POSTER ABSTRACTS (*presenter, **student presenter)

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*The fine-scale behavior of downstream migrating silver European eels (*Anguilla anguilla*) immediately upstream of pumping stations*

The critically endangered European eel (*Anguilla anguilla*) has a catadromous life cycle, spending the majority of its life in freshwater before migrating downstream to spawning grounds in the Sargasso Sea. Pumping stations that drain the catchment are essential for flood control and are abundant in many parts of the UK, but are likely to contribute to eel population decline because eel must pass through pumps in order to escape from the catchment. Aside from injury or mortality during passage through pumps, delays caused by these structures may increase predation risk, deplete energy reserves and increase susceptibility to diseases due to stress. The EC Eel Regulation (1100/2007) establishes measures for the recovery of European eel and is enacted in England through the Eels Regulations 2009 Statutory Instrument, which will help protect eel and ensure their safe passage through rivers, including screening abstractions (>20 m3 a day), unless exempted by the Environment Agency. However, little research has been conducted on the impact of pumping stations on eel behavior. Fine-scale behavior of eels implanted with an acoustic tag was investigated using arrays of acoustic receivers to triangulate tag detections directly upstream of two different pumping stations. One pumping station represents the sole discharge route for the catchment and the other has a co-located gravity door which is opened when tidal river levels downstream permit. Eel movement tracks were produced for individuals that had multiple consecutive detections in the array. Detected eels performed extensive searching behavior with some entering the array on multiple occasions, including during periods when pumps were not operational. These findings suggest that pumping stations do affect eel behavior and cause migration delays. The need to deter eels from potentially harmful routes and provide eels with a safe alternative is essential to ensure the potential spawning success of this species.

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Comparing the effects of culvert fragmentation on potential functional connectivity of diadromous fish species using morphometrics

Stream fragmentation due to culverts affects the functional connectivity of various fish species differently. Particularly, diadromous species, which require migrating through both freshwater and marine habitat to complete their lifecycle, are impacted by the cumulative encounter of obstacles upstream. Accessiing habitat upstream requires fish to overcome obstacles throughout streams. They can do so if they have good swimming abilities and strength. Yet swimming strength is mostly unknown for many species. To address this knowledge gap, we used a morphometric approach based on the aspect ratio of the caudal fin and total fish length to infer the swimming strengths of two diadromous species—Atlantic salmon (*Salmo salar*) and alewife (*Alosa pseudoharengus*), where the former is a stronger swimmer than the latter—found in the watersheds of New Brunswick, Canada. We applied two connectivity indices to quantify the potential functional connectivity as these species pass through culverts located by Fisheries and Oceans Canada within the stream networks of three watersheds. First, we used a directional Probability of Connectivity to identify specific critical barriers that affect potential functional connectivity accounting for the upstream movement of each species. Second, we calculated the Dendritic Connectivity Index to assess the overall potential functional connectivity of the stream network for each species. We then performed a sensitivity analysis to determine the importance of specific species traits and culvert features that greatly affect potential functional connectivity. Future directions include expanding the analyses to a total of 25 species, which includes non-diadromous species found within these watersheds, using the morphometric approach. Overall, our findings will provide insight as a species-based approach to inform policy and management for species persistence in stream networks.

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Optimal sampling effort for estimating juvenile alewife densities in freshwater lakes using a pelagic purse seine

Anadromous alewives (*Alosa pseudoharengus*) transport large amounts of nutrients across marine and freshwater ecosystem boundaries during migration and provide forage for a variety of species. Alewife populations, and thus their role in aquatic ecosystems, have declined throughout their range over the past five decades due in part to habitat degradation and overfishing. Currently, anadromous alewife populations are monitored using adult run counts at river fishways and fisheries surveys at sea and in large rivers and estuaries. However, both types of monitoring have limitations. Run counts have logistical challenges (e.g., equipment failure, irregular volunteer counters, costs of electronic monitoring) and provide only a snapshot into one facet of alewife population status, while fisheries surveys catch individuals from many population sources, making discernable links to individual runs difficult. Quantifying recruitment of juveniles in freshwater nursery habitat is essential to determining alewife stock status and management targets for mortality. We are exploring the sampling effort required for using a small-sized pelagic purse seine in freshwater lakes to capture juvenile alewife and estimate densities. Thirty-two lakes from Connecticut to Maine were sampled in 2014 and 2015. We will describe variation in catch data across systems and investigate the effect of incremental purse seine sampling on density estimates. The goal is to determine the optimal sampling effort required in lakes of varying size to obtain sufficient estimates given limitations in cost, time and personnel. Ultimately, we will provide guidance for using pelagic purse seines for assessing juvenile alewife populations to better understand stock status and help develop monitoring strategies.

Dotson, C. [1], and L. Sullivan*[2]. [1]Public Utility District No. 2 of Grant County, Washington; [2]Blue Leaf Environmental, Inc.

Providing Upstream Passage of Adult Salmon and Lamprey at Wanapum Dam During Atypical Emergency Draw-down Operations

Wanapum Dam is a large hydroelectric dam that spans 8,637 feet (1.6 miles) across the Columbia River. On February 24, 2014, a 65-foot-long, two-inch-wide horizontal crack was discovered along the spillway that was causing an uplift and forward tilt of the dam. Grant Public Utility District (PUD) initiated a 26 foot draw-down of the Wanapum Reservoir to reduce pressure against the dam; however, this action left the exit of both fish ladders 13 feet above water and the top third dry. Without operational fish ladders at Wanapum Dam, the anticipated adult salmon (Chinook, sockeye, Coho) and steelhead run of one million and additional lamprey would be blocked from spawning grounds. Grant PUD had six weeks to determine how upstream passage would be provided, and collaborated with resource agencies and tribes to develop a plan that would successfully pass fish upstream of Wanapum Dam. The resultant plan was to pump water from the lower pool into the dry portion of the fish ladder; water entered the top of the ladder through a seven-foot-tall, 16-foot-wide upwell box that spanned the width of the ladder. The upwell box created a false weir that delivered water to the top of the ladder, stopped water from spilling back into the reservoir, and provided flow through the ladder. This flow attracted salmon and lamprey to swim up the ladder and jump over the weir, while also providing some water for the fish to slide down a wooden ramp and into a spiral outfall that released fish two feet above the reservoir and upstream of the dam. By the end of the 2014 adult salmon migration season, ~ 800,000 salmonids and ~ 4,700 lampreys were passed upstream of Wanapum Dam, and spawning escapement was consistent with passage numbers, suggesting that delayed passage effects did not affect spawning performance.

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Manager, Media, and Community Member Representations of Dam Tradeoffs in New England, USA

Hydropower is a major source of low-carbon energy in New England and with more than 50 hydropower dams in the region scheduled for relicensing in the next decade, communities need 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. Despite these positive aspects, dams can have adverse effects on ecosystems and economies. They can block economically and ecologically important fish migrations, and some obsolete dams pose safety and liability risks as aging infrastructure could fail and flood surrounding areas. Concerns about fish passage, safety issues, water quality, and other conflicts place constraints on decisions to remove, relicense, or retrofit existing dams. 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 poster describes a portion of our work on the National Science Foundation-funded Future of Dams project, a multi-state, interdisciplinary research initiative focused on developing a methodology for making these important decisions about the future of dams. As one aspect of that work, we analyzed media discourse about New England dam decisions in local, regional, and national news media, and also conducted and analyzed a set of interviews with restoration managers in Rhode Island related to dam removals. Here we present the results of that work, focusing on the ways that managers and various stakeholders make arguments about the aesthetic, economic, and ecological tradeoffs of dams as they make decisions under conditions of uncertainty.

Foster**, B. [1], E. Cashman[1], B. Draeger[1], M. Lang[1], M. Love[2], M. Nyberg[1], and B. Weekly[1]. [1]Humboldt State University; [2]Michael Love and Associates.

An Investigation of Pool-and-Chute Fishway Hydraulics for a Prototype Vortex Weir Design for Anadromous Fish Passage

A physical model of an improved vortex, pool-and-chute fishway designed by Michael Love and Associates is being evaluated at Humboldt State University. The fishway weirs slope downward towards the channel center, and are V-shaped in the longitudinal direction, with apexes located upstream. Two orifices penetrate each weir. As with standard pool and chute fishways, this fishway produces plunging flow along the edges of the wetted weirs and streaming (skimming) flow through the center of the fishway. This poster presents the results of determining the Chezy resistance coefficients for streaming flow, 3-D point velocities, and turbulence characteristics through the fishway model at an 8% slope over a range of discharges. Design prototype flow rates were determined using Froude scaling and data was collected from ten experimental runs, at seven different flow rates ranging from an equivalent prototype flow rate of 58 cfs to 283 cfs. Chezy coefficients were calculated using two different methods of selecting discharge, the streaming flow method used only the portion of flow streaming in the fishway, and the streaming and plunging flow method used the entire fishway flow. Chezy coefficient estimates using the streaming flow method resulted in values ranging from 30.4 ft1/2/s at lower flows to 22.3 ft1/2/s at higher flows, with one outlier of 39.2 ft1/2/s. Chezy coefficient estimates using the streaming and plunging flow method resulted in values ranging from 25.0 ft1/2/s at lower flows to 18.9 ft1/2/s at higher flows. Point velocities and turbulence were measured throughout the fishway in a gridded pattern and at three depths (surface, middle, bottom) per point. These data were used to quantify fishway performance and identify potential pathways for anadromous fish passage. The results from this work may be directly applied to design of vortex, pool and chute fishways.

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1000th Culvert Removed or Upgraded for Aquatic Organism Passage across the Forest Service

In 2015, the USDA Forest Service reached a milestone of removing or upgrading its 1,000th road-stream crossing for Aquatic Organism Passage under the Legacy Roads and Trails Program since that program began in 2008. The 1,049 culvert projects restored 1,671 miles of stream habitat for fish and other important aquatic species. The agency spent over $75 million in CMLG funding that had a directly benefitted aquatic habitat and aquatic species and improved flood resiliency of local transportation infrastructure. Total costs, including the Congressionally Designated Legacy Roads & Trails funding combined with other leveraged FS funds and over $14 million in partner funding, reached nearly $105 million. Of these projects, 152 involved external partners, and 189 benefitted federally listed Threatened or Endangered Species. Average cost per structure removed or upgraded for AOP was $162,608, while average cost per mile of aquatic habitat restored was $54,687 per mile.

Haker*, C. [1]. [1]Tighe & Bond.

Lower Mill Pond Dam / Stony Brook Fish Passage

Lower Mill Pond is a freshwater pond in the Stony Brook watershed that provides spawning and nursery habitat for herring and alewife. The Stony Brook fish passage is known as the "Disney World" of herring runs and is one of the most valuable fish runs in the Commonwealth of Massachusetts. Lower Mill Pond Dam also has significant historical value, and is used to convey water to power the historic gristmill located downstream of the dam. Tighe & Bond provided analysis, design, permitting, bidding assistance, and construction administration services for the complete reconstruction of Lower Mill Pond Dam due to its poor condition. A hydraulic/hydrologic analysis was performed by Tighe & Bond to assess the adequacy of the spillway, and to aid in the design of fish passage improvements. Tighe & Bond then developed construction drawings and technical specifications, which included replacement of the upstream stone masonry wall, spillway, and training walls with new concrete structures. To maintain the historical and aesthetic value of the site, the new concrete structures were designed with a native Cape Cod stone facing. The design also included installing a new metal sluice gate, and clearing woody vegetation around the dam. Due to minimal freeboard during the spillway design flood, overtopping protection in the form of vegetated geocell panels was included to further protect embankments. In addition, Tighe & Bond provided construction observation and project closeout services. Construction was substantially completed in time for the spring herring run. Between 2007 and 2012 herring counts ranged between 11,000 and 48,000; after completion of dam and fish ladder improvements, herring counts skyrocketed to 150,000 in 2013 and over 270,000 in 2014. The project went on to receive the President's Coastal America Partnership Award as part of the multifaceted coastal restoration of the Stony Brook watershed.

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Influence of reservoir size on migration and loss of Atlantic salmon smolt

Reservoirs upstream of power station dams create a habitat to which many migratory fish-species are not well adapted. Conditions found there may, for example, produce favorable habitats for predatory fish species and thereby increase mortality of migrating salmon smolt. Further migration may be delayed in reservoirs, which may additionally increase predation risk. This study compared migration speed and loss of smolt through three different German reservoirs. The reservoirs studied varied in size with the first reservoir being the largest of the three sites, with slow-flowing water more resembling a lake than a river. The second reservoir was much shorter, with slightly reduced water velocity, whereas at the third site no clear reservoir was distinguishable. Smolt were radio-tagged and released several kilometers above each reservoir in unimpounded stretches of the river. Smolt migration was documented by stationary receivers along the river. To calculate extra loss, reservoir mortality rates were compared to the rates occurring in unimpounded regions of the river. Migration speed in the two habitat types was analyzed in the same manner. Migration speed of smolt was not reduced in all three reservoirs compared to unimpounded stretches. However, our results show that reservoirs upstream of power stations can be areas of high mortality for downstream migrating smolt and that loss due to the reservoir was even larger than loss caused by the power station. Loss of smolt attributable to an impounded instead of a free-flowing river habitat was highest at the largest reservoir. The medium-sized reservoir produced low mortality rates, whereas at site three where the reservoir was only marginal no extra loss was documented. This suggests that the size of reservoirs might have crucial influence on the loss of downstream migrating smolt.

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Inventory of Freshwater Fish Species in the Buriganga River, Dhaka, Bangladesh

Inventories of fishes were carried out in the Buriganga River, which is regarded as the most polluted river in Bangladesh. The study was carried out on stretches of the river starting from Posthoghola Bridge (90°26´12" E and 23°40´25"N) and ending at Amin Bazar Bridge (90°20´12"E and 23°46´25"N) Fish species were collected fortnightly for a period of twelve months from December 2012 to November 2013, and obtained directly from fisherman during their fishing time to confirm identification. A total of 56 species of fishes were recorded from the Buriganga River, representing 9 orders and 20 families. The highest number of fish species (n = 56) was recorded in August and the lowest (n = 3) in April and May 2013. Due to irrational fishing practices, environmental aberrations that reduce water volume, water quality, increased sedimentation, dam construction, and water pollution over the years, fish diversity is on a decline and a few species have been lost from the freshwater ecosystem of the Buriganga River.

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Little River Fish Passage Naturalization Project, Gloucester, MA

The Little River drains a small (1.5 square miles) and lightly developed (1.24% impervious cover) coastal watershed that provides drinking water for the City of Gloucester, Massachusetts. Since colonial times the stream has been dammed, physically relocated, and flow-stressed by water extraction and inter-basin transfers. Despite this litany of historic and current impacts, the river continues to support a small run of anadromous alewife (*Alosa pseudoharengus*), averaging just over 2,000 fish between 2000 and 2015. The Little River also provides spawning habitat for anadromous rainbow smelt (*Osemerus mordax*). A collaboration of local, state, federal and NGO partners have been working together for well over 15 years to promote local stewardship, monitoring and assessment, and develop options for improving diadromous fish passage, stream function, and habitat quality. The focus of this poster will be on the fall 2015 removal of an approximately 500-foot long, deteriorated fish ladder that was built at the head-of-tide in 1970 to facilitate the construction of a municipal water treatment plant. In the fall of 2015, the partnership removed the entire fish ladder and an associated sludge lagoon. A restored stream channel of appropriate width and depth was built in its place - with a series of cobble and boulder weirs and off channel wetlands - in order to “re-naturalize” the system, enhance connectivity, and restore the free movement of sediment and organic matter to the downstream estuary. The project also included restored smelt spawning habitat, riparian and wetland and upland plantings, and a new area of salt marsh in the lower intertidal reach of the stream (formerly within the footprint of the sludge lagoon). This poster will include preliminary physical and biological observations regarding the performance of the restored channel and ability of alewife to navigate up the Little River in April and May of 2016.

Jacobson*, P. [1], S. Ault[2], J. Caumartin[3], J. Gerlach[4], D. Hatin[5], S. LaPan[6], B. Lenz[4], A. Mathers[2], T. Maynard, S. Patch[8], T. Pratt[9], J. Sanna[10], S. Schlueter[8], D. Stanley[10], and A. Stuart[11]. [1]Electric Power Research Institute; [2]Kleinschmidt Associates; [3]Hydro Quebec; [4]New York Power Authority; [5]Quebec Ministry of Natural Resources and Wildlife; [6]New York State Department of Environmental Conservation; [7]Ontario Ministry of Natural Resources; [8]U.S. Fish and Wildlife Service; [9]Fisheries and Oceans Canada; [10]Ontario Power Generation; [11]Duke Energy.

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

The Electric Power Research Institute formed the Eel Passage Research Center (EPRC) in 2013 to address the challenge of safe passage for out-migrating 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. EPRC research has examined electricity, velocity plume, vibration, and EMF in laboratory flumes for their guidance potential. A literature review and white paper examined recent developments in science and technology of visible light for eel guidance. Three acoustic technologies have been evaluated in the field for observing the distribution, abundance, and behavior of eels in the St. Lawrence River at water velocities in excess of 1 m s-1. Computational fluid dynamics (CFD) models developed for the Iroquois Control Dam reach and the Beauharnois Power Canal will serve as tools for investigating eel-flow field relationships and for designing guidance and collection structures. Future work will identify and develop the most promising technologies for guiding and collecting eels for safe passage around the hydropower projects.

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The Wetted Ramp for use in Passage of Non-Target Species over Low-Head Sea Lamprey (Petromyzon marinus) Barriers, Fish Length Dictates Passage Efficiency

Passage of non-target finfish species over sea lamprey (*Petromyzon marinus*) barriers has become an issue of increasing importance as lamprey control efforts in the Great Lakes region have sought to move away from harmful lampricide applications towards lamprey barriers and more efficient trapping techniques. One possible solution for this problem is the smooth wetted ramp, used in conjunction with low-head lamprey barriers. Due to the difference in swimming style, finfish are able to scale low-incline wetted ramps while lampreys are not. However, low success rates in field tests have led to a need for a better understanding of what it takes for successful passage up the wetted ramp. In this study, we use high speed video recordings to look at how creek chub (*Semotilus atromaculatus*) and common sucker (*Catostomus commersonii*) respond to changes in angle of inclination on the wetted ramp, or a bent ramp as opposed to a straight ramp, as well as how fish length effects passage efficiency. We hypothesize that passage efficiency will be related to fish size and that changes in angle of inclination will alter fish behavior. Our findings suggest that there is a negative linear relationship with increasing fish size and distance traveled on the wetted ramp. In addition, Initial velocity appears to be more important for large fish while on-ramp acceleration seems to be most important for smaller individuals. Finfish did not appear to respond to changes in ramp angle of inclination. These data suggest that manipulating ramp angle of inclination (using “bent ramps”) may not effect passage efficiency. Additionally, the wetted ramp appears to be size selective, a characteristic that could potentially impact breeding size of migrating fish stocks. Future studies should address whether this relationship holds true for other non-target finfish species.

Lickus*, M. [1], E. Ham[1], and C. Hebson[1]. [1]Maine Department of Transportation.
Use of PIT tag technology to assess fish movement through two highway culverts in Maine
The Maine Department of Transportation (MaineDOT) uses both hydraulic and geomorphic-based approaches to provide fish passage and improve habitat connectivity at road-stream crossings. Post-construction monitoring efforts have traditionally relied on capture/recapture methods or hydraulic measurements to assess passage success. Beginning in 2014, MaineDOT used PIT tags to evaluate the movement of brook trout (*Salvelinus fontinalis*) and other resident species during summer lower flow conditions at two stream crossings in Maine. The crossing on Dunn Brook in Smyrna (Aroostook County) is a rehabilitated 11-foot-wide metal pipe arch that was retrofitted with concrete weirs. The crossing on Whetstone Brook in Brownville (Penobscot County) is an embedded and backfilled 26-foot-wide concrete box structure. Antennas were installed upstream and downstream of each culvert to track the movement patterns of individual fish near and through the culvert. Stream water levels (stage) and temperature were also monitored during the study period. Passage performance at each culvert was evaluated and preliminary results include time at liberty, passage efficiency, and transit times through the structure. The Dunn Brook results show that fish movement varied with flow conditions and seasonal temperature changes, and that the weirs enabled fish to successfully move upstream through the culvert. Data collection at the Brownville site was cut short by damage to the system during a large storm event, but show similar fish movements. Challenges encountered during the design, testing, construction and operation of the system will also be presented.

Linnansaari*, T. [1], A. Babin[1], S. Andrews[1], D. Arluison[1], B. Dixon[1], G. Yamazaki[1], S. Peake[1], and R. A. Curry[1,2]. [1]Canadian Rivers Institute and Department of Biology, University of New Brunswick; [2]Faculty of Forestry and Environmental Management, University of New Brunswick.
To remove or repair: How is fish passage science informing a decision for the future of a large dam?
The Saint John River (SJR) is managed for hydropower by a provincial owner-operator, the New Brunswick Power Corporation (NBP). NBP operates a number of hydropower dams in the SJR system, but the largest and lowermost dam in the SJR system, the Mactaquac Generating Station, is expected to reach the end of its service life in 2030 because of problems with concrete expansion. NBP has started a process to evaluate future options for the MGS, and three alternative options has been presented: 1) to repower the facility; 2) to retain the reservoir but with no hydropower; or 3) to remove the dam and restore the river to a free-flowing state at the site. Canadian Rivers Institute (CRI) in undertaking a large, multidisciplinary aquatic ecosystem study to help the company make an informed, science-based decision for a preferred option. The CRI has initiated the Mactaquac Aquatic Ecosystem Study (MAES) which is a planned, whole-river ecosystem study and manipulation. Up- and downstream fish passage are major considerations in the MAES program. The fish passage theme currently addresses specific critical questions regarding Atlantic salmon, striped bass, Atlantic and shortnose sturgeon, and American eel and these studies, in addition to expert workshops, are used to inform the decision and/or to develop a conceptual design for fish passage. The poster will discuss the five species specific studies in detail using preliminary data collected in 2014-15.

Longenecker*, R. [1], J. Taylor[1], L. McLaughlin[1], L. Eaton[1], W. Crouch[1], W. Thompson[1], N. Bush[1], and E. Martin[2]. [1]U.S. Fish & Wildlife Service; [2]The Nature Conservancy.

Stream connectivity assessments on National Wildlife Refuges in northeastern USA

Assessing and replacing road-stream crossings (crossings) is a high priority in the northeastern USA, where large numbers of crossings potentially disrupt stream connectivity and contribute to fish and mussel decline. Movement of aquatic biota can be restricted by hydrological changes resulting from crossings, specifically, increased velocities, outlet drops, insufficient depths, and lack of bank habitat. Passage can be restored by replacing or re-engineering crossings, but efforts are hindered by lack of information on crossing passability and the high cost of construction projects. The National Wildlife Refuge System in the northeast region has initiated a stream connectivity project to prioritize crossings for replacement by surveying passability, using the protocol created by the North American Aquatic Connectivity Collaborative, and fish and mussel occupancy upstream and downstream of the crossings at priority National Wildlife Refuges (refuges). Priority refuges were identified systematically based on the number of Federal Trust species (threatened or endangered aquatic species and inter-jurisdictional fish) that occurred currently or historically on the refuge, and the ecological integrity and resilience of the freshwater aquatic habitat on the refuge. To measure and compare ecological integrity and resilience, we used newly available, regionally consistent datasets (Index of Ecological Integrity and Freshwater Resilience) produced by the North Atlantic Landscape Conservation Cooperative, University of Massachusetts Designing Sustainable Landscapes project and The Nature Conservancy. By prioritizing crossings using passability and aquatic species occurrence at locations with high aquatic habitat quality that contain Federal Trust species, we will ensure that replacement funds and effort will maximize benefits for aquatic species. As region-wide momentum around improving stream connectivity grows, strategic restoration of crossings can serve as a model for other aquatic connectivity efforts.

Marshall**, A.[1]. [1]Connecticut College.

Spatial variation in characterized buried soils and legacy sediments of the Northeast USA

In the New England and mid-Atlantic Piedmont physiographic provinces of the United States, large post-settlement alluvium “legacy” deposits originating from colonial-era deforestation and ongoing hillslope disturbances characterize floodplains. These legacy sediments are frequently deposited behind mill dams and overlay comparatively organic-rich, pre-colonial buried floodplain soils. Debate has emerged regarding the ubiquity of both the interpreted pre-disturbance land surface, and the thickness of the legacy sediment layers in modern floodplains. The potential for legacy sediment to serve as a source for nutrient-rich sediment pollution and the rise of a $1 billion stream restoration industry necessitates an understanding of the nature and extent of these floodplain deposits. In this study, field sampling of exposed riverbanks was carried out along two major tributaries to the Christina and Brandywine Rivers in Pennsylvania and two tributaries to the Salmon and Connecticut Rivers to characterize the nature and spatial variation of floodplain sediments. Deposits were analyzed for thickness, organic material, grain size, and elemental content, and were mapped using GIS in combination with known historical dams. Results indicated that floodplain deposits vary greatly within and between watersheds as well as different geographic settings. Buried soils were consistently richer in organic content than legacy alluvium, but both layers had similar characteristic grain-size distributions. Legacy deposits varied widely in thickness within and between watersheds (20-160 cm in PA, 51-143 cm in CT), as did buried A horizon (0-80cm in PA, 20-48cm in CT). The technical history of damming at each site appeared to influence the characteristics and extent of legacy deposits. The overall trends in the buried A horizons suggest patchy distributions of pre-colonial floodplain conditions (e.g. grass dominated wetland, bottomland forest) as well as a patchy post-settlement depositional environment.

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Damning of New England Watersheds and Consequences to Freshwater Ecosystems

The damming of New England watersheds obstructed anadromous fish access to spawning habitat beginning in the 1630s. This reduction in habitat has contributed to large-scale population declines of anadromous river herring, however, historical population estimates of river herring are uncertain due to a paucity of historical catch data. We combine historical habitat obstruction records with freshwater productivity information to assess historical populations of river herring in New England. We produce a timeline of lost river herring production due to dams and detail the decline of adult spawning alewife and freshwater and marine forage. Using nutrient data from previous research, we estimate lost marine-derived nutrients from adult river herring through mortality and excretion. Our results indicate a significant decline in river herring production and marine-derived nutrients by 1900. Juvenile river herring are important to the diets of freshwater fishes, as evidenced by examining the diets of predator fishes from 28 coastal ponds with alewife, and declines in production due to dams has likely dramatically affected freshwater food webs. A more comprehensive view of freshwater ecosystems is required to inform restoration goals and to adequately assess the ecological significance of lost river herring.

Maxwell*, S.[1], and B. Strawn[1]. [1]AECOM.

Challenges of Small Town Atlantic Salmon Habitat Restoration in their Critical Habitat

A stream crossing in the remote town of Mount Chase, Maine, was badly damaged by heavy flows from multiple storms. Improvements had to be made, but many challenges had to be faced, for which this crossing was at the intersection. The culverts carrying Crystal Brook under Owlsboro Road did not have the capacity to accommodate high flows. The existing stream crossing also inhibits passage of aquatic organisms, including endangered Atlantic salmon (*Salmo salar*) to an area designated as critical habitat. This project designed a new open-bottom aluminum arch box culvert that will expand the flood capacity of this crossing and improve the ecological functions of the stream, likely without adverse effect on listed species or designated critical habitat. Furthermore, the project operates with very limited funding as the town's tax base is small. This poster displays how these adversities have been overcome by a team of incredible people.

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Diadromous Fish Passage Evaluation and Drivers of Movement in an Alaskan Steeppass

Fishway attraction and passage success is critical to the restoration of diadromous fish, however, few fishways have been evaluated for their capability of passing multiple species. Three diadromous fish species were monitored in the Carmans River (Long Island, NY) from 2012 to 2015 using Passive Integrated Transponder (PIT) tag telemetry to evaluate fishway efficacy. An Alaskan Steeppass was installed in 2008 at the most downstream barrier, restoring access to 5km of freshwater habitat. Attraction and passage efficiency at this fishway were calculated for River Herring (n=479), White Perch (n= 458) and transplanted American Eel (n=210). To determine potential drivers of movement within the fishway, generalized linear models were developed to model passage using environmental and biological variables for each species and compared to video monitoring data. Telemetry results showed River Herring exhibited low attraction efficiency at only 30% of fish entering the fishway, half of which successfully passed over the dam. White Perch had a higher attraction efficiency at 70% attempting to pass, but only 3% were successful. American Eel had both a high attraction efficiency (79%) and passage efficiency (56%), however, they averaged a one-month delay following transplantation to below dam habitat. Generalized linear model results showed length was significantly correlated to River Herring passage success ($p=0.004$), indicating fishway selectivity towards larger individuals. Video monitoring and telemetry results showed River Herring passage peaked at dusk (17:00 to 19:00), while White Perch and American Eel would only attempt passage at night, between 21:00 and 4:00. Understanding multispecies passage efficiency and drivers of movement is important when designing and maintaining a fishway. Our results show that the fishway exhibits low attraction rates and size selection of River Herring, suggesting modifications are necessary to optimize connectivity.

McDermott, S. [1], B. McDavitt*[2], and S. Tuxbury[1]. [1]NOAA Fisheries Service; [2]Integrated Statistics.

NOAA Fisheries Service fish passage and hydropower review

The National Marine Fisheries Service engages Federal Energy Regulatory Commission licensed hydropower operators to design, improve and maintain upstream and downstream fishways for diadromous species such that safe, timely and effective fish passage can be achieved. A team of biologists, fishway engineers, and attorneys work to develop sound guidance for licensees, which is intended to mitigate impacts of the project and restore diadromous fish populations. Within the Greater Atlantic Regional Fisheries Office, staff primarily focus their efforts on large mainstem rivers which include the: St. Croix, Penobscot, Kennebec, Androscoggin, Saco, Merrimack, Connecticut, Hudson and Susquehanna. These rivers have been identified as priority rivers based on available diadromous species habitat and restoration potential. Agency staff participate in ongoing FERC relicensing efforts and they ensure compliance with ongoing licensed projects. Settlement agreements have been found to be a good way to develop a partnership with licensed hydropower operators while providing mutual benefits for each other and fishery resources.

Morales*, J.[1]. [1]U.S. Fish & Wildlife Service.

USFWS Engineering Criteria and the Design of Attraction Water Systems

At dams and other stream barriers, successful fishways must discharge sufficient attraction flow to maintain hydraulic cues that persist in the presence of competing signals (e.g., powerhouse turbine discharge, spill). At FERC-jurisdictional hydropower projects, U.S. Fish and Wildlife Service (USFWS) engineering criteria provides guidance on the flow, water velocities, and energy dissipation rate required to provide safe, timely and effective fish passage. Since fish ladders convey only moderate amounts of water, the majority of attraction flow is typically provided by supplemental or auxiliary water. Unlike conventional conveyance systems, which often seek to maximize flow, auxiliary water systems (AWS) must dissipate significant amounts of energy to ensure velocity criteria are met at the outlet. These velocity requirements pose an uncommon challenge for the hydraulic engineer designing a fishway. This poster presents a hydraulic analysis of a typical fishway AWS, focusing on the components needed to achieve high levels of energy dissipation or head loss. The results highlight relative losses in various conduits, valves, and other appurtenances, while informing best practices for the proper design of fishways.

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Providing Refuges for Pacific Lamprey in Lower Columbia River Fishways

Many fish species are sensitive to unnatural features in fishways and they may delay or abandon migration when confronted with man-made passage structures. We placed novel “refuges” within technical fishways at a Columbia River hydroelectric dam to improve retention and passage of a nocturnal migrant, adult Pacific lamprey. The 1.1 × 0.4 × 0.2 m refuges were designed to provide low-velocity, dimly lit refuges from both adverse abiotic conditions and predators. The refuges were also equipped with antennas to detect lamprey tagged with passive integrated transponders (PIT-tagged n = 3,248). In each year of study (2012-14), 11 – 28% of the PIT-tagged lamprey in the study area used a refuge. In addition, of 217 lamprey tagged with radio transmitters in 2014 and detected in the study area, 29% used a refuge. The average time that lamprey resided in the refuges each year was 49.7 - 57.2 h. Greatest use of the refuges occurred during the day: entrance rate peaked at 0300 – 0500 hr and lamprey typically left the refuges at around 2000 hr. Analysis of the radio-telemetry data indicated that refuge users were more likely to pass over the dam than lamprey that did not use a refuge. However, refuge users were detected less frequently at sites further upstream, perhaps owing to their longer dam passage times. While refuges show promise for improving lamprey retention in fishways, further study is needed to insure that these structures do not negatively affect overall lamprey fitness (by delaying migration). Our results suggest that providing fishway elements that go beyond those related to hydraulic conditions may increase passage success in multi-species assemblages.

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The indirect impact of pumping station operation on the downstream migration of silver European eels (Anguilla anguilla)

The downstream passage of European eels (*Anguilla anguilla*) though pumping stations is a concern currently being addressed in Europe. The EC Eel Regulation (1100/2007) establishes measures for the recovery of European eel and is enacted in England through the Eels Regulations 2009 Statutory Instrument, which will help protect eel and ensure their safe passage through rivers, including screening abstractions (>20 m3 a day) unless exempted by the Environment Agency. It is imperative that optimal solutions for minimizing the impact of these structures are found. Thus far, investigations have largely focused on direct mortality caused by entrainment but potential sublethal impacts are also a concern. Specifically, the timing of downstream migration through the catchment may be driven by pump operation, rather than environmental cues (river flow, water temperatures, lunar phase and time of day) as reported for rivers with a natural flow regime. Further, migration may be delayed by the structure, possibly causing reductions in fitness and increasing susceptibility to predation. The timing and speed of downstream movements of acoustic tagged eels was established using acoustic receivers strategically located throughout two catchments where water level was controlled by pump operation. A multi-beam sonar (ARIS) was used to establish eel behavior immediately upstream of a pumping station and the number of eels that pass downstream through two different pumps intakes and a gravity bypass channel. The structures studied had an indirect impact on eels by altering natural migratory flow cues, leading to indirect route patterns through the river. Furthermore, aversion behavior immediately upstream of the trash screen was observed and delays at pumping stations were found. Based on this evidence, operational changes to the pumping regime and installation of alternative routes could be the most effective mitigation measure for heavily modified systems.

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Mimicking Fish with a Convolutional Neural Network in 2D Domain

Understanding, thereby predicting how fish make decisions while negotiating a way through fish passage structures are critical for researchers to design and build a fish passage with high passing through rate. In this study, an agent-based ConvNet model was proposed and trained to tackle this problem. The physical model of a fish provides training pairs: multi-sensory inputs, such as current velocity, pressure, and turbulence intensity, and corresponding fish movement decisions, such as continuing to swim straight upstream or turning to avoid unfavorable flow conditions. The training pairs are fed into the ConvNet model. The model is able to learn from fish in the physical model to make decisions. Thus, a well-trained ConvNet model is able to predict fish decision-making step by step. This predicting capability is proposed as a tool to facilitate fish passage in areas of interest. Hidden units of a ConvNet model contain high-level information directly related to fish actions. Since ConvNet is able to ‘sense’ the environmental variables like fish do, a fish-preferred ‘road map’ can be depicted by visualizing the response maps of the hidden neurons in the ConvNet. Therefore, the most sensed features ‘picked up’ by the ConvNet would be the most wanted ‘markers’ for guiding fish migration in a fish passage. The ‘markers’ can be created intentionally in the design of fish passage.

Rueter*, A. [1], B. Mockenhaupt[1], and C. Schuetz[1]. [1]German Federal Institute of Hydrology.
Comparison of the detection rate of three telemetry systems
We measured the detection rate of three different telemetry systems in the headwater of a hydropower dam at the Main River (Germany). The test was performed simultaneously with receivers from a Vemco (69 kHz), a ThelmaBiotel (69 kHz) and a JSAT (LOTEK, 416.7 kHz) system. Three buoys were each equipped with three receivers, one from each firm. We tested the detection rate for stationary and moving transmitter signals at different ranges. The result shows different advantages and disadvantages of the systems.

Sears*, M.[1]. [1]HDR Engineering, Inc.
A 3-year Evaluation of Atlantic Salmon Passage and Survival at a Hydroelectric Facility in Maine
The 19.4 MW Worumbo Hydroelectric Project is located on the Androscoggin River in Maine. The Project area is within designated critical habitat for Atlantic salmon, and licensee has conducted Endangered Species Act (ESA) Section 7 compliance activities since the species was listed as endangered within the river. As require through the ESA process, downstream Atlantic salmon smolt passage and survival studies were conducted over three years (2013, 2014, and 2015). Each year 150 study smolts were surgically implanted with radio telemetry tags. Several remote telemetry monitoring stations were installed upstream of the dam, at the passages routes of the dam, and downstream of the dam to measure migration rates, passage route utilization, and passage survival. Utilizing a paired-release model, treatment groups were released upstream of the dam, while control groups were released downstream of the dam to account for natural background mortality. The first study conducted in 2013 resulted in an overall Project downstream passage survival estimate of 70.7%. River flows were unusually low in 2013; therefore, there was little spill during testing, and most smolts used the turbine passage route. Based on results of the initial study, different levels of floodgate releases were tested to encourage spillway passage and enhance smolt survival in 2014. Higher river flows in 2014 resulted in increased spillway flows, which, along with floodgate releases, resulted in a substantially higher smolt survival estimate of 97.2%. Additional floodgate releases were tested in 2015, another lower than average flow year. Total Project survival was estimated at 93.5% in 2015. The influence of variable environmental conditions among study years on salmon smolt migration rates, migration initiation, predation, passage route utilization, and passage survival will be discussed.

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DATA Collection: A critical component in supporting a successfully operating fishway
Fishways are designed and constructed to operate in a very specific manner to provide conditions that are conducive for fish passage. All too often, monitoring of a fishway's effectiveness is not conducted. This "if you build it they will come" mentality has severe consequences on safe, timely, and effective fish passage, which in turn reduces the pace at which important species can re-inhabit historical spawning grounds. As fish passage issues arise, it is critical to have the capability of analyzing past operational data in order to pinpoint areas that can be and should be improved. The purpose of this poster is to express the intricacies of a properly operating fishway and the data required on an annual basis (or finer temporal resolution) to validate that a fishway is performing as designed. The intent is to highlight the need to collect and analyze data in order to make informed decisions and improve fish passage performance in an efficient and effective manner.

Stettiner**, S. [1], M. Staudinger[1,2], J. Sheppard[3] and A. Jordaan[1]. [1]University of Massachusetts Amherst; [2]DOI Northeast Climate Science Center; [3]Massachusetts Department of Fish and Game – Division of Marine Fisheries.

Climate change induced shifts in the timing of migration of alewife (Alosa psuedoherengus) in Massachusetts natal streams

Climate change is causing species to shift their phenology, or the timing of recurring life events such as migration and reproduction, in variable and complex ways. This can potentially result in mismatches or asynchronies in food and habitat resources that negatively impact individual fitness, population dynamics, and ecosystem function. This project seeks to improve our understanding of shifts in the timing of seasonal migration and spawning of adult anadromous alewife, *Alosa psuedoherengus* in eight natal stream systems within the state of Massachusetts: Acushnet, Agawam, Herring, Jones, Monument, Nemasket, Stoney Brook, and Town Brook Rivers. Initial analyses examined if and how the direction and magnitude of annual spawning run initiation, peak and end dates have shifted over recent decades. Preliminary results suggest that changes in alewife migration timing are not consistent across runs within Massachusetts. Trends from overall analysis of all sites show a shift towards earlier run initiation dates and a shift towards later run end dates. Ongoing work seeks to evaluate the extent of estuarine habitat availability around each of the eight alewife run sites; this will be accomplished by measuring the area of continuous wetland habitat downstream from alewife spawning ponds. Additionally, shifts in the timing of alewife migration in relationship to environmental conditions such as river and sea surface temperature, river flow and tidal patterns are being evaluated. Project results will help managers assess the vulnerability of alewife and other coastal species to the interactive effects of environmental and anthropogenic stressors influencing their populations across the region.

Towler*, B. [1], A. Haro[2], and K. Mulligan[2]. [1]U.S. Fish and Wildlife Service; [2]USGS S.O. Conte Anadromous Fish Research Center.

Energy Dissipation Factor (EDF) and the Design of Fishways

Reducing turbulence and associated air entrainment is generally considered advantageous in the engineering design of fish passage facilities. The well-known energy dissipation factor (EDF) correlates with observations of the phenomena. However, inconsistencies in EDF forms exist and the bases for volumetric energy dissipation rate criteria are often misunderstood. A comprehensive survey of EDF criteria is presented. Clarity in the application of the EDF and resolutions to these inconsistencies is provided through formal derivations; it is demonstrated that kinetic energy represents only 1/3 of the total energy input for the special case of a broad-crested weir. Specific errors in published design manuals are identified and resolved. New, fundamentally sound, design equations for culvert outlet pools and Standard Denil fishway resting pools are developed and presented. The utility of EDF equations demonstrate the transferability of volumetric energy dissipation rates, and provide a foundation for future refinement of component-, species-, and life-stage-specific EDF criteria. This poster is an extrapolation of work recently published by the same authors in “Derivation and application of the energy dissipation factor in the design of fishways” in *Ecological Engineering* 83 (2015) 208-217.

Turek*, J.[1], A. Haro[2], and B. Towler[3]. [1]NOAA Restoration Center; [2]USGS Conte Anadromous Fish Laboratory; [3]U.S. Fish and Wildlife Service.

Federal Interagency Passage Design Guidelines: Application to Nature-like Fishways for Atlantic Coast Diadromous Fishes

The National Marine Fisheries Service (NMFS), the U.S. Geological Survey (USGS) and the U.S. Fish and Wildlife Service (USFWS) have collaborated in developing a set of passage design guidelines for use by engineers and other restoration practitioners planning and designing nature-like fishways (NLFs). The primary purpose of these guidelines is to provide safe, timely and effective passage for 14 diadromous fish species and life stages using Atlantic Coast rivers and streams, and at passage sites where full barrier removal is not possible. This technical guidance presents seven key physical design parameters based on the biometrics, swimming mode and performance of each target fish species for application in NLF design addressing the passage of one or an assemblage of diadromous fish. Passage parameters include six dimensional guidelines recommended for minimum weir passage opening width and depth, minimum pool length, width and depth, and maximum channel slope, along with a maximum flow velocity criterion for each species. Maximum fish species body length and depth as well as morphologic body type form the basis for the metrics presented. These guidelines are targeted for the design of step-pool NLFs, although this information may also have application in the design of other NLF types being considered at passage restoration sites, and in assessing performance at passage sites. Information is also presented on applying these guidelines to a SMath model for developing and advancing preliminary step-pool NLF design.

Watten*, B.[1], P. L. Sibrell[1], and J. F. Noreika[1]. [1]USGS Leetown Science Center.

Exploring the impacts of a concentration dependent fish passage rate: Application of reactor theory Part II.

The S.O. Conte laboratory is developing air directed passage (ADP) technology designed to supplement volitional behavioral cues so as to improve the rate at which diadromous fish enter, pass through and exit fish passage structures. Recent laboratory tests conducted with migrating adult Connecticut River American shad (*Alosa sapidissima*) showed fish passage rates were influenced by fish concentration or numbers. In the present study we develop algorithms, based on reactor theory, which simulate the movement of fish through a hypothetical fishway that includes, in order: an entrance slot, an initial set of four consecutive pool and weir sections, a resting pool, a second set of four consecutive pool and weir sections and, finally, a constricted exit. Section specific passage rates are based on reversible first order (r=K1C) reaction kinetics then compared to predictions based on a zero order (r=K0) model, where, C is concentration and K values are rate constants. The latter are dependent on both volitional and active driving forces known to vary with time, system geometry as well as prevailing hydrodynamic conditions. The differential rate forms were coupled with a series of finite difference calculations, to provide time specific estimates of fishway section populations, entrance and exit rates. The spread sheet that evolved was then used to provide insight into the sensitivity of fish passage rates to changes in certain fishway design variables including (1), the sizing of system components, such as pools, that influence effective fish density and (2), the use of drop screens that prevent reverse movement/escape of fish that have failed to pass when coupled to a sundown or low light level trigger. Regarding the sizing of system components, we tested the net result of controlling effective pool volumes on passage, based on time dependent fish loading rates, as achieved by the staged activation of pool subsections (N=3).

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A vacuum assisted weir (VAW) that reduces nappe velocities for enhanced fish passage at diversion structures: scale model and field trial results

Enabling northeastern diadromous fishes to enter, pass through and exit fish diversion structures, such as fishways, with minimal delay remains a challenge. Air directed passage (ADP) technology is under development at the Conte Laboratory to supplement volitional behavioral cues by exploiting fish aversion to high energy flow fields established with a sequentially activated series of air diffusers positioned at strategic locations along the floor of a test fishway. Trials were performed at full-scale in a 3 m wide, 18 m long laboratory flume that incorporated 14 rows of bottom diffusers positioned at 1.2 m centers along its longitudinal axis. Water passed into the upstream end of the diffuser section via a 91 cm wide rectangular surface weir with a head drop of 0.36 m. The flume bulkhead supporting the weir incorporated aprons and a ramped floor to streamline flow as well as to guide fish up to the weir crest. Tests of ADP were conducted using actively migrating wild adult Connecticut River American shad (*Alosa sapidissima*) collected mid-May through early June 2014 and 2015. Passage ranged from about 70 -90% of the test group per 8 min test period despite water velocities in the weir nappe of about 9 ft/sec which, in general, represent a velocity challenge for American Shad. Further increases in weir Delta H above that tested would provide for a reduction in the number of pools (and associated costs) required for a given total fishway drop, but may result in excessive nappe velocities. We developed a vacuum-assisted weir (VAW) modification that allows for increases in weir Delta H while reducing resultant nappe velocities by a factor of about 3. The weir assembly streamlines flow upstream and downstream of the crest, eliminates local air - water interface areas and linked air entrainment while reducing head loss at a given flowrate. We report ¼ scale model test data describing velocity vectors generated with and without the weir modification at a fixed flow rate. We also describe the influence of the VAW weir modification on American Shad passage in 2016 with and without ADP.

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Economic Effects of Small Dam Removal in Massachusetts

A growing body of research has established several ecological benefits from the removal of low head dams. In addition to restoring passage for migratory and resident fish, dam removal can result in improvements not realized from other fish passage methods including water quality improvements, restoration of sediment transport regimes, and alleviation of flooding concerns. While the scale of these benefits is very site dependent, there is a need among managers to be able to generalize predictable ecological and economic effects from proposed dam removal projects. Beginning in 2011, the Massachusetts Division of Ecological Restoration undertook a series of investigations into quantifying the economic benefits from dam removal projects. The first of these investigations examined the labor market effects from investments in dam removal and other ecological restoration projects. The second study evaluated owner and community benefits from eliminating dams that are liabilities and public safety risks. This poster also describes several ecosystem services benefiting from dam removal and the Division's plans to quantify those returns.