Rory Alsberg, Project Manager, North American Hydro, Jesse Waldrip, Kleinschmidt Associates

Rory Alsberg (Project Manager, North American Hydro) will discuss the hydro owner’s perspective and experiences about working with multiple agencies to develop Sturgeon Passage at the Menominee and Park Mill hydroelectric facilities on the Menominee River, located on the border of Wisconsin and Michigan’s Upper Peninsula. In the hydroelectric industry fish passage is typically dealt with as a compliance task within the licensing process. However, fish passage was not identified by the resource agencies as a compliance task during the previous relicensing effort for these sites in the mid-1980’s. Since that time there has been a lot of emphasis placed on restoration of sturgeon populations in the Great Lakes and the Menominee River has been identified as having the largest population of lake sturgeon in the Lake Michigan basin. For this reason, even though it is not a requirement of their current hydroelectric license, North American Hydro has worked closely with multiple state, federal, and nongovernmental agencies for almost a decade on planning and implementing sturgeon passage at the Menominee and Park Mill dams. Tasks have included creating an Implementation Team consisting of the hydro owner, Michigan Department of Natural Resources (DNR), Wisconsin DNR, United States Fish and Wildlife Service, River Alliance of Wisconsin, and Michigan Hydro Relicensing Coalition; creating a conceptual report specifically outlining the proposed process for providing sturgeon passage; applying for and receiving grants needed to fund the sturgeon passage projects; performing the engineering design necessary for construction of the proposed sturgeon passage facilities; and initiating preliminary construction activities. This presentation will focus on the process that has been undertaken to accommodate sturgeon passage and the challenges faced in keeping both the owner’s and agency’s best interests in mind while discussing flow requirements, invasive species, and the layout, design and operation of sturgeon passage facilities.

Midwest Fish Passage And Concerns With Invasive Species, Disease, And Contaminants

Nick Utrup, U.S. Fish and Wildlife Service

Historically, many Midwestern migratory fish species, such as lake sturgeon (Acipenser fulvescens) and paddlefish (Polyodon spathula), had free and unobstructed access to feeding and spawning areas in rivers and tributaries throughout their range in the Midwest. Major river systems, such as the Menominee River in northern Wisconsin and the Wisconsin River in central Wisconsin, at one time supported vast spawning migrations. Within the past 100 years, however, construction and operation of hydroelectric dams on these river systems has interrupted much of these great migrations. This fragmentation and loss of habitat has contributed to the decline of the lake sturgeon and paddlefish populations throughout the Midwest. One method for reestablishing this lost connection is to create an artificial pathway such as a fish passage facility (i.e., fishway). The U.S. Fish and Wildlife Service (FWS) has been working with state and local partners in Wisconsin and Michigan to design and build fishways to reestablish migratory corridors on rivers historically important to lake sturgeon and paddlefish. In particular, the FWS has been working on two fish passage projects, one on the Wisconsin River near Prairie du Sac, WI (a hydroelectric dam licensed by the Federal Energy Regulatory Commission; FERC) and another at a FERC dam on the Menominee River, a tributary to Lake Michigan near Menominee, MI. At both of these locations,
Daily Counts Of White Sturgeon Passing Columbia River Fishways Reveal Details About Dams, Fishways, Sturgeon, And Passage

Michael J. Parsley, U.S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory

Summaries of the timing of counts and estimated lengths of white sturgeon passing dams reveal interesting information. Mean lengths and peak of timing of white sturgeon counted in fishways suggests that upstream passage is not related to a spawning migration. Differences in white sturgeon lengths and differences in timing of counts between fishways at individual dams suggest that physical or hydraulic conditions influencing approach, attraction, entry, and ultimately passage differ among sites. In turn, these findings suggest that further study could provide information on ways to improve upstream passage of white sturgeon. The Columbia River Basin is reported to be the most dammed river system in North America. Home to 5 species of iconic anadromous Pacific salmon, the 9 mainstem dams on the Columbia River and 4 on the Snake River were constructed with fishways to enable salmon to return upstream to natal spawning rivers and tributaries. Given the large size of these two rivers and the dams impounding them, most dams were constructed with two fishways; one adjacent to each riverbank. Monitoring of the timing and magnitude of individual salmon runs was deemed so important that fish counting stations were constructed in all fishways and counters enumerate individual fish passing windows. Ironically, white sturgeon, a species native to the Columbia Basin and once thought to be anadromous, were not mandated to be counted until 2006 despite knowledge of their presence in fishways dating back to the 1940’s. However, due to their charismatic appearance and relative scarcity in fishways, many fish counters voluntarily enumerated them and often estimated their size and noted direction of movement within fishways. Data on daily...
passage of white sturgeon dating back to 1998 are now available and summaries of that data through 2011 are presented here.

**Mr. Parsley** is the project lead for sturgeon and American shad studies at the USGS’s Columbia River Research Laboratory. He has been a Research Fishery Biologist with the USGS for over 20 years. Prior to becoming a Federal employee and moving out west, he earned a Master’s degree in Fisheries from the University of Wisconsin at Stevens Point, and a Bachelor’s degree in Fish and Wildlife Biology from Iowa State University.

**Migratory Behavior Of Sturgeon In The Yolo Bypass**

M. Johnston, *University of California at Davis*, A.P. Klimley, *University of California at Davis*, T. Sommer, *California Department of Water Resources*

The Yolo Bypass is one of two flood bypasses in the Sacramento Valley of California. The Yolo Bypass protects Sacramento and other riverside communities from flooding through a system of overflow weirs. These weirs connect the bypass to the Sacramento River as well as to various local creeks where the water is eventually drained into the Sacramento-San Joaquin River Delta. Although the Yolo Bypass floodplain has been demonstrated to benefit a suite of native fishes, particularly in flood years, little is known about the movement patterns and residence time of migratory fish such as white sturgeon in the Yolo Bypass. In cooperation with the California Department of Water Resources (DWR), the Biotelemetry Lab at UC Davis implanted 68 white sturgeon with VEMCO V16 coded acoustic telemetry tags. Using an array of VEMCO VR2W 69kHz receivers, including those maintained by the California Fish Tracking Consortium, the sturgeon’s movement patterns were monitored throughout the Yolo Bypass (a total reach of 38.5 river kilometers) and into the San Francisco Bay. These fish face numerous barriers to migration through the Yolo Bypass under varying river flow conditions, the most significant of which being the Fremont Weir, which blocks sturgeon passage in all but completely inundated conditions. This presentation will address the migratory behavior of sturgeon in the Yolo Bypass and will specifically focus on the analysis of residence time, reach-specific behavior, pulse-flow dynamics relative to sturgeon movement, and sturgeon behavior at the various migratory barriers.

**Myfanwy Johnston** is a first-year graduate student in the Animal Behavior Graduate Group at UC Davis. Her research interests include conservation biology, behavioral ecology as it relates to migratory behavior, and behavioral responses to human-induced rapid environmental change (HIREC). She is a member of the Biotelemetry Lab at UC Davis, and is studying white sturgeon and Chinook salmon movements in the Yolo Bypass of California.

**D2**

**Ecohydraulic Analysis Of Fish Speeds For Subcarangiform And Anguilliform Swimmers**

C. Katopodis, *Katopodis Ecohydraulics Ltd.*, R. Gervais, *Freshwater Institute, Fisheries and Oceans Canada*

Speeds and endurance of subcarangiform and anguilliform swimming fish are investigated in the burst and prolonged ranges. In subcarangiform swimming, undulations are limited to the posterior one-half to one-third of the body, while anguilliform swimming involves sinusoidal undulations of virtually the entire body length. For single species and progressively larger groups of species in each swimming mode, data from the literature are analysed by correlating expressions of fish speed and endurance, i.e. deriving fatigue curves. Two expressions for fish speed are
used, the traditional BL/s, which is used most frequently in biology to normalize speed, and the dimensionless fish speed, which is used in an ecohydraulic analysis and includes the square root of body length as a scale. The results presented compare the biological and ecohydraulic expressions for fish speed and demonstrate that improved regressions are achieved with the latter approach. For subcarangiform swimmers these analyses are illustrated with data for the freshwater (rainbow trout) and anadromous (steelhead trout) forms of Oncorhynchus mykiss, separately and combined, several trout species as a Trout subgroup (6 species), several salmon added to the trout species as a Salmoninae subgroup (13 species), the Salmonini with Coregoninae and Thymallinae added, forming the Salmonidae group (22 species in 3 subfamilies) and the Salmon and Walleye group, which adds Catostomidae (6 species), Cyprinidae (47 species), Moronidae (2 species) and Percidae (4 species) to the Salmonidae group (81 species in 5 families). Similarly, for anguilliform swimmers analyses are illustrated with data for two species individually - sea lamprey (Petromyzon marinus) and burbot (Lota lota) - or as the Eel group consisting of four species by adding more limited data on Pacific lamprey (Lampetra tridentata) and European eel (Anguilla anguilla). Regression results indicate similarities in biomechanical capabilities between single species, subgroups or larger subcarangiform or anguilliform groups. The dimensionless fish speed offers robust fatigue curves with stronger regressions when compared to the traditionally normalized fish speed for single species or groups of species. The ecohydraulic approach utilized data collected by various methods, made best use of existing limited data sets for several species and improved estimates for both the group and the single species. Furthermore, this approach generalizes fish speed versus endurance relationships and bridges data gaps by providing estimates for species in the group that lack data. This is important for scientific as well as practical purposes since just 5 of the 81 subcarangiform species, 3 Oncorhynchus sp. (mykiss or steelhead, tshawytscha or chinook, and kisutch or coho), walleye (Sander vitreus), and white sucker (Catostomus commersoni), and 2 of the 4 anguilliform species, sea lamprey and burbot, have a wide range of data on endurances, speeds and fish lengths over the burst and prolonged ranges to derive well-defined individual fatigue curves.

**Juvenile Eel Recruitment In The River Shannon, Ireland: Impact Of Hydropower, Development Of Mitigation Measures And Decline In Eel Numbers**

T. K McCarthy, F. Egan, R. MacNamara, D. Nowak, A. Bateman, C. Lawton, School of Natural Sciences, Ryan Institute, National University of Ireland, Galway, Ireland, D. Doherty, N. Grealy, Fisheries Conservation, Electricity Ireland, Ardnacrusha, Co Clare, Ireland

The River Shannon has been regulated for hydroelectricity generation since construction of the Ardnacrusha dam and associated structures began in 1929. Adverse effects on eel fisheries became evident within about two decades and, following compensation payments to fishery stakeholders, the Electricity Supply Board assumed a statutory fishery management role. Stock restoration measures were focused on capture of juvenile eels in the lower section of the river system and in estuarine tributaries. The trapping protocols that were developed and the results of studies on natural upstream...
Migration of eels will be described. Diel, lunar and seasonal migratory cycles by glass eel, elvers and fingerlings (bootlace eels) were investigated using a variety of techniques that included: monitoring trap catches, use of experimental fishing methods, video observations and mark-recapture experiments. The effects of environmental factors, including water temperature, discharge, light and lunar cycles, in upstream juvenile migration were demonstrated. Modelling of long-term trends in recruitment, eel fishery yield and spawner escapement, suggests that the eel populations of the river system will undergo a serious decline within a decade. Facilitation of upstream migration of juvenile eels is therefore being prioritised in current research and management programmes.

**Dr T. Kieran McCarthy**, though recently retired from active teaching, is actively involved in researching various aspects of European eel biology. His research on Irish eel populations, which involves studies on both upstream and downstream eels, is now mostly focused on hydropower regulated rivers. He works with various national and international research partners. Since 1992 he has been collaborating with Electricity Ireland (formerly the Electricity Supply Board) in management of eel populations on the River Shannon.

**Effect Of Unsteady Flow On Downstream Behaviour And Passage Of The European Eel And Iberian Barbell Over A Spillway**


The behavioural response of downstream moving European eel and Iberian barbel to unsteady flow created by standard WES ogee spillways with upstream face inclinations of \( \theta = 90^\circ \) (standard) and \( \theta = 45^\circ \) and \( 30^\circ \) (modified geometry) were studied. Detailed velocity measurements made using particle image velocimetry (PIV) and acoustic Doppler velocimetry (ADV) at the upstream end and over the spillway in the streamwise-wall-normal plane were used to characterize flow and link fish behaviour with local hydrodynamic variables. A distinct recirculation pattern was found upstream of the 90\(^\circ\) spillway, which was not observed in the other two spillways. This recirculation area seemed to have a strong impact on individuals of both species. Fish exhibited strong avoidance behaviour to turbulence as well as to rapid changes in flow velocity, in particular Iberian barbel. Interspecific variations on behaviour were evident. Eel moved downstream and passed the spillway headfirst. They were predominantly thigmotactic exhibiting a more structure–oriented behaviour and responded after physical contact with the spillway. Barbel moved downstream headfirst but switched orientation at points of rapid velocity variation.
and passed over the spillway tail first without contacting the structure. Geometry-related differences were found for the eel, which exhibited the highest rates of passage success in experiments conducted with upstream inclinations of $\theta = 45^\circ$ and $30^\circ$, and the greatest times of passage and resident times when tested under spillway designs of $\theta = 90^\circ$. Overall European eel had a higher passage success (80%) when compared to Iberian barbel (32%) which spent more time in the test section and took longer to pass the spillway. Results indicate that the design of spillways and associated hydrodynamics strongly impact downstream movements of these two species which have distinct biomechanical capabilities and behaviour. The observed reduction of delay time before passage and the highest passage success rates for the modified spillways suggest that these facilitate appropriate timing of migration and enhance passage survival. Results may have direct application for spillway design to improve survival rates for these and other fish species, as well as other aquatic biota. Future tests should expand this work across species, life stage and body morphology.

**Seasonal And Diel Movement Patterns Of Yellow Eels Migrating Through A Fish Lift**

José Maria Santos, João Oliveira, Rui Rivaes, Raul Pizarro, Centro de Estudos Florestais, Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Lisboa, Portugal

João Pádua, Labelec - Estudos, Desenvolvimento e Actividades Laboratoriais, Lisboa, Portugal,

Teresa Ferreira, Centro de Estudos Florestais, Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Lisboa, Portugal

The blockage of upstream movements by high dams and subsequent reduction in availability of habitat has been reported as a key factor contributing to population decline of inland stocks of the European eel Anguilla anguilla. Although a significant amount of research has been carried out on the migration of descendent silver eels, much less information is available on the migratory ecology of upstream yellow eels and also on their ability in using fish lifts, the most cost-effective mitigation measures for high dams. This study aims to determine i) the seasonal and daily upstream movement patterns; ii) the environmental factors associated with the triggering of the upstream migration and iii) the ability of yellow eels in using fish lifts during their upward migration. Upstream eel passage was continuously monitored over an annual cycle in the fish lift built at the Touvedo dam on the Lima River, north Portugal. Monitoring consisted in the use of an automatic video-recording system in combination with monthly electrofishing samplings undertaken in a 200-m river segment immediately below the dam. Parallelly, hydraulic characterization of the entrance collection system was performed by an Acoustic Doppler Velocimeter (ADV) to assess species capacity to negotiate existing velocities.
at the entrances and within the circuit. A total of 1207 eels were transferred by the lift, of which 98.4% passed during the summer and in the beginning of autumn. Movements occurred independently of time of day. Of the environmental factors considered, only moon phase (-) and daily accumulated rainfall (+) correlated significantly with daily numbers of eel. Overall the fish lift was found to be non-selective for the eel, however size-related differences were detected as the smallest size-class (< 10 cm TL) was under-represented in the facility relatively to the river downstream. The use of fish lifts by eels may be improved by reducing the free gap between retention screens and providing adequate water velocities in the entrances and within the attraction circuit.

José Maria Santos is an assistant researcher at Instituto Superior de Agronomia, Technical University of Lisbon, Portugal. His research interests focus primarily on ecohydraulics, fish passes and freshwater fish ecology. His PhD (2004) was focused on the effects of flow regulations on fish population and communities and the role of different types of fish passes. Since 1997, he has collaborated in several research projects encompassing specific areas such as ecohydraulics, monitoring and evaluation of fish passes and spatio-temporal organization of fish communities and populations.

D3

Fish Friendly Tide Gate Management In The Netherlands, A Regional Perspective.

Peter Paul Schollema, Regional Water Authority Hunze en Aa’s

Regional Water Authority Hunze en Aa’s is one of the 25 regional water management organizations in The Netherlands and is positioned in the NE corner of the country. The main responsibilities are water level management, flood defense and water quality management in the regional lakes, canals and river systems. As part of the water management tasks, RWA Hunze en Aa’s operates several tidal gates that discharge water from the regional rivers into the estuary of the River Ems. These gates play an important role as access to the hinterland for several diadromous species like smelt, Atlantic eel, three spined stickleback, flounder and river lamprey. In the past these tidal gates showed to be an almost impassable barrier for these species. Since 2001 several projects have been carried out to adjust the management and make it more fish friendly. The presentation will give an impression about the practical discussions (salinity, sediment, safety) and monitoring results for 3 of these tidal gates.

Peter Paul Schollema is a specialist Aquatic Ecology working for the Dutch Regional Water Authority Hunze en Aa’s. The last 12 years he has been working on a large number of river and lake restoration projects with a strong focus on planning, monitoring studies and implementation of measures in the Northeastern part of The Netherlands. During this period he worked on the realization of about 80 fish migration facilities ranging from small ramps in upper reaches to high tech fish passes at tidal barriers. He worked as editor and author on both projects; the European Guidance on fish migration From sea to source (2006) and the worldwide guidance From sea to
The Rhine is one of the largest rivers on the European continent. It runs from Switzerland through Germany and the delta covers almost half of the area of the Netherlands. The river basin covers 185,000 km². In early ages the river ended in the estuary ‘Zuiderzee’, an open, tidal estuary that provided habitat for many species of fish. The Zuiderzee was particularly famous for its rich fishery grounds. To prevent future flooding and to develop new agricultural polders the Zuiderzee was closed off and separated from the Wadden Sea in 1932 with a 32km long dike, the ‘Afsluitdijk’. The dike served as a protection against storm floods and as salt levels gradually decreased this new lake ‘IJsselmeer’ transformed into a huge freshwater storage with significant economical benefits.

On the downside, the gradual intertidal fresh-saltwater gradient disappeared, and so did many of the characteristic fish like smelt, houting, sea trout, sea lamprey, herring, alosa, anchovy, etc. The Afsluitdijk had become a barrier between salt and fresh and closed off one of the main doors for fish migration into the river Rhine. The current tidal discharge sluices only open to release superfloow freshwater in the rainy season and most of the time water currents are to high to allow fish to migrate from sea into the lake and hence the rivers upstream of the lake. The negative effects on fish populations resulted in a strong decrease of fishery. Commercial fishermen had to adapt to the new situation and their fishery had to change gradually into freshwater fishery. But nowadays this freshwater fishery is decreasing as well. It is widely accepted that opening the door for fish will greatly improve local and migratory fish populations and both biologists and engineers have proposed several solutions in the past. The major challenge in design remains the fact that the inland lake needs to remain fresh at all times. This limits the possibilities for the ideal solution; an open connection with free tidal characteristics. In 2012 both economic and nature conservation stakeholders have launched the idea of the Fish Migration River, designed to break the barrier. The idea is to construct an artificial river connecting the tidal saltwater Wadden Sea with the freshwater IJsselmeer, with enough length to buffer the saltwater flowing in during high tide. Situated next to the main sluices, a working Fish Migration River can serve multiple goals. It facilitates the return of freshwater fish unintentionally flushed out by the discharge sluices. It opens the dike for a wide range of migratory fish, and provides them with a gradual habitat for physiological adaptation. Furthermore this location has a added value for recreational and education activities. A visitor center is included in the plan as well. The plan has received positive reactions by local, regional and national government and a feasibility study has resulted in a primarily design. For an optimized design further research is needed. It is essential to understand both (local) ecological demands of the fish and potential morphological effects on the Wadden Sea.

Herman Wanningen is an aquatic ecologist with more than 15 years experience in freshwater ecology and water management. He has worked for the regional Water Authority Hunze and Aa's (The Netherlands) on estuary, river, and lake restoration projects. In 2007 Herman started Wanningen Water Consult. He develops fish migration visions and policies and gives advice on implementing different types of fishway techniques. He gives advice on national and international projects dealing with the theme fish migration and river connectivity. He organizes conferences, network meetings and is founder of the World Fish Migration Network and Fish Ecology Network on LINKEDin. Herman initiated and coordinated the European guidance on fish migration From sea to source.

**Fish Passage Design For Tide Gates**

Ryan L. McCormick, P.E., M.S.C.E, *Oregon Department of Fish & Wildlife*

Providing adequate fish passage at tide gate facilities has become a pressing need in Oregon. This discussion will highlight some research data, design procedures and how to apply current State of Oregon design criteria.

**Tide Gate Impacts On Juvenile Coho Salmon Movement**

Guillermo Giannico

**Practical Considerations For Fish Passage Tide Gates**


Tide gates serve an important role in drainage and maintenance of low-lying estuarine environments for agricultural and urban development. However, the benefits of a properly functioning traditional-style tide gate are contrasted by its reduction of aquatic and terrestrial species habitat. Where water would naturally ebb and flow in and out of estuaries, tidal marshes, and low-lying coastal streams and tributaries, the tide gate effectively cuts off this important interaction between fresh-water and salt water and significantly reduces aquatic species opportunity to migrate between coastal and upland environments. In recent years, new designs for tide gates have emerged, that not only maintain focus on flood risk reduction for reclaimed lands, but also improve fresh-water and salt water interaction as well as maximize opportunities for aquatic species to migrate. The new tide gate designs provide much more flexibility for meeting habitat targets, while minimizing flood risk, however, they pose a significant challenge to the hydraulic analysis, design, and construction aspects. The presentation will discuss challenges posed to the design and construction team, and will offer practical considerations and guidelines from hydraulic design to installation. Focus will be paid to the difficulties of numerical modeling of complex tide gate operations, as well as permitting challenges. Finally, construction and installation techniques will be discussed.

**Fish Friendly Floodgates - Hope At Last.**

Kelly Hughes, *NZFSS, IPENZ, Royal Society, ITE*

A detailed description of the engineering concept used to delay the closing moment of flood gates thereby improving both fish passage and tidal exchange. The system has been developed with a view to retro-fitting the device to existing structures offering a quick and relatively cheap solution.

**Kelly Hughes** has 10+ years experience in designing and installing engineering solutions to improve fish passage. Challenges have been tackled in both lowland and upland systems targeting a variety of species. Solving the issues relating to flood gates has been a rewarding exercise with global relevance.