Assessing Silver Eels in Hudson River Tributaries

Final report to the Hudson River Foundation

Grant #005/13A

Karin E. Limburg

SUNY College of Environmental Science and Forestry
Syracuse, NY 13210

Robert E. Schmidt

Simon's Rock of Bard College
Great Barrington, MA 01230

July, 2017

SUMMARY

The goal of this project was to extend understanding of American eel (*Anguilla rostrata*) maturation processes, as well as further study of their use of Hudson River tributaries. In the benchmark assessment of American eel (ASMFC 2012), understanding and predicting the transition of eels to the silver stage (ready to migrate back to the Sargasso Sea to spawn) was an identified need. Our project addressed this. Originally, we posited the following hypotheses:

1. Eel maturation (silvering) is contingent upon reaching some minimum size AND some minimum fat content.
2. Silvering is only weakly correlated with eel age, although we expect to see sex-specific differences (Holmgren and Mosegaard 2005);
3. Silvering is affected by parasite burden, which reduces the functioning of the swimbladder vital to ocean migrations (Palstra et al. 2007) and by the presence of dams, which affects eel growth (Machut et al. 2007); and
4. Finally, parasite burden affects overall condition of eels, which is not well assessed with conventional methods, but is better assessed by fat content.

Objectives: Accordingly, we set out the following objectives:

1. Develop a predictive set of maturation metrics that will build off those developed for *Anguilla anguilla* by Caroline Durif and colleagues (Durif et al. 2005, 2009);
2. Complete the calibration of fat content analysis to its proxy measurement (bioelectrical impedance analysis, see below);
3. Test whether addition of fat assessment improves the prediction of maturation;
4. Test the relationship of eel fat content and *Anguillacoloides* parasite burden;
5. Quantify the numbers of emigrating silver eels in two tributaries, and identify these eels so that previously taken metrics can be used to develop probabilities of migration;
6. Apply these metrics to assess the likelihood of emigration of individual eels in other tributaries in the lower, middle, and upper parts of the estuary across a range of habitats that include both urban areas and areas with high incidence of dams.
7. Additionally, by analysis of otolith microchemistry, we will assess the prior migratory history of selected eels, and relate this to growth rate. This will shed insight into the importance of prior habitat use, i.e., the extent that eels used marine or estuarine vs. fresh water, on maturation.

Major findings:

- (Objective 1) A selection of external, morphological features (eye diameter, head length and width, body length and depth, pectoral fin length) could be used to classify eels into seven maturity clusters: silver females, 2 clusters of silver males, two clusters of maturing female yellow eels, and two clusters of undifferentiated yellow eels. In

particular, Pankhurst's eye index (eye area/total length x 100) and fin length/total length separated mature eels from other groupings.

  - Quadratic discriminant function analysis classified eels correctly to cluster 83% overall, with highest classification rates for Silver M1 (a mature male cluster) and Yellow 2 (an immature cluster). Larger sample size would likely reduce the error rate.
  - Eels caught later in the season (August, September, October) displayed greater frequency of mature or maturing characteristics.
  - There was general agreement with other schemes used to assess silver eel maturation (European eels, St. Lawrence eels), including the observation that Pankhurst's index alone tends to over-estimate % mature.

- (Objectives 1 and 3) Of internal characters examined, gut index (weight of the GI tract) was inversely correlated with external characters, gonadosomatic index (GSI) positively correlated, and fat content was highly variable.
- (Objective 2) Bioelectrical impedance analysis (BIA), a means to measure fat and proximate composition in humans, has been explored for use in fishes. In our project, BIA was exhaustively tested with different probe types. During the course of our study, the manufacturer came out with some new electrode designs which we tested. Our best results were obtained with pressure electrodes that did not require skin penetration. These would be recommended on the basis of least disturbance to the animal and most consistency in readings.
  - BIA metrics were highly correlated to eel water content. Fat content was measured by lipid extraction. Fat content as percent of wet weight was inversely correlated with water content (% Lipid = $0.025X^2 – 4.63X + 212.85$, X = % water content, $R^2 = 0.92$).
  - Fulton's condition index was significantly related to % extracted lipid.
  - We concluded that water content may be a simpler, more direct method to assess fatness, and that simple measurements of eel density (e.g., by measuring displacement of water) could be a cost-effective alternative to lipid extraction and/or BIA.
- (Objective 6) Eels were studied in six Hudson River tributaries: Minisceongo (lower estuary), Black Creek, Fall Kill, Crum Elbow Kill, Indian Kill (mid-estuary), and Vlockie Kill (upper estuary). Eels were sampled below and above the first dam; eel densities were an order of magnitude less above the dams than below, but eel lengths were greater above the dams. This is in agreement with findings of our previous study (Machut et al. 2007). Burdens of the swim bladder parasite *Anguillicolloides crassus* were quantified and were examined as a function of land use characteristics, since Machut and Limburg (2008) found that urban areas had greater incidence of parasites. Prevalence (percent occurrence of parasites) increased since Machut's study, from a mean of 39% in 2004-05 to 65% ± 17.6% s.d. This was anticipated by Machut, as the infection was in its early stages in tributaries at the time of his Master's project. In contrast to Machut and Limburg (2008), we currently found higher prevalence in more forested watersheds. It is

possible that more forested watersheds have more intact food webs, and thus may have more available intermediate hosts.

- (Objective 7) Otoliths were analyzed from 53 individuals. A suite of trace elements (Mg, Mn, Cu, Zn, Sr, Ba, and Pb) were analyzed in relation to calcium (the dominant element in otolith aragonite).
    - Sr:Ca ratios can be used to identify freshwater vs. brackish habitat in Hudson River eels (Morrison et al. 2003); following Morrison et al.'s threshold for Sr:Ca corresponding to freshwater habitat (Sr:Ca < 0.002), all eels moved rapidly from marine areas into fresh water.
    - However, differences in uptake patterns of the trace element barium suggested that eels may be using different within-Hudson environments prior to settling in the tributaries where they were ultimately caught.
    - Multivariate analyses of Element:Ca ratios on the outer edges of the otoliths (100-micron and 200-micron) could separate fish by tributary; moreover, they could be classified to tributary with 100% accuracy.

Recommendations:

- Adopt the external characters for classifying eels by maturity class;
- Conduct maturation surveys in September and October;
- Explore the use of eel density as a proxy for fat content;
- Monitor tributary populations for *Anguillicolloides*, in particular contrasting forested vs. urbanized watersheds;
- The potential exists to use otolith trace elemental microchemistry to identify silver eels back to tributary, if a database of such chemistry were to be constructed.

Durif, C., P. Elie, C. Gosset, J. Rives, and F. Travade. 2003. Behavioral study of downstream migrating eels by radio-telemetry at a small hydroelectric power plant. In Biology, Management, and Protection of Catadromous Eels (Dixon, D. A., eds.), pp. 343–356. Bethesda, MD: American Fisheries Society, Symposium 33.

Durif, C., S. Dufour, and P. Elie. 2005. The silvering process of *Anguilla anguilla*: a new classification from the yellow resident to the silver migrating stage. Journal of Fish Biology 66: 1025-1043.

Holmgren, K., and H. Mosegaard. 2005. Implications of individual growth status on the future sex of the European eel. Journal of Fish Biology 49: 910-925.

Machut, L.S., K.E. Limburg, R. E. Schmidt, and D. Dittman. 2007. Anthropogenic impacts on American eel demographics in Hudson River tributaries, New York. Transactions of the American Fisheries Society 136: 1699-1713.

Machut, L.S. and K.E. Limburg. 2008. *Anguillacoloides crassus* infection in *Anguilla rostrata* from small tributaries of the Hudson River watershed, New York, USA. Diseases of Aquatic Organisms 79: 37-45.

Morrison, W.E., D.H. Secor, and P.M. Piccoli. 2003. Estuarine habitat use by Hudson River American eels as determined by otolith strontium:calcium ratios, p. 87-99 In Biology, Management, and Protection of Catadromous Eels (D.W. Dixon, ed.). American Fisheries Society Symposium 33.

Palstra, A.P., D.F.M. Heppener, V.J.T. van Ginneken, C. Székely, and G.E.E.J.M. van den Thillart. 2007. Swimming performance of silver eels is severely impaired by the swim-bladder parasite *Anguillicola crassus*. Journal of Experimental Marine Biology and Ecology 352: 244-256.

OUTCOMES

Student Thesis

Mount, Sarah J. 2016. *Searching for silver: an examination of the physical and environmental characteristics of maturing silver eels*. M.Sc. thesis, SUNY College of Environmental Science and Forestry, Syracuse, NY. 171 pp.

Publications

In preparation: Mount, S.M., K.E. Limburg, R.E. Schmidt, and C.H. Bowser. In prep. Biological aspects of silvering American eel in Hudson River tributaries.

Oral Presentations

Mount, S.J., K.E. Limburg, R.E. Schmidt, and C.H. Bowser. The development of a non-lethal maturity index for American eels. Presented at the 144th Annual Meeting of the American Fisheries Society, Quebec City, August 2014.

Limburg, K.E., S.J. Mount, C.H. Bowser, and R.E. Schmidt. American eels in the Hudson River estuary: from glass to silver. Edward Ames Lecture Series, Hudson River Foundation, May 2017.

Mount, S.J., K.E. Limburg, R.E. Schmidt, and C.H. Bowser. The development of a non-lethal maturity index for American eels. Presented at the 1st UK International Eel Science Symposium, June 13-15, London, U.K.

Poster presentations

Mount, S.J., K.E. Limburg, R.E. Schmidt, and C.H.Bowser. The development of a non-lethal maturity index for American eels. New York Chapter Meeting of the American Fisheries Society, Geneva, NY, February 2014.

Mount, S.J., K.E. Limburg, R.E. Schmidt, and C.H.Bowser. The development of a non-lethal maturity index for American eels. SUNY Senate Research Conference, Albany, NY, February 2015.

Extensions and Collaborations

Research on eels at the main study site, the Indian Kill in Staatsburg, has continued as part of education efforts at the Hudson River National Estuarine Research Reserve. Teams of college and high school students assist in electrofishing surveys and fyke netting to continue the assessment of eel maturity, growth, and movement in this stream. Thus, our project has "spawned" continued interest, education, research, and monitoring in what may now be considered a sentinel stream for silver eels in the Hudson River estuary.

Photo Gallery

Checking the fyke net for eels in the fall.

Checking an eel for the presence of a PIT tag.

Poughkeepsie High School students catching eels to be PIT tagged.

Poughkeepsie Day School student holding a male silver eel caught in the fyke net.

A male eel with enlarged eyes and expanded head. He is about to become a silver phase eel.