CONNECTICUT SEA GRANT PROJECT REPORT

Name of Submitter: Eric Schultz

Date of Report submission: 9 June 2023

Project #: EPA - Long Island Sound Study / Sea Grant New York / Sea Grant Connecticut R/FBF-25-CTNY, EPA Award LI-00A00284
Final report

Duration (dates) of entire project, including extensions: From [1 March 2021] to [28 February 2023].

Project Title or Topic: Can They Get Out? Assessing Effects of Low Streamflow on Juvenile River Herring Outmigration

Principal Investigator(s) and Affiliation(s):

1. Eric Schultz, Ecology and Evolutionary Biology, University of Connecticut

2. James Knighton, Natural Resources and Environment, University of Connecticut

3. Cary Chadwick, Extension, University of Connecticut

A. COLLABORATORS AND PARTNERS:

B. PROJECT GOALS AND OBJECTIVES:

This project aims to quantify the lost opportunity for out-migration suffered by juvenile river herring leaving nursery habitat for Long Island Sound (LIS), identifying spatially-varying risk factors that can guide management to improve habitat connectivity. The project objectives are to:

1. Profile land cover, water use, hydrology and geospatial characteristics of Connecticut's (CT's) river herring migrations (runs);
2. Construct and calibrate a hydrological model of CT's river herring runs;
3. Characterize the timing of juvenile outmigration and its dependence on stream discharge;
4. Develop an interactive tool that quantifies risk of connectivity loss at river herring runs, enabling vulnerability assessment and decision-making;
5. Inform stakeholders on river herring vulnerability to low flows.

C. LISS CCMP IMPLEMENTATION ACTIONS:

Implementation Action HW-4: By 2024, agree upon an applicable habitat connectivity model and apply metrics for all restoration and protection projects.
Implementation Action: HW-16: Collect and analyze data on, and restore habitat for, Species of Greatest Conservation Need, including forage species.

D. PROGRESS:

Work on objectives commenced once the project team received an approved Quality Assurance Plan, on 7 December 2021. Prior to that date, supplies had been ordered and personnel to assist the PIs had been identified.

Progress on Objective 1:

We compiled land use (i.e. land cover type), topography, soil textures, and meteorological conditions for four of five target river herring runs (Bride, Pattagansett, Whitford, and Branford; we did not do so for Fishing Brook as explained below). These data are stored in SWAT+ database formats and are available for visualization within the QGIS environment. We also performed two years of hydrologic monitoring at these site.

Progress on Objective 2:

We developed SWAT+ models of each of the four sites listed above (we could not find a suitable placement for a pressure transducer at Fishing Brook) using publicly available data. Each model was compared to observed streamflow data (collected in objective 1) as a validation check on the water mass balance.

Progress on Objective 3:

We designed and deployed an outmigration monitoring system using time-lapse photography. Details of the design and the history of its development were provided in the January 2022 progress report. We deployed the system in 2022 at four of five target river herring runs (Bride, Fishing Brook, Pattagansett, Whitford; the run at Branford has apparently failed). We also deployed the system at an additional site, Black Hall Pond, upon realizing that an experiment in Alewife run restoration had begun there.

Data collection from the images is nearly complete, enabling us to profile the temporal distribution of emigration at several sites, while at others we detected no outmigrating juveniles.

For a several-day period of sustained emigration we deployed a video camera in parallel with the time-lapse photography setup. We will use the comparison of fish counts for the two systems as a means of calibrating the time-lapse system readings of emigration.

A prolonged drought in summer 2022 enabled estimation of minimum flows permitting outmigration. We used the calibrated SWAT+ models to develop Random Forest (RF) classification models to predict the probability of migration loss at each of the sites given current-day hydrometeorological variables.

Progress on Objective 4:

The RF models are being integrated into a website to support water manager predictions of outmigration loss. This work is nearly complete for public release.

Progress on Objective 5:

Planning for workshops and discussions with stakeholders is underway.

E. PROJECT PUBLICATIONS, PRODUCTS, PRESENTATIONS AND PATENTS:

Journal Articles:

King, K., Burgess, M., Schultz, E., Knighton, J. (In Revision). Forecasting Juvenile River Herring Out-Migration Loss with Process-Based Hydrologic Modeling and Machine Learning. *Journal of Environmental Management.*

Publications planned / in progress:

We expect M. Burgess's MS Thesis to yield two papers, which will be submitted in late 2023 or early 2024.

Presentations and Posters:

King, K., Burgess, M., Schultz, E., (2022, December 2). Can They Get Out? Loss of Connectivity for Juvenile Alewives Out-Migrating to Long Island Sound [Remote live presentation]. Long Island Sound Study STAC Committee.

King, K., Burgess, M., Schultz, E., Knighton, J. (2022, December 12). A Watershed Management Decision-Support Tool to Predict Juvenile Herring Out-Migration Loss Using a Process-Based Hydrologic Model [Conference presentation]. American Geophysical Union Annual Meeting, Chicago, IL, United States.

King, K., Burgess, M., Schultz, E., Knighton, J. (2023, January 9). A Watershed Management Decision-Support Tool to Predict Juvenile Herring Out-Migration Loss Using a Process-Based Hydrologic Model [Conference presentation]. SNEC-NED-AFS Joint Meeting, Boston, MA, United States.

King, K., Burgess, M., Schultz, E., Knighton, J. (2023, February 16). Predicting Out-Migration Loss of Juvenile Herring Using a Process-Based Hydrologic Model to Inform Watershed Management Decisions [Conference presentation]. Northeast Aquatic Biologist Conference, Plymouth, MA, United States.

Burgess, M., Schultz, E., Knighton, J., King, K., Adams, R. (2023, January 9). Characterizing the Timing of Juvenile Alewife Outmigration Using Time Lapse Photography: I'll Be Watching You! [Conference poster]. SNEC-NED-AFS Joint Meeting, Boston, MA, United States.

F. FUNDS LEVERAGED:

We received funding of $146,678 from the Foster Davis Foundation (information not to be disseminated as the foundation wishes to remain anonymous).

G. STUDENTS:

Total number of **new** undergraduates who worked with you: 1

Total number of **new** Masters degree candidates who worked with you: 2

Graduate students:

Michael Burgess, M.S., Title of thesis pending; expected date of thesis completion and graduation: August 2023

Katherine King, M.S., Forecasting Hydrologic Controls on Juvenile Anadromous Fish Out-Migration with Process-Based Modeling and Machine Learning; thesis completion and graduation in May 2023

H. VOLUNTEER HOURS:

Nine undergraduate students (one of whom is also listed above because he was paid during the summer as a field assistant) earned independent study credits, for a total of 673 hours over one academic year. They reviewed images recovered from the time-lapse photography setup (millions of images) and recorded data on fish presence or absence.

I. PICTORIAL: Images attached as separate files.

J. HONORS AND AWARDS:

a) Name of person or group receiving recognition: Eric T. Schultz
b) Name of award or honor: 2022 American Fisheries Society Northeast Division Dwight A. Webster Memorial Award
c) Group or individual bestowing the award or honor: Northeastern Division, American Fisheries Society
d) What it was for: lifelong contributions to fisheries science and the profession in the Northeast, meritorious/prestigious service to the profession and fisheries, significant academic or technical accomplishments and long-term service in the Northeastern Division as an AFS member.
e) Date: January 10, 2023

K. DATA MANAGEMENT PLANS: Proposals funded in 2014-2016 and later cycles are required to have a data management plan in place. All environmental data and information collected and/or created must be made visible, accessible, and independently understandable to general users, free of charge or at minimal cost, in a timely manner (typically no later than two years after the data are collected or created). This is a reminder that your CTSG funded research data needs to be archived and accessible as outlined in the data management plan you submitted with your proposal. If there have been any modifications, adjustments or new information available regarding the location, timing, type, formatting and metadata standards, content, sharing, stewardship, archiving, accessibility, publication or security of the data produced please elaborate here.

L. PROJECT OUTCOMES AND IMPACTS:

RELEVANCE OF PROJECT:

Populations of anadromous Alewife and Blueback Herring (collectively, river herring) have been greatly impacted by loss of connectivity to freshwater habitats due to dams and other anthropogenic barriers. The magnitude of the decline and its impact on marine ecosystems spurred official recognition that concerted attention should be devoted to stressors on river herring populations and opportunities for restoration. Indeed, considerable resources have been put into restoring fish passage for upstream migration of adults. In contrast, barriers to out-migration of juvenile river herring have been largely overlooked. Of particular importance, low flows during summer and fall can prevent successful migration to the ocean at critical times, restricting the export of forage fish biomass to marine habitats. This project aimed to quantify the lost opportunity for out-migration suffered by juvenile river herring leaving nursery habitat for Long Island Sound (LIS), identifying spatially-varying risk factors that can guide management to improve habitat connectivity.

RESPONSE:

We conducted hydrological modeling of watersheds and biological sampling via time-lapse photography; in combination the separate data streams provided unparalleled insight into how rainfall and local conditions interact to affect flow in small watersheds in which

juvenile river herring are born and from which they leave for the ocean. We employed machine learning to predict the probability that connectivity would be lost for outmigrant river herring in multiple sites, conditional on recent meteorological conditions. The target audiences for this work include resource managers, municipalities and land owners, and fisheries scientists concerned with population dynamics of resource species, particularly those that migrate through lotic habitats.

RESULTS:

The project yielded innovative applications of physical and digital technology. The use of time-lapse photography to monitor migration is unique and should provide a new tool for biologists and researchers who are concerned with population processes of migratory fishes (and potentially other organisms in lotic habitats). The application of machine learning to predict the probability that migration will be disrupted is also innovative. Both of these innovations are being received with great interest among professional groups.

The project has advanced public understanding of river herring and the dependence of these species on connections between fresh water habitats and Long Island Sound. Our project was featured in article in UConn Today, The Travails of an Alewife: Dams, Drought, and Climate Change on October 18, 2022. Should drought conditions recur (and indications are developing of a second summer of drought this year), we will alert Connecticut print and other media of the likely inability of juvenile river herring to migrate out of their natal ponds.

Publication and other outreach are continuing beyond the close date for the LISS grant, because of leveraged funds that remain. We expect to conduct trainings and workshops for resource managers, prepare a story map for public use, and prepare a database and online portal for users to recover the history of each river herring run and efforts to restore it, in association with local physiographic and biotic features. Such efforts will substantially enhance the information resources on Connecticut's diadromous fishes.

We hope that this project will help to sustain and enhance river herring populations, by highlighting the benefits of wise water management. We have directly observed how juvenile Alewives can be blocked in their efforts to continue their life cycle, and indeed how many can die when the stream they are using to emigrate dries up around them. We are working to inform municipal water managers and town planners whose decisions affect the flows on which these species depend.

J. Stakeholder Summary:

Anadromous fish, migratory species spend their adult lives in marine environments and spawn in freshwater, need aquatic connection and humans are making it hard to meet this need. Streams that provide passage between marine and freshwater spawning habitats are critical to completion of these species' life cycles. This requirement for continuity and connection has made anadromous fishes exceptionally vulnerable to changes that humans have made to flowing waters. Perhaps the most familiar of these human-imposed changes to flowing waters is dams. Dams represent an obvious and well-documented impediment to the population viability of fishes such as trout and salmon, sturgeon, and shad, and considerable resources are now invested in helping adult anadromous fish migrate upstream to spawn, through construction of fish passage and, increasingly, outright dam

removal. Such resources are poorly spent if the juvenile fish spawned by these adults are unable to pass from freshwater habitats to the sea. Unfortunately, when droughts occur such losses of migratory passage can occur, and drought events are expected occur more frequently and for extended periods in the future as a result of climate change. This raises the question addressed by this project: can the young fish get out when they need to? This project involved collaboration between hydrologists who investigate the factors affecting water flow, and fish biologists who study fish movement. They monitored conditions during the summer of 2022, when a drought substantially impaired juvenile fish outmigration, essentially bottling up young fish in ponds at a time when they would otherwise be in Long Island Sound. Information gathered during that season enabled them to develop the ability to predict when it will happen again based on weather patterns. The ability to predict connection loss has been incorporated into an online tool that can readily be employed by members of the public and by resource managers, so that measures to protect migratory routes might be taken.