ouse (UK). The primary role of this barrage, which has two undershot sluices, is to prevent tidal water intrusion. The navigation lock (~5 m wide and ~4 m deep) was operated as a vertical slot fish pass by opening and adjusting the gates during the early part of the ebbing tide to provide attraction flow and access at head (ca. 0.20 m per gate pair, total ca. 0.40 m) and associated water velocities believed to be passable upstream by river lamprey. To evaluate the attraction and passage of lamprey, PIT (322 tagged individuals), acoustic (n=59, double tagged with PIT) and radio telemetry (n=8, double tagged with PIT) were used on lamprey caught from the Ouse. Of lamprey released within the navigation lock (n=156) and immediately downstream of the navigation lock (n= 107), 58% and 38% successfully passed through the navigation lock. In addition, 27% of the acoustic tagged individuals released 500 m downstream of the barrage, in the Ouse, entered the Derwent and passed the barrage. Further details concerning the route taken, time to passage and influence of environmental factors will also be presented. These results reveal the use of navigation locks as fish passes as a promising method to improve passage of diadromous species and as a contribution to conservation measures at tidal barriers, and with potential utility for non-tidal areas.

Spares*, A. [1], G. Nau[1], N. McLellan[2], S. Andrews[1], M. Mallory[1], and M. Stokesbury[1]. [1]Acadia University; [2]Ducks Unlimited Canada.

Mutiyear evaluation of fishway passage, river switching and survival of alewife (Alosa pseudoharengus) within the Tantramar Marshes, Canada.

From 2013 to 2015, we tagged 3,577 alewife (*Alosa pseudoharengus*) with Passive Integrated Transponders (PIT) during their annual spawning migration in the Tantramar Marsh, Canada, to quantify passage rate through three fishways, describe intra- and inter-annual river switching behavior, and estimate freshwater and marine survival. Fishway attraction efficiency was estimated at 98% and 85% for a Denil and pool-

and-weir structure, respectively, during the 2015 upstream spawning run. Passage rates ranged from 74% to 97% for two Denil style fishways, while rates for a pool-and-weir fishway were 0%, 50% and 63% during 2013, 2014 and 2015 spawning runs, which related to a dysfunctional, repaired and replaced structure, respectively. Alewife detected within fishways were significantly longer than undetected individuals ($p \leq 0.001$), which may indicate older, more experienced migrants. Successful migrants spent significantly less time downstream of fishways post-tagging ($p < 0.001$), and remained above fishways 1-4 weeks before returning downstream to demonstrate an impoundment survival minimum estimate of ≥ 72%. Spawning run returns were estimated at 22% and 10% of alewife detected after one and two years at large, respectively. River switching occurred for migrants during runs (1% to 9%) and in subsequent years, suggesting inter-annual straying on systems sharing a marine outlet can be as high as 56%. Recaptured individuals revealed a mean ± SD annual growth rate of 10 ± 10 mm fork-length and 9 ± 21 g wet body mass. Our results advocate for regular operational maintenance of fishways, regardless of monitoring to verify passage success. Size differences of migrants attempting and successfully passing fishways, in combination with river switching behavior, complicate fisheries and river connectivity management. Single barriers within different systems may potentially drain the energy reserves of anadromous fishes multiple times during upstream and downstream movements.

Straughan*, E. [1]. [1]Straughan Environmental, Inc.
Design and Construction of a Riffle Grade Control to Restore Fish Passage
A riffle grade control (RGC) was designed and constructed to restore fish passage on White Marsh Run, a tributary of the Bird River, in Baltimore County, Maryland, USA. The project was part of a comprehensive plan to mitigate unavoidable impacts to wetlands and streams that accompanied construction of the US Interstate-95 Express Toll Lanes project. The plan included construction of the riffle grade control, stream bank stabilization, vernal pool creation, and wetland preservation and restoration on a 169-acre parcel purchased by the Maryland Transportation Authority for mitigation and conservation purposes. Fish blockage was created by a five-foot drop to the water surface from the bottom of a box culvert structure that carries U.S. Route 40 over White Marsh Run. A fish ladder had been installed to overcome the existing blockage, however the fish ladder was plagued with maintenance issues and did not function effectively for fish passage. The presentation will address design constraints, parameters governing design, elements of the design process, and challenges faced during construction. Hydrologic and sediment transport regimes were assessed with stream gages, discharge and bedload measurements, and sediment transport modeling. Design constraints included a minimum flow depth and maximum velocity to provide fish passage during spring baseflows, structural stability during the 10- and 100-year discharges, competence and capacity to transport existing bedloads, maintenance of the existing floodplain elevation along U.S. Route 40, strict grading limitations due to nearby buried diesel fuel soil contamination, and utility rights-of-way. Hydraulic and sediment transport analyses (HEC-RAS, iSURF, various stone sizing and gradation equations) were solved iteratively to design a stable structure, constructable from a mixture of regional stone sources, that would maintain the minimum baseflow depth, not exceed the maximum baseflow velocity, promote surficial flow, transport bedload, include fish resting areas, and not increase the floodplain elevation over U.S. Route 40.

Teichert*, M. [1], T. Havn[2], E. Thorstad[2], F. Økland[2], O. Diserud[2], S. Sæther[2], J. Borcherding[1], M. Tambets[3], L. Heermann[1], and R. Hedger[2]. [1]University of Cologne; [2]Norwegian Institute of Nature Research; [3]Estonian Wildlife.
Comparison of three downstream fish pass solutions in Germany, using Atlantic salmon smolt
Different technical solutions are currently in use to improve downstream fish passage. However, due to the lack of standardized studies, it is usually difficult to directly compare the efficiency of such installations. Here, we aimed at examining migration routes and comparing losses of Atlantic salmon smolt past three German hydropower stations. Each power station uses a different technological approach to minimize harm to affected fish populations, i.e. narrow trash rack bar spacing combined with several bypasses, an Archimedean screw and a movable turbine. Data was gathered by tagging 525 Atlantic salmon smolt with

radio transmitters and recording their migration past the power stations. A baseline mortality was measured on an unimpounded section of the river, upstream of the hydropower installation and compared to mortalities recorded in the reservoir and power station. Loss of downstream migrating smolt due to hydropower production was approximately 10%. This represents the minimum percentage of smolt entering the power station that were lost due to the presence of the power station rather than a free-flowing river. Results showed that reservoirs upstream of power stations can also be areas of high mortality. The main reason was likely the presence of more piscivorous fish in the deep and slow flowing reservoir compared to unimpounded river stretches.

Verep*, B. [1], S. Küçükali[2], D. Turan[1], and A. Alp[3]. [1]University of RTE; [2]University of Çankaya; [3]University of Kahramanmaraş Sütçüimam.

A critical analysis of existing fish pass structures at small hydropower plants in Turkey

In this study, the status of the existing fish pass structures at Small Hydropower (SHP) plants in Turkey has been analyzed critically. In addition, the effect of legislation on the design and construction of fish pass structures in the country is evaluated. In Turkey, as of January 2016, 451 SHP plants are in operation with a total installed capacity of 6790 MW under the scope of the Renewable Energy Law. It is argued that conventional fish pass structures are not adequate for those SHP plants, which are mostly situated on small river basins, because most fishways are not designed to facilitate the passage of low swimming capacity fish. It is proposed that brush fish pass structures are more suitable for those SHP plants. Brush-type fishways are known to provide low velocity areas less than 1 m/s, a variety of structures inside the water body, and ample of resting area for small and juvenile or weak fish. For instance, migration through the brush and vertical slot fish pass was monitored daily at a site on the River Havel in Fuerstenberg, north of Berlin. Less than one month after both passes were operational more than 14,200 individuals of 14 species migrated through the brush fish pass, with no size selection, although the size range of fishes started at 4 cm and was probably down-limited by trap mesh size. In the same period around a tenth of this number, representing 12 species, used vertical-slot fish pass. This monitoring data indicates the functionality of brush fish passes. Using this approach, the efficiency of the vertical-slot fishway at a SHP plant on the Ceyhan River in Turkey will be assessed based on fish monitoring data. A brush fish pass structure is designed for an existing SHP plant on the İyidere River, which has a catchment area of 835 km2 and annual discharge of 28 m3/s. The İyidere River basin, located on the east coast of the Black Sea in Turkey, is an area rich in biodiversity where 13 fish species have been identified. Streams of the Eastern Black Sea Region of Turkey have rich fish populations (approximately 20 taxa including 2 trout species). But in this region, SHP development is important nowadays (419 SHP projects are planned for Black Sea Region). Every hydropower plant has to build fish passage structures to protect vulnerable fish populations according to the environmental laws of Turkey, but how well these fish passages work remains largely unanswered.

Vorenkamp**, K. E. [1], B.J. Sansom[1], J.F. Atkinson[1], and S. J. Bennett[1]. [1]SUNY University at Buffalo.

Quantifying the swimming capacity of emerald shiner minnows (Notropis atherinoides*) from the Upper Niagara River, and determining fish passage criteria.*

Along the Upper Niagara River, near its outlet from Lake Erie, structures such as the international Peace Bridge and the Broderick Park Seawall have altered river flow, increasing water velocity to an extent that may negatively impact wildlife, specifically emerald shiner minnows (*Notropis atherinoides*). The emerald shiner minnow (ESM) is prey to many fish and migratory birds, and is considered to be a keystone species for the area's ecosystem. If increased water velocity has created an unnatural hydrodynamic barrier to fish

migration upstream, the ESM population may be impacted. We are conducting swimming capacity and endurance trials to quantify the swimming ability of the ESM, which will then be used to design fish passage amendments for the ESM to help the fish swim upstream to Lake Erie. A total of 97 ESMs were tested at water velocities ranging from 0.10 to 0.70 meters per second (m/s). There is no distinct trend for the success/failure rate of an ESM for a given velocity. The only definite observation made was the inability of any ESM to successfully swim at speeds greater than 0.60 m/s. The Upper Niagara River recorded water velocities exceeding 1 m/s. Based on initial observations, the swimming capacity of an individual ESM would not enable the fish to navigate upstream under these conditions. In general, it appears that the top swimming speed for these fish is between 0.60 and 0.70 m/s, and that larger (older) fish can generally swim faster that smaller (younger) fish. Future work will focus on improving our estimate of the critical swimming speed for ESMs by conducting additional individual and schooling swim trials. These data will then be incorporated into the modeling process to design appropriate fish passage structures along the Upper Niagara River to ensure successful connectivity to Lake Erie.

Wagner*, J. [1]. [1]US Bureau of Reclamation.

Fish Passage - Challenge Grants

Fish Passage Challenge Grants - much more than a penny for your thoughts. The Bureau of Reclamation is launching a new initiative where specific "Challenges" are outlined, and the general public is invited to submit solutions. Additionally, the challenges will contain a significant cash award to the top, or top few submissions. As part of the "challenge.gov" initiative, Reclamation has already launched several of these for remote fish detection, quantifying drift invertebrates, and downstream juvenile fish passage. This is similar in many ways to crowdsourcing, with the exception that there are prizes associated with innovative solutions. This will be a presentation of interest to many participants, and we may have a booth set up as well. The challenges are ongoing, and changing, and have cash prizes in excess of $10,000. One of the goals is to further the state of the art as related to fish passage, ecohydraulics, ecohydrology and related issues, and where applicable, share the results of these challenges in future years at conferences. As this is a new program, more details will be provided before the conference, as many are dynamic at the time of abstract submission. Please contact me with any questions. Thanks -Jason Wagner 303-445-3136 jwagner@usbr.gov

Walker*, K. [1], T. Vermeyen[1], and C. Svoboda[1]. [1]US Bureau of Reclamation.

Physical modeling of the Inskip Diversion Dam Fish Screen

Inskip Diversion Dam is a Pacific Gas & Electric project that diverts water from the South Fork Battle Creek located in Tehama County, northern California, through a canal to an offsite powerplant. This location has a unique volcanic geology that provides winter and spring-run Chinook salmon, and also Central Valley Steelhead, with year-round cold water springflow into Battle Creek. As part of a larger watershed restoration program, the Inskip Diversion Dam is being modified to provide a fish screen for the powerplant canal and fish ladder / bypass passage of the 28 ft high dam. Due to high sediment loads from the high gradient Battle Creek, a sediment basin has been incorporated with the design, and has been modeled at U.S. Bureau of Reclamation’s Hydraulics Laboratory. The model study includes both a 1:5 Froude scale model of the sediment basin and fish screen structure as well as a 1:8 Froude scale model of the diversion dam and fish ladder entrance chamber. This paper presents a brief background of the Battle Creek Restoration project and focuses on the physical model results and the ability of the design to manage sediment loads.

Wechsler*, J. [1]. [1]Kleinschmidt.

Monitoring juvenile American eel movements to inform the design of eel fishways - location, location, location!

Juvenile American eels require safe upstream passage over dams to access freshwater rearing habitat. The location and design of upstream eel fishways is critical to successful passage. Eel fishways must attract and pass eels successfully; withstand large river flows, ice, and debris; and they may need to be removed annually to accommodate normal dam operations (i.e., opening gates, spill over the dam). Prior to designing and installing an upstream eel fishway, researchers often perform nighttime surveys or install temporary traps to find where juvenile eels congregate or ascend a dam or others structures. Similarly, post-installation surveys are often completed to determine whether eel fishways are effectively capturing juvenile eels during their upstream migration. Scientists at Kleinschmidt routinely perform these surveys to provide biological data used in the design and location of upstream eel fishways. This presentation describes (1) techniques used to survey and monitor juvenile eels prior to, and after eel fishway installation (2) the design of several upstream eel fishways that have been installed in river systems along the Atlantic coast and (3) a straightforward way to test whether juvenile eels are able to ascend eel fishways.

Weiter*, R. [1], and E. Mas[1]. [1]Fuss & O'Neill, Inc.

Assessment and Prioritization of Stream Crossings for Flood Resiliency and Ecological Connectivity in the Wood-Pawcatuck Watershed

Historically in New England, inland flooding associated with extreme precipitation has been a leading threat to infrastructure and public safety. The Wood-Pawcatuck watershed has experienced significant and increasing flood damages to public and private property in both Rhode Island and Connecticut, including the Great Rhode Island Flood of 2010 and other large storms that have occurred in the past few years In 2014, the Wood-Pawcatuck Watershed Association (WPWA) was awarded a Hurricane Sandy Coastal Resiliency Grant through the U.S. Department of the Interior and the National Fish and Wildlife Foundation to help communities become more resilient to the impacts of coastal and inland flooding. WPWA is interested in identifying opportunities for improved flood resiliency that will also result in improved ecological connectivity and aquatic organism passage within the watershed. WPWA is leading a two-year project to assess the vulnerability of the Wood-Pawcatuck watershed to inland flooding and to develop a watershed based management plan to enhance flood resilience and strengthen natural ecosystems. The project consists of several technical evaluation tracks including a stream geomorphic assessment; bridge, culvert and dam assessment; natural resource inventory; green infrastructure assessment; and land use regulatory review. This presentation reviews an assessment of more than 500 dams, bridges, and culverts in the watershed, using an integrated approach for prioritizing improvements to hydraulic structures that considers hydraulic capacity, flood impact potential, geomorphic compatibility, overall condition, and aquatic organism passage. The presentation will review the assessment methods, findings, and recommendations to date, as well as general implications for municipal infrastructure planning.

Wilson*, J. [1], K. Connell[1], and J. Perry[2]. [1]Fuss & O'Neill, Inc.; [2]CTDEEP.

Sediment Redistribution & Impact Analysis at Springborn Dam, Enfield, CT

Fuss & O'Neill, in cooperation with the Connecticut Department of Energy and Environmental Protection (DEEP), completed an assessment of sediments impounded by the Springborn Dam in Enfield, Connecticut. The dam is currently in disrepair and serves no purpose, and the DEEP would like to remove the dam to eliminate liability and the need for continued maintenance and repair. Sediment sampling has been conducted to assess potential water and sediment quality impacts to downstream river reaches if some or all of the sediment contained by Springborn Dam was allowed to naturally erode from the impoundment

and be redistributed downstream. The purpose of this assessment was threefold: First to evaluate the likelihood that adverse ecological effects may occur or are occurring as a result of sediments impounded by the dam by comparing chemical concentrations to ecological screening criteria; Second, to assess toxicity of in-situ sediments, suspended sediments and the water column; Third, to evaluate the sediments against Connecticut Remediation Standard Regulation criteria for the purposes of guiding the disposal of dredge sediments. Early results of sediment testing indicated that over 30,000 cubic yards of sediment may need to be removed. This current analysis included chemical and toxicological evaluation of impounded sediment. Based on the results of both the chemical and toxicological investigations, a portion of impounded sediments were shown to possess characteristics of ecological toxicity and/or exceed the regulatory cleanup criteria. This portion of the sediment would need to be removed and disposed of off-site. The remaining sediment was determined to be clean and suitable for on-site reuse or natural redistribution without adverse impacts on downstream aquatic organisms. The results of the supplemental testing and analysis reduced the volume to less 14,000 cubic yards.

Woodworth*, P. [1]. [1]Princeton Hydro.

Comparing sediment contamination, regulatory responses, and sediment management approaches among dam removal projects in the northeastern US.

Many dams that are no longer serving an economic purpose and are no longer being maintained are being removed to reduce liability, to ensure public safety, and to restore river ecology. The management of impounded sediments is one of the greatest challenges to the removal of dams, presenting a potentially costly and complicated situation. A comparison of multiple dam removal projects across the northeastern US reveals that (1) many impoundments, regardless of size or geographic location, have low concentrations of contamination that represent potential ecological effects according to established ecological screening criteria, and that (2) the wide-spread low-level contamination, which may eclipse the most protective ecological screening criteria (i.e. threshold effect levels), appears to represent ambient or background conditions. Regulatory concerns have also focused on sediment quantity and minimizing potential impacts to wetlands on-site. Response and guidance from agencies regarding sediment quality, quantity, and wetland impacts has varied widely among states and agencies. Balancing these concerns has produced dam removals that involved passive sediment release, re-location of sediment on-site, or, less frequently, excavation and off-site disposal of impounded sediment. These trends within the region based on the varied regulatory responses and resulting sediment management approaches provides valuable insight and guidance to dam owners, regulators, and dam removal practitioners when analyzing alternatives for a dam, and developing engineering designs for permitting a dam removal project.

Wright*, J. [1], A. Abbott[1], and J. O'Hanley[2]. [1]U.S. Fish and Wildlife Service; [2]University of Kent.

What can we learn from 17,000 structures?

Maine leads the nation in surveying road-stream crossings. Since 2007, a broad partnership has developed a massive culvert dataset based on a standard field protocol. Statewide surveys contain information on location, structural dimensions and condition, and habitat values. Survey data has been used in a larger variety of applications including watershed planning, engaging municipalities and private landowners, and generating public support for fish passage. Our presentation begins with a summary of structural information and relationships between environmental variables including drainage area, slope and position. We use network analysis to summarize the impact of road-stream crossings on aquatic landscapes in Maine. We then explore methods to best make sense of this large dataset including focus area, optimization and prioritization approaches. We utilize OptiPass software at various scales and provide lessons learned from attempts to utilize optimization outputs for on-the-ground applications. Our presentation will provide attendees with a better understanding of the relative merits of different approaches for barrier removal decision making and will show lessons learned from such a rich dataset.

Young*, S. [1]. [1]Shawn Paul Young Environmental Consulting, LLC.
A 10-year history of Alabama Shad restoration via renewed fish passage
An overview of a 10-year effort to restore Alabama Shad in the Apalachicola-Chattahoochee-Flint (ACF) River Basin will be presented. Beginning in 2005, a project was initiated to evaluate whether Alabama shad could be passed upstream using the navigation lock at Jim Woodruff Lock and Dam, Florida/Georgia. After several years of promising results, an otolith microchemistry study was completed in conjunction with the passage evaluation to determine if restored access to upstream spawning habitat was responsible for population increases observed from 2010 - 2012. Project results will be presented; and the implications for Alabama Shad restoration will be discussed.

Zielinski*, D. and P. Sorensen. University of Minnesota.
Acoustically guided avoidance responses in three invasive carp species
Acoustic (sound) deterrents are one type of behavioral guidance technology that has been proposed to control movement of invasive fish with specialized hearing abilities like the common carp (*Cyprinus carpio*), silver carp (*Hypopthalmichthys molitrix*), and bighead carp (*H. nobilis*). In order for sound to guide movement, fish need to be able to use information from the local sound field to either orient to or localize its source. Currently, it is unclear what orientation mechanism guide fish movement during avoidance responses. We characterized phonotaxic (movement oriented with respect to the sound direction or gradient) orientation mechanisms used by invasive common, silver, and bighead carps to avoid a sound source through laboratory trials using underwater speakers playing outboard boat motor sounds. Avoidance behaviors of all three species were characterized by >70% reduction in time spent near the speaker when sound was played. Comparisons between fish movement and local sound field components (pressure and particle motion) demonstrated that carp are strongly repelled in a highly directional manner associated with the axes of local particle motion. In this talk I will discuss past and ongoing results as well as the potential role of acoustic deterrents in management efforts to control movement of invasive common, silver, and bighead carp. (Funded by the Environmental and Natural Resources Trust Fund).

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A landscape-scale watershed assessment method to support fish passage restoration strategies in Puget Sound, Washington State: A case study for the Fish Barrier Removal Board
In 2014, the Washington State Legislature directed the creation of the Fish Barrier Removal Board (FBRB), a multi-entity committee tasked with the development of a statewide strategy for removing anadromous fish barriers. In accordance with legislation, the strategy will identify individual watersheds with the greatest potential for salmon and steelhead recovery, and develop plans for the removal of multiple barriers within those watersheds. Prioritizing whole watersheds for barrier removal is a new and untested management approach to fish passage restoration in Washington State. To inform the FBRB's watershed-based strategy, this case study applied aquatic habitat indicators to a landscape-scale assessment of current and potential salmon and steelhead habitats in Puget Sound watersheds. Puget Sound watersheds were divided into 92 hydrologic units for a spatial analysis of 2 selected habitat indicators that correspond to habitat suitability and anthropogenic disturbance. Measurements of intrinsic potential for steelhead rearing and impervious surface land cover are presented in a decision support matrix.