STATE OF MAINE
DEPARTMENT OFMARINE RESOURCES
MARINE RESOURCES LABORATORY
P.O. BOX 8, 194 MCKOWN POINT RD
W. BOOTHBAY HARBOR, MAINE 04575-0008

PAUL R. LEPAGE
GOVERNOR

JOSEPH E. FESSENDEN
ACTING COMMISSIONER

Fourth North American Workshop on Rainbow Smelt

At the Holiday Inn by the Bay in Portland, Maine, January 24-25, 2011

Keynote Presentation:

Intraspecific morphological divergence in freshwater and estuarine rainbow smelt (*Osmerus mordax*).

Dodson, Julian*, Gaétan Daigle, Marie-France Barrette, Marie-Andrée Godbout, Gabriel Colbeck and Frédéric Lecomte.
Université Laval and Ministère de Ressources Naturelles et de la Faune, Québec
**Corresponding author: Julian.Dodson@bio.ulaval.ca*

Historical vicariant isolation and resource partitioning have been identified as processes contributing to morphological intraspecific divergence. Here we review the evidence in support of these processes in the contemporary morphological divergence of Rainbow smelt (*Osmerus mordax*) in both freshwater and estuarine ecosystems. This species is characterised by two historical clades originating in two intraspecific lineages associated with independent glacial refuges. The historical genetic segregation was initiated approximately 350,000 years ago, whereas the divergence of contemporary populations arose within the past 10,000 years. In freshwater, we demonstrate that independent suites of correlated morphological traits are associated with either vicariant history or contemporary feeding specialisations. Adaptive radiation associated with ecological resource partitioning and feeding specialisations in freshwater is strongly influenced by intraspecific phenotypic diversification resulting from vicariant histories. In an estuarine ecosystem, the mtDNA signature of historical divergence led to the recognition of two sympatric populations occupying the north and south shores of the St. Lawrence estuary. Studies of these populations over 30 years have revealed clear and temporally stable morphologies characterising the two sympatric populations that are not associated with feeding specializations. The morphology of the north shore population is clearly divergent from that of all other populations studied to date. Recent distributional studies of larvae, yearling and adult smelt revealed that the so-called north-shore population is distributed throughout the estuary in a variety of habitats whereas the south shore population's distribution is restricted to the shallow margins of the south shore. Morphological and allometric divergences were found as early as the post-metamorphic stage suggesting that this distinction is mainly an imprint of their historical past. The morphological differences attenuated between the two populations during subsequent ontogenetic stages, indicating morphological convergence, consistent with the view that the habitats exploited by the two smelt populations are less distinct than previously thought.

1. Rainbow smelt population monitoring on the Gulf of Maine coast of New England.

Chase Bradford C*[1], Claire Enterline[2], Katherine Mills[3], Matthew H. Ayer[1], Scott P. Elzey[1], Jessica Fisher[4], Steve Correia[1], and Chris Woods[1]
[1]*Massachusetts Division of Marine Fisheries*
[2]*Maine Department of Marine Resources*
[3]*University of Maine, Gulf of Maine Research Institute*
[4]*New Hampshire Department of Fish and Game*
**Corresponding author: brad.chase@state.ma.us*

Anadromous rainbow smelt (*Osmerus mordax*) have traditionally supported popular recreational fisheries and small-scale commercial fisheries on the Gulf of Maine coast of New England. These fisheries have declined in recent decades and concerns have grown over the health of smelt populations throughout much of their range. The states of Maine, New Hampshire and Massachusetts received a grant from the National Marine Fisheries Service's Office of Protected Species to investigate the status of smelt and to develop a conservation plan for the Gulf of Maine coast of New England. Fyke net stations were established in 2007 at coastal rivers to intercept adult smelt on their spring spawning runs. Biological data were recorded to characterize the smelt runs and develop fishery independent indices of smelt population abundance. Analyses were conducted on size and age composition, catch-per-unit-effort, and mortality. Comparisons of smelt population demographics were made among rivers and to previous studies. Smelt catches among stations displayed distinct characteristics of run peak, run duration, size composition and sex composition. Catches in southern Gulf of Maine showed evidence of reduced presence of older smelt and a higher proportion of age 1 smelt.

2. Population genetic structure of anadromous rainbow smelt (*Osmerus mordax*) in the Northeast U.S.

Adrienne I. Kovach[1] , Timothy S. Breton[2], and David L. Berlinsky[2]
[1]*Department of Natural Resources and the Environment, University of New Hampshire*
[2]*Department of Biological Sciences, University of New Hampshire*
**Corresponding author: adrienne.kovach@unh.edu*

Consideration of the genetic structure of marine and anadromous fish populations is recognized as important for their successful management and conservation. This objective is germane to the rainbow smelt (*Osmerus mordax*), a Species of Concern in the Northeast U.S. Due to their close association with estuarine habitats and the potential for estuarine retention of larvae, anadromous smelt are expected to exhibit population structuring at the scale of estuaries or retention areas. The goal of this study was to determine the genetic variation among rainbow smelt from multiple river systems in New England. Smelt were sampled during the spring spawning season in 2006-2010 from the Weweantic, Fore, Saugus, and Parker rivers in Massachusetts, the Bellamy, Oyster, Lamprey, and Squamscott rivers in New Hampshire, and the Harraseeket, Kennebec, Penobscot, Pleasant, and Chandler rivers, Schoppee Brook, and Cobscook Bay in Maine. Genetic analysis was conducted using 11 microsatellite markers. We found a temporally stable genetic structure, with significant genetic differentiation among smelt from most river systems, with the exception of the ones in closest geographic proximity (e.g. Bellamy and Lamprey Rivers of New Hampshire). Genetic structure followed an isolation-by-distance model, as smelt from the most distant locations displayed the highest levels of differentiation, and genetic connectivity was highest within regional river groupings. Genetic diversity was slightly reduced in the most northern (Cobscook) and southern (Weweantic) rivers. These results can be used to inform the designation of genetically distinct management units, which may guide restoration and restocking efforts.

3. Relationships between watershed conditions and rainbow smelt spawning populations

Mills, Kathy*[1], and Claire Enterline[2]
[1]*University of Maine, Gulf of Maine Research Institute*
[2]*Maine Department of Marine Resources*
**Corresponding author: kmills@gmri.org*

Watershed land use and land cover has been associated with differences in water quality, habitat conditions, invertebrate communities, and fish assemblages in a wide variety of aquatic ecosystems. In this study, we investigate direct and secondary relationships between watershed features and rainbow smelt at regional and sub-regional scales. Watershed features considered in the analyses included watershed size, stream crossings, and the proportion of land cover in four categories--developed, forest, agriculture, and wetlands. We used multivariate ordination and regression models to evaluate direct relationships between these features and the use of a stream by smelt for spawning. We also considered potential indirect implications of watershed features on rainbow smelt by evaluating associations between land use and water quality conditions during the spawning season. Our ultimate goal is to develop a model that can predict smelt spawning use of specific river systems from widely available GIS-based data. Such a predictive relationship would have beneficial implications for monitoring and conservation planning to protect rainbow smelt during their spawning runs and early life stages.

4. Monitoring within-season spawning behavior by rainbow smelt *Osmerus mordax* using passive integrated transponder (PIT) systems

Enterline, Claire*[1], Alex Haro[2], and Bradford C. Chase[3]
[1]*Maine Department of Marine Resources*
[2]*S. O. Conte Anadromous Fish Research Laboratory, U. S. Geological Survey*
[3]*Massachusetts Division of Marine Fisheries*
**Corresponding author: Claire.Enterline@maine.gov*

During the spring rainbow smelt spawning run, a highly skewed sex ratio is observed in which many more males visit the spawning grounds compared to females. Sampling large groups of smelt during other seasons finds a fairly even sex ratio. Previous mortality estimates have been based on total catch during the spawning season and may be biased. Quantifying the rate of within-season repeat spawning by age and sex allows the frequency at age to be corrected and accurate mortality estimates calculated. Small passive integrated transponder (PIT) tags were placed intraperitoneally in smelt during the spawning run in the Harraseeket River, Maine. Half-duplex (HDX) radio frequency identification (RFID) transponder detection antennas systems were placed in an array just downstream of the spawing area for the duration of the rainbow smelt spawning season (March-June) and monitored movement of tagged fish twenty-four hours a day. In 2009, 165 smelt were tagged (117 male; 48 female). Post-tagging detection rate differed between the sexes: all females either exited the spawning area immediately after tagging or returned only once, however, males returned to the spawning area up to six times within a season. Returning males tended to enter the spawning area with the daytime incoming tide, whereas male and female smelt that returned only one or two times were found to enter the grounds only during the nighttime spawning event. Frequency at age tables and mortality estimates will be adjusted based on the rate of repeat spawning.

5. Rainbow Smelt Culture in Recirculating Systems

Berlinsky, David*, Abigail B. Walker and Heidi R. Colburn.,
Department of Biological Sciences, University of New Hampshire
**Corresponding author: david.berlinsky@unh.edu*

A series of experiments were conducted to evaluate the growth and survival of juvenile rainbow smelt reared in recirculating systems under different environmental conditions (16, 20 and 24°C; 0, 5 and 15 mg/L salinity) and fed 3 dietary protein levels (35, 42 and 50%). Larval smelt were initially fed live prey (rotifers and *Artemia*) and gradually weaned to commercial formulated diets over a 2 or 3-day period. Growth was significantly greater in juveniles fed the highest protein diet (50%) and reared at the lowest temperature (16 °C), although survival did not differ among treatment groups. Growth and survival were high and did not differ among salinity treatment groups. While smelt are highly adaptable to culture in recirculating systems, high levels of cannibalism will need to be addressed before commercial-scale production can be realized.

6. Spawning strategies and dynamics among anadromous smelts, are we aware only of the tip of the iceberg ?

Frédéric Lecomte
Ministère de Ressources Naturelles et de la Faune, Québec
**Corresponding author: Frederic.Lecomte@mrnf.gouv.qc.ca*

Fishes belonging to the order Osmeriforms exhibit almost the complete variety of spawning strategies known for anadromous species. Among rainbow smelt populations (*Osmerus mordax*), a certain variability exists but has yet to be fully appreciated. While the typical spring exploitation of tributary streams appears to be the norm, alternative spawning strategies appear more widespread than originally thought. Proximal and ultimate causes may explain which strategies are used by distinct populations. The St. Lawrence Middle Estuary is exploited by two ecologically distinct sympatric populations. Among many aspects of their life-cycle, they differ in spawning strategies. While one population appears to fit the norm (stream spawning), the second population exhibits a totally distinct strategy as they migrate up to 100 km upstream of the saline intrusion (used as a nursery area) and spawn directly within the St. Lawrence river over shallow shoals. The co-existence of ecologically-distinct sympatric populations allows us to examine the implication of the use of different spawning grounds in the long-term maintenance of sympatric populations. A theoretical model is presented to illustrate the case and how such a situation may be evident in other anadromous or lacustrine populations.

7. Ghost hunting; quantifying and localizing alternative spawning grounds used by anadromous rainbow smelt (*Osmerus mordax*)

Legault, Michel*, and Frédéric Lecomte
Ministère de Ressources Naturelles et de la Faune, Québec
**Corresponding author: michel.legault@mrnf.gouv.qc.ca*

The existence of alternate spawning strategies used by the sympatric smelt population exploiting the St. Lawrence Middle Estuary is an exciting yet challenging new perspective we are facing in recent years. While the typical use of spawning habitat is relatively easy to quantify and yearly surveys can be implemented thanks to a certain predictability in the localization of spawning activities, satisfactorily quantifying the alternative spawning habitat is complicated by the sheer size of the area exploited and the presumed spatial variability. Moreover, the initial identification of alternative spawning strategies is complicated by the discovery of the simultaneous use of the same area by the two populations. The

proximity is such that within less than several hundreds of meters, one population spawns in a tributary stream (exploiting the freshwater plume) while the second spawns over extensive shallow shoals within the main river (St. Lawrence). We here present new tools and techniques that we have developed to clarify this situation. We also discuss the implication of these findings for management practices and how we plan to embed these procedures in the yearly surveys aimed at monitoring the status of the two populations.

8. Nuclear (AFLP) population genetic structure of the St. Lawrence estuary smelt complex

Colbeck, Gabriel*[1], Julie Turgeon[2] and Julian Dodson[1]
[1]*Université Laval, Québec*
[2] *Ministère de Ressources Naturelles et de la Faune, Québec*
**Corresponding author: gabriel.colbeck.1@ulaval.ca*

In order to better understand nuclear gene flow amongst contemporary populations of the St. Lawrence estuary smelt complex, we employed AFLPs on 16 sample sites (N=315) across the estuary, with multiple sites representing each of the two historical lineages. In preliminary results, 4 primer combinations yielded 154 loci, 67 (43%) of which were polymorphic. We find two distinct genetic clusters, but they do not conform to the classic north/south dichotomy. One cluster is found primarily upstream on the south shore, while a second cluster is found on the north shore, as well as in downstream populations of the south shore (i.e. from Riviere Ouelle to Rimouski). While most individuals are distinctly one genetic population or the other, genetic intermediates (i.e. hybrids) exist, suggesting gene flow between the clusters. In terms of the historical lineages, these results suggest nuclear introgression from the north shore ecotype to the south shore ecotype in populations from Ouelle to Rimouski, since these sites putatively have 'south shore' mtDNA (further mtDNA sequencing results pending). On the other hand, upstream south shore ecotype populations appear to remain relatively distinct. Firm conclusions await additional samples and analyses.

9. Quantifying zooplankton consumption of larval and juvenile rainbow smelt using a mercury mass balance model

Plourde, Jérôme*[1], Pascal Sirois[1] and Marc Trudel[2]
[1]*Research Chair, Université du Québec à Chicoutimi, Département des sciences fondamentales*
[2]*Pacific Biological Station, Fisheries and Oceans Canada, British Columbia*
**Corresponding author: jerome.plourde@uqac.ca*

Consumption rate have seldom been directly estimated in the field for larval fish. Such estimation is valuable to assess the feeding demand during early life and the top-down effect on zooplankton populations. The general objective of this study was to quantify zooplankton consumption by young-of-the-year and yearling rainbow smelt, a key forage species in several aquatic ecosystems. A mercury mass balance model has been used to determine rainbow smelt consumption rate in Lake Saint-Jean, a large boreal reservoir. In 2009, fish were sampled seven times from June to October to measure methylmercury concentration in smelt and determine their diet. Zooplankton was sampled two times during the same period and was sorted to the lowest taxonomic level to determine methylmercury concentration in each prey species. Results showed that rainbow smelt feed almost exclusively on zooplankton between June and October. In early summer, young-of-the-year smelt ingested nearly 70% of their body weight whereas in early autumn, consumption declines to less than 5%. On the other hand, yearling smelt ate 30% of their body weight early in the summer and consumption declines to less than 5% in October. These consumption rates corresponded roughly to 1 mg of zooplankton per day in early summer to 250 mg/day in early autumn for young-of-the-year smelt. This can be compared to an average of 500 mg/day for yearling smelt during summer and 100 mg/day in October.

These results provided new data on zooplankton predation by rainbow smelt in Lake Saint-Jean and will contribute to evaluate the carrying capacity of the lake for future enhancement programs.

10. Carrying capacity of Lake Saint-Jean for rainbow smelt

Sirois, Pascal*[1], Alexandra Marion[1], Jérôme Plourde[1], Stéphane Plourde[2] and Michel Legault[3]
[1]*Research Chair, Université du Québec à Chicoutimi, Département des sciences fondamentales*
[2]*Pêches et Océans Canada, Direction des sciences océaniques et de l'environnement*
[3]*Ministère de Ressources Naturelles et de la Faune, Québec*
**Corresponding author: pascal_sirois@uqac.ca*

It is now well established that the production of landlocked Atlantic salmon (*Salmo salar*) in Lake Saint-Jean is limited by the abundance of its preferred prey, the rainbow smelt (*Osmerus mordax*). Hence, managers are considering to stock millions of larval smelt or to develop new reproduction sites in order to increase the abundance of this forage species. However, it is important to assess the feeding demand and the food supply for rainbow smelt in Lake Saint-Jean. The general objective of this study was to assess the carrying capacity of Lake Saint-Jean for rainbow smelt. To reach this objective we sampled young rainbow smelt and zooplankton in Lake Saint-Jean during the ice-free season (May to October). First, we described the diet of larval and juvenile rainbow smelt and we used a mercury mass-balance model to estimate the feeding demand. Then, we estimated the production of the main prey items to evaluate the food supply and we calculated the mortality of zooplankton due to rainbow smelt ingestion. Finally, we simulated different scenarios of larval and juvenile smelt abundance in order to assess the impact on zooplankton stock. Results of this study will provide management strategies for future enhancement program.

11. Early life history dynamics and recruitment of rainbow smelt in Lake Huron

O'Brien, Timothy P. *[1, 2], and William W. Taylor[2, 3]
[1] *USGS Great Lakes Science Center, Ann Arbor, Michigan*
[2] *Michigan State University, Department of Fisheries and Wildlife, East Lancing*
[3]*Michigan State University, Center for Systems Integration and Sustainability, East Lancing*
**Corresponding author: tiobrien@usgs.gov*

Rainbow smelt are an important prey species for native and introduced piscivores in the Great Lakes, but also function as a predator on native fish and zooplankton species. Rainbow smelt abundance in Lake Huron is currently at historic low levels with most of the population comprised of age-0 and age-1 fish. To determine sources of recruitment variability and understand long term population decline, we studied larval stages of rainbow smelt during 2008-2009 and modeled stock recruitment relationships based on bottom trawl catches during 1976-2009. Peak larval rainbow smelt densities in 2008 were double densities observed in 2009. Length frequency analysis revealed a second cohort of lake spawned larvae appeared in late June and early July of both years concurrent with an increase in larval density. Growth rates of larvae were significantly higher during 2009. Early hatching cohorts during 2008 suffered high mortality, whereas early and late hatching cohorts had relatively high survival during 2009. Stock-recruit models for 1976-1991 appeared asymptotic and recruitment variability was best explained by a combination of lake trout abundance, rainbow smelt stock size, and Lake Huron water levels. During 1994-2009, compensatory processes were evident at high stock sizes and recruitment variability was explained largely by lake trout abundance. These results indicate that variable growth rates and survival of early hatching cohorts strongly influence year class formation of rainbow smelt in Lake Huron. Furthermore, lake trout abundance had a substantial influence on rainbow smelt recruitment dynamics in Lake Huron during 1976-2009, presumably through predation on larval and/or adult life stages.

12. History and Status of Landlocked Rainbow Smelt (*Osmerus mordax*) in Maine

Halliwell, Dave[1], and Dave Boucher[2]
[1]*Maine Department of Environmental Protection, Augusta*
[2]*Maine Department of Inland Fisheries and Wildlife, Strong*
**Corresponding author: David.Halliwell@maine.gov*

Rainbow smelt are an anadromous fish species which are indigenous to most coastal Maine estuarine waters. They also occur as native and introduced landlocked populations in numerous fresh water inland lakes and ponds statewide. Rainbow smelt are the primary forage fish species for landlocked Atlantic salmon in Maine and elsewhere, and are thought to have originated in the same four river basins – St. Croix (West Grand Lake, Washington Co.), Union (Green Lake, Hancock Co.), Penobscot (Sebec Lake, Piscataquis Co.) and Presumpscot (Sebago Lake, Cumberland Co.) – as well as associated free-flowing waters within these river basins. Late 1800's fishery records indicate that landlocked Atlantic salmon were primarily found to occur in the presence of landlocked populations of rainbow smelt, and the two species were widely disseminated for the purpose of generating sport fisheries as early as 1868. After more than a century of stocking and active management, Maine's Department of Inland Fisheries and Wildlife reported in 2006 that 176 Maine lakes (about 485,000 acres) provided a significant fishery for landlocked Atlantic salmon (and rainbow smelt) – nearly 50% of Maine's total freshwater acreage. Rainbow smelt are also exclusively sold as a primary bait fish in Maine for salmonid fisheries statewide, particularly during the winter fishing season. Big Reed Pond (a 94-acre pond in the St. John River drainage) – home to the regionally endemic Arctic char (*Salvelinus alpinus*) and surrounded by old growth forest – is currently being reclaimed in an attempt to extirpate a population of illegally introduced rainbow smelt.

13. Water quality and habitat assessment of rainbow smelt (Osmerus mordax) spawning locations in the Gulf of Maine

Chase, Bradford C.*[1], Claire Enterline[2], Katherine Mills[3], Matthew H. Ayer[1], Scott P. Elzey[1], Jessica Fisher[4], Steve Correia[1] and Chris Woods[1]
[1]*Massachusetts Division of Marine Fisheries*
[2]*Maine Department of Marine Resources*
[3]*University of Maine, Gulf of Maine Research Institute*
[4]*New Hampshire Department of Fish and Game*
**Corresponding author: brad.chase@state.ma.us*

Anadromous fish migrate between marine and freshwater for important life history stages. Widespread reductions have occurred in populations of several species of anadromous fish in New England in recent years. Population trends are not well-documented and causal factors remain speculative. Spawning habitat degradation has long been a suspected contributor to the declining health of sea-run fish. The reproductive strategy of depositing a demersal, adhesive egg in freshwater habitats may be challenged by the influence of watershed alterations, particularly in urban areas. Coinciding with the population reductions is a growing public interest in restoring these traditional and popular fish runs. Restoration efforts have focused on structural solutions to migration impediments, with less guidance available on the role water and habitat quality have in restoring anadromous fish habitat and populations.

The states of Maine, New Hampshire and Massachusetts are collaborating on a conservation plan for anadromous rainbow smelt in the Gulf of Maine. This effort includes the development of a Quality Assurance Program Plan (QAPP) for monitoring water and habitat quality at smelt spawning habitat at

coastal rivers on the Gulf of Maine coast. The monitoring relates species life history requirements to state and federal water quality criteria and habitat thresholds. The project goals include developing a standardized process to classify the suitability of smelt spawning habitat and contributing to water quality and habitat restoration efforts in New England. Smelt spawning habitat monitoring from 2008-2010 will be presented with analyses on causal and response variables and discussion on remediation.

14. Pleasant River Estuary, Smelt Fisheries from Past to Present - a ray of hope for a declining species?

Shaw, Dwayne*
Executive Director, Downeast Salmon Federation, Columbia Falls, Maine
**Corresponding author: dsf@panax.com*

The Pleasant River and other nearby estuaries are home to some of the most highly productive smelt populations remaining along the US Atlantic seaboard. The surrounding watersheds are among the least developed in the Gulf of Maine. A small number of commercial fishermen continue to harvest smelt and tom cod using gill nets and bag nets in a locally important and unique heritage fishery - a fishery which once extended well beyond the region into the southern range of the species. Fishermen have worked closely with staff and volunteers of the Downeast Salmon Federation and with multiple agencies and municipalities to protect, study, and maintain this fishery over many years. We have been working to document the history of the fishery and also to study the status of the population to help us better maintain the commercial fishery. Water quality and fish health monitoring, habitat restoration and protection and other conservation measures are underway. Results of some of the past efforts and descriptions of the ongoing work will be summarized.

15. Evaluation of passage efficiency of rainbow smelt in a nature-like fishway and characterization of the spawning migration

Clément, Marie*[1], Jean-Baptiste Torterotot[2], Normand Bergeron[2], and Francois Plante[1]
[1]*Department of Fisheries and Oceans Canada, New Brunswick*
[2]*INRS-Centre Eau Terre et Environnement, Québec, Canada*
**Corresponding author : Marie.Clement@dfo-mpo.gc.ca*

Fishways are often used by migrating fishes to access habitats upstream of dams and other obstacles. However, most fishway designs remain untested. Because of its poor swimming performance, rainbow smelt is an excellent indicator species to determine the passage efficiency of a fishway. The aim of this project is to evaluate the smelt-passage efficiency of the nature-like fishway constructed in the Pisquid River (Prince Edward Island, Canada) using passive integrated transponder (PIT) technology (half-duplex; fixed antenna arrays). PIT-Tags (23 mm, 0.6g) were surgically implanted in the abdominal cavity of 465 smelts (230 males, 235 females) captured and released downstream of the fishway. Results indicated that 46% of the tagged smelts approached the fishway and only 17% successfully crossed over the first weir and entered the fishway. However, only 1% of the tagged smelt successfully navigated the entire fishway. Males were the predominant gender that approached (60%), entered (69%) and navigated the entire fishway (83%). However, these results could be influenced by the fact that females seemed to experience higher handling (tagging) mortality. High spawning activities were observed downstream and within the fishway. The low entrance and passage success could also be attributed to a lack of migration urge caused by the presence of adequate spawning habitat downstream and within the fishway. Migratory and spawning behaviour were also documented by underwater camera images.

The biological characteristics and timing of the spawning migration were quantified. The migration in the Pisquid River was initiated when water temperature reached 4.5ºC (April 15, 2009). The migration was bimodal and the second peak occurred when water temperature reached 8ºC (April 23, 2009). Over the course of the migration, 1233 smelt were randomly sampled downstream of the fishway. Seventy-four percent of these fish were male and 26% were female. The temporal variation of the sex-ratio showed a tendency for the proportion of females to increase throughout the spawning migration. No significant difference in fork length was observed between males (mean ± SD: 15.9 ± 1.6 cm) and females (16.2 ± 1.9 cm); however, females (32.6 ± 1.5 g) were found to be significantly heavier than males (30.3 ± 1.1 g). Fish size tended to decrease throughout the migration and both males and females followed the same temporal pattern. Age was determined on a random sub-sample of 138 individuals. The subsampled smelt population was composed of four age groups (age 2 to 5) with the vast majority of the fish being age 2 and 3 years.

This study indicated that some smelts can successfully navigate the nature-like fishway in the Pisquid River. However, further research is required to better understand the migratory behaviour and swimming capacity of smelt in relation to hydraulic conditions within fishways. The effects of PIT-tagging on the swimming performance of smelts remains to be determined.

16. Laboratory marking of rainbow smelt embryos and larvae and the implications for restoration

Ayer, Matthew H.*, Scott Elzey, and Bradford C. Chase
Massachusetts Division of Marine Fisheries
**Corresponding author: Matt.Ayer@state.ma.us*

The decline of rainbow smelt (*Osmerus mordax*) in Massachusetts throughout the last decade has increased the need for developing practical restoration practices. Utilizing recently developed culture techniques, this study developed practical methods for marking otoliths in rainbow smelt embryos and larvae. Adult smelt in spawning condition were captured from spawning runs in coastal Massachusetts Rivers and strip-spawned in the laboratory. Oxytetracycline was applied using multiple treatments to eyed embryos and newly hatched larvae. Fish were retained and reared in a recirculating water system in the laboratory and sampled at regular intervals up to 12 months to examine otoliths for the persistence of an oxytetracycline mark under ultraviolet light. Otoliths from larvae marked with buffered 500mg/L oxytetracycline showed the most visible and persistent marks. The viability and survival of embryos and larvae was not significantly different between oxytetracycline treatments and controls. Results were used to direct the marking of mass numbers of larval rainbow smelt which were stocked into a river with suitable spawning habitat but minimal spawning activity. Sampling during subsequent years has revealed a quantifiable contribution to the spawning population. Successful marking of hatchery stocked smelt is critical in order to identify and quantify effectiveness of restoration efforts.

17. The Rainbow Smelt restoration Plan for the St. Lawrence estuary: Where are we 8 years later?

Verreault, Guy*, Guy Trencia and Michel Legault.
Ministère des Ressources Naturelles et de la Faune, Québec
**Corresponding author: Guy.verreault@mrnf.gouv.qc.ca*

In the St. Lawrence Estuary (Canada), the anadromous Rainbow Smelt (*Osmerus mordax*) was listed as a vulnerable population in 2005. In response to a sharp decline in abundance, a restoration program was developed with stakeholder to reverse the trend by identifying and implementing management

actions and research activities. Among factors affecting the stock, spawning habitat rehabilitation and fishing mortality were identified as major restoration objectives. Protection of remaining active spawning rivers and restoration of the ones previously used received the highest priority and watershed management was implemented on those tributaries to restore water quality. An integrated restoration plan involving public agencies, universities and non governmental organizations was put in place to enhance collaboration for fishery surveys, estuarine distribution and spawning ecology. Assessment procedures and monitoring activities were developed and standardized as performance measures. These efforts begin to pay: water quality increased on spawning grounds, adults abundance is slightly increasing, and smelt spawning were reappearing in two historically abandoned tributary. Although these encouraging observations remain fragile, it proves that restoration objectives can be achieved and declining trends reversed with a team-work approach. Most significant findings and will be reviewed and discussed.

Poster Abstracts

Poster-1. Gene flow between Anadromous and Freshwater Rainbow smelt (Osmerus mordax)

Campbell R, C Chipman, A Cundy, S Derrig, L Fournier, T Gelineau, A Gordon, N Hinds, P Mccann, A Walker, E Williams.
Advisors: Ehrenfeld E, Tarbox B*
Southern Maine Community College, Portland
**Corresponding author: BTarbox@smccme.edu*

Five microsatellite loci were used to estimate gene flow between anadromous rainbow smelt (*Osmerus mordax*) from Casco Bay, Maine and Sebago Lake, Maine. Sebago Lake is drained by the Presumpscot River which flows into Casco Bay. The river has been dammed since the early 18th century. A stock enhancement project transferred 10,000,000 anadromous smelt eggs taken from Casco Bay fish into Sebago Lake over a five year period from 2002 to 2006. Gene diversity indices calculated using Fstat software are consistent with limited gene flow between populations (F_{st} = 0.035, G_{st}= 0.017, R_{st} = 0.079). Cluster analysis indicates that the direction of gene flow was from Casco Bay to Sebago Lake.

Poster-2. Microsatellite Analysis & MHC 2a of Rainbow Smelt, *Osmerus mordax*, in the Pleasant River Watershed

K.D. VanGorden, G.P. Zegers*
University of Maine at Machias
**Corresponding author: gzegers@maine.edu*

Rainbow smelt, *Osmerus mordax*, is an economically important fish for the Downeast fishing industry as well as being a major food source for many other species in the area including *Salmo salar*. We will use microsatellites and other genetic markers to determine if population structure exists in the Pleasant river watershed. We will use the tetranucleotide microsatellite primers that were found in existing literature. Samples were collected from four rivers during the 2010 season: Pleasant River (47 individuals), Narraguagus River (54 individuals), Harrington River (30 individuals), and East Machias River (2 individuals). Although microsatellites are polymorphic among our samples, a preliminary survey using a major histocombatibility complex (MHC) marker suggests that our samples are monomorhphic. In contrast, a sample of 24 Atlantic salmon from the pleasant river had four alleles at (we believe) the same locus.

Poster-3. Using otolith microchemistry to distinguish rainbow smelt larvae from different natal rivers

Fortin, Anne-Lise*[1], Pascal Sirois[1] and Michel Legault[2]
[1]*Université du Québec à Chicoutimi, Département des sciences fondamentales*
[2]*Ministère des Ressources Naturelles et de la Faune, Direction de l'expertise sur la faune et ses habitats, Québec*
**Corresponding author: anne-lise_fortin@uqac.ca*

The St. Lawrence south shore population of rainbow smelt (*Osmerus mordax*) spawn in four known locations (Rivière du Loup, Rivière Fouquette, Rivière Ouelle and Ruisseau de l'Église). It is important to distinguish the origin of larval smelt in order to evaluate the contribution of each river to the natural population in the St. Lawrence estuary. The general objective of this study was to evaluate the use of the otolith microchemistry method for distinguishing the origin of rainbow smelt larvae from different natal rivers. The otolith core from rainbow smelt larvae from four spawning sites were

analysed with a solution-based inductively coupled plasma-mass spectrometry (ICP-MS). A discriminant function analysis based on the concentrations of the most important trace elements in the otolith will be used to separate the larval smelt into their natal river.

Poster-4. Diadromous Species Restoration Research Network: A Five-year Collaborative Research Effort

Arter, Barbara* and Matthew Dietert
Senator George J. Mitchell Center, University of Maine, Orono, Maine,
**Corresponding author: barbara.s.arter@umit.maine.edu*

The goal of the Diadromous Species Restoration Research Network (DSRRN) is to advance the science of diadromous fish restoration and promote state-of-the-art scientific approaches to multiple-species restoration at the ecosystem level. DSRRN integrates many diverse activities that improve the understanding of ecosystems and enhance restoration outcomes, facilitates the study of questions fundamental to diadromous fish ecology and restoration through scientific meetings, workshops and local networking, and enhances coordination of diadromous species restoration efforts of academic, government, and watershed stakeholders. The Network which is funded through the National Science Foundation, provides information and networking on research and restoration funding opportunities, research, and restoration project partnerships, conferences and meetings, the Penobscot Science Exchange, fisheries and restoration links, and the Gulf of Maine Knowledge Base which provides access to spatially referenced bibliographic information so that users can locate information using text-based and map-based searches by state/province and by watershed.

Poster-5. Penobscot River Science Exchange: A Consortium for Dam Removal and Diadromous Fish Restoration Research

Arter, Barbara* and Matthew Dietert
Senator George J. Mitchell Center, University of Maine, Orono, Maine,
**Corresponding author: barbara.s.arter@umit.maine.edu*

Covering 8,570 square miles, the Penobscot River is Maine's largest and New England's second largest watershed. Unfortunately, centuries of dam construction have blocked the migration of diadromous fish to their up-stream spawning and juvenile-rearing habitats. The Penobscot River Restoration Project will restore nearly 1,000 miles of sea-run fish habitat by removing two large hydro-electric dams in the lower part of the river and providing improved fish passage at a third dam upstream. In 2008, the Penobscot River Restoration Trust and agency and academic researchers began conducting studies and environmental monitoring on the river in order to establish pre-dam removal conditions that will allow managers to document restoration outcomes. This group of approximately 30 researchers makes up the Penobscot Science Exchange, which is a collaboration with the Diadromous Species Restoration Research Network (DSRRN), a five-year, NSF-funded collaborative research effort to advance the science of diadromous fish restoration.

This poster provides descriptions and photographs of research projects currently being conducted on the Penobscot in conjunction with the dam removals and the Penobscot Science Exchange. Projects include shortnose sturgeon movement and spawning, bird assemblages, sea lamprey movement in tributaries, iron-drainage impacts to water quality, alewife population structure and migration, marine-freshwater food web linkages, sea lamprey and Atlantic salmon interactions, and dam removal impacts on fish assemblages.

Poster-6. A Historical View of Anadromous Rainbow Smelt Populations and Fisheries in the Eastern United States

Wood, Christopher H.*, Bradford C. Chase, and Matthew H. Ayer
Massachusetts Division of Marine Fisheries
**Corresponding author: Christopher.Wood@state.ma.us*

The rainbow smelt (*Osmerus mordax*) is a prized table fish that has demonstrated cultural, ecological, and economical importance along its native range from Virginia to the Canadian maritimes. Smelt fisheries were prominent in numerous coastal communities on the US east coast and the Canadian Maritimes until the latter half of the 20th century. The southern populations of smelt have gradually declined and appear to have been recently extirpated. Presently, Massachusetts supports the southernmost viable population of smelt.

We reviewed available historical information regarding smelt harvests, fishing interest, and market demand for smelt throughout the Eastern U.S., and have provided a summary of these findings. This poster focuses on the mid-Atlantic and Northeastern U.S. smelt stocks where significant changes have occurred to anadromous smelt populations. In this work we also summarize the following causal factors linked to the historical decline: 1) coastal river dam creation, 2) overfishing, 3) industrial water pollution, and 4) climate change. This summary offers a broad historical perspective on this once important recreational and commercial fish, and discusses present threats and challenges.

Poster-7. Are common smelt (*Retropinna retropinna*) a sustainable food source for rainbow trout (*Oncorhynchus mykiss*) in Lake Rotoiti, New Zealand?

Blair, Jennifer M.*[1], Brendan J. Hicks[1], Nicholas Ling[1], and Rob Pitkethley[2]
[1]*University of Waikato, Hamilton, New Zealand*
[2]*Eastern Region Fish and Game, Rotorua, New Zealand*
**Corresponding author. Email: jmb90@students.waikato.ac.nz*

Lake Rotoiti is a warm, monomictic, eutrophic lake in the North Island of New Zealand. It is home to a popular rainbow trout fishery (*Oncorhynchus mykiss*) which is supplemented by hatchery-raised yearlings. Native common smelt (*Retropinna retropinna*) constitute 83% of the diet of rainbow trout over 200 mm long. Despite their importance as a prey species, the life history of smelt in Lake Rotoiti is poorly understood, and the capacity of the smelt population to support increased levels of trout stocking is unknown.

In 2008, the Ohau Channel Diversion Wall was installed to improve water quality in Lake Rotoiti. The effect of this wall is to divert nutrient rich water from Lake Rotorua directly down the Kaituna River, rather than into Lake Rotoiti. It is possible that the diversion wall has had a negative impact on spawning migrations of common smelt between Lake Rotorua and Rotoiti, which could in turn affect food supply for rainbow trout.

Sampling is currently being carried out in order to assess abundance and dynamics of smelt in Lake Rotoiti. In the past year, littoral catch rates of smelt varied diurnally and seasonally, with highest catches of up to 2,000 smelt in an 800 m^2 electric fishing transect in autumn, which was likely due to a migration of smelt into the littoral zone to spawn. Semi-quantitative sampling of smelt eggs, coupled with monitoring of reproductive maturity of spawning adults, shown that spawning is most prevalent at the lake's more exposed eastern beaches. In addition, numbers of larvae were highest in this area. This suggests that smelt are reproducing locally, providing a sustainable food source for rainbow trout. This study also indicates the importance of exposed beach habitat for sustaining smelt populations.

Poster-8. The Penobscot Estuarine Fish Community Survey: An Overview with Rainbow Smelt Monitoring Components

Stevens, Justin.* M. O'Malley, L. Shaw, R. Saunders, C. Lipsky and J Kocik
National Ocean and Atmospheric Administration, Fisheries Service, Orono, Maine
**Corresponding author:* Justin.Stevens@noaa.gov

The Penobscot ecosystem allows a unique opportunity to monitor estuarine responses to major upstream river restoration projects including main-stem dam removal, active diadromous species population enhancement, and habitat improvement projects. There is also a growing need to understand interactions between freshwater, diadromous, and marine species in estuaries. Therefore, we developed the Penobscot Estuarine Fish Community Survey, which is part of the wider Maine Estuaries Diadromous Survey. The primary aim of the former is to describe the spatial and temporal distribution of fish in the Penobscot estuary. A fishery-independent time series dataset will be developed from environmental monitoring capturing all habitats within the estuary system coupled with surveys of the multiple and diverse species using the estuary. The project will begin with initial exploratory and descriptive analyses and will evolve to include impact assessment and hypothesis testing where possible. Feasibility studies began in 2010 and will continue in 2011-12; the goal of this work was to conduct a fish community survey in the estuary utilizing various fish capture techniques including beach seining, fyke netting, midwater trawling and hydroacoustics. These techniques will be tested for effectiveness of quantifying runs of diadromous species including: rainbow smelt Atlantic salmon, shortnose sturgeon, American shad, alewife, blue-back herring, sea lamprey and American eel. Such data are currently unavailable without the bias of hydroelectric passage effectiveness or directed fisheries effort. Initial results of the Survey provide evidence of natural reproduction of rainbow smelt American shad, and river herring (alewife and blueback) in the Penobscot. Goals for 2011 are to begin sampling in the spring at the onset of the adult rainbow smelt migration and continue through juvenile emigration. We anticipate that the most efficient gear to capture rainbow smelt will be large fyke nets positioned in the upper estuary to gather relative abundance of the adult spawning run in the spring and a combination of trawling and seining to develop abundance numbers for juvenile recruitment in the fall. These data are complementary to developing efforts by Maine Department of Marine Resources in the Penobscot and coastal Maine for rainbow smelt stock assessment and will serve to provide novel population level information to better manage this species of concern.

Poster-9. Improving methods to accurately age rainbow smelt (*Osmerus mordax*)

Enterline, Claire,*[1] Scott Elzey,[2] Jessica Fischer[3]
[1]*Maine Department of Marine Resources*
[2]*Massachusetts Division of Marine Fisheries*
[3]*New Hampshire Department of Fish and Game*
**Corresponding author:* Claire.Enterline@maine.gov

Various methods of cleaning and aging rainbow smelt (*Osmerus mordax*) scales, and of validating these ages, are examined to establish standard protocols. State fisheries managers in Massachusetts, New Hampshire, and Maine are working collaboratively to create mortality estimates for rainbow smelt to address concerns about population decline. Reference collections of scale images are being developed to determine accurate age-length keys for the species, as existing keys have been applicable only to small geographic areas or short time periods. Scales are cleaned using a 5% diluted solution of pancreatin to digest mucus followed by a 15 minute bath in a high-frequency sonic cleaner. Scales are viewed using the image analysis program Image Pro (V6.2) which drives a digital video camera mounted atop a dissecting microscope with transmitted lighting. Image Pro software and transmitted lighting enable enhancement of the image to emphasize true and false annuli. The accuracy of aging

rainbow smelt scales has yet to be validated. Validation of age one smelt can be accomplished by comparing otolith daily ring counts to scales. Older ages can be validated by oxytetracycline hydrochloride (OTC) marking during the spawning run at streams sampled annually. Validation of all ages is crucial to accurately determine mortality.

Poster-10. Out on the Ice – Sampling Maine's Recreational Winter Smelt Fishery on the Kennebec River and Merrymeeting Bay

Enterline, Claire,* Chris Uraneck
Maine Department of Marine Resources
**Corresponding author:* Claire.Enterline@maine.gov

Ice fishing on frozen tidal rivers is a long standing tradition in New England. In Maine, industrious entrepreneurs have made a seasonal business out of setting up hundreds of small ice-fishing shacks for recreational smelt fishing on the Kennebec River and Merrymeeting Bay. These fishing camps dominate fishing on the river. Although these shacks must acquire a state license each season, fishermen and camp owners are not required to report any of their catch information. Adopting sampling methods developed by the New Hampshire Department of Fish and Game, the Maine Department of Marine Resources began conducting creel surveys of these fishing camps in 2009. As part of this survey, we visited participating camps to collect biological information of the recreational catch multiple times a week. Staff measured smelt to the nearest millimeter, determined sex, and collected scale and fin clip samples. A sub-sample of adult smelt are collected for toxic contaminants analysis to update intake and health advisories. Comparing data for the two years of study, we have found that the mean catch per unit effort (CPUE) for all the sites declined from 2009 to 2010 but not significantly (2009 CPUE = 39.75; 2010 CPUE = 11.71; $p = 0.087$). The lack of statistical significance was likely due to a relatively small sample size. The mean length for both males and females increased significantly in 2010 from 2009, indicating a possible problem with a younger age class in 2010 (M 2009 mean length = 181.34; M 2010 mean length = 192.40; $p < 0.0001$; F 2009 mean length = 194.24; F 2010 mean length = 210.00; $p < 0.0001$). In both 2009 and 2010, the mean sex ratio was roughly even (2009 SR = 1.61M:1F; 2010 SR = 1.53M:1F). Catch Card boxes are also posted at each camp for fishermen to voluntarily report information about their total smelt catch and any bycatch. Catch Card responses varied widely between sites and between years. In 2009, the number of responses varied from 1 response for the entire year to 59. In 2010, we only received 6 responses from all the camps combined. The low response in 2010 was most likely due to anger about the new required Salt Water Fishing License, which was undergoing state public hearings during the fishing season. Despite the low number of responses in 2010, the Catch Cards still reflected a sharp and significant decline in catch from 2009 to 2010 (2009 mean catch = 118; 2010 mean catch = 45; $p = 0.012$). This trend was also evident in the creel survey data. We will continue to monitor the camps to understand more about inter-annual variability and changes in the population.