



**Reference SON:** *SON 2020-1227*

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### **Project Development**

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**Other Partners:** *Katie Irving (SCCWRP), Kate Buenau (PNNL), Jeff Janvrin (WI-DNR), Nicole Ward (MN-DNR), Charles Yackulic, Jeff Hauser (USGS), Thomas Archdeacon (USFWS), Mike Hatch (NM State Univ), Phaedra Budy (Utah State), Lynette Gieson (USBR), Eric Gonzales (USBR), Cait Rottler (West Consulting)*

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**Keywords:** *ecological models, population modeling, agent-based models, machine learning*

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## **Emerging approaches for USACE Ecological Modeling**

### **Research Need**

USACE projects directly influence a diversity of ecological outcomes such as restoration of habitat, impacts to imperiled species populations, movement of migratory organisms, and nutrient dynamics. However, assessments of ecological outcomes typically focus on habitat impacts and benefits (often with 30–40-year-old USFWS “blue book” models). Although habitat models are useful in many contexts and applications, ecological modeling methods have grown to include dozens of approaches that could improve USACE project outcomes from planning through operation. Specifically, these tools often more directly measure project objectives and may improve communication regarding restoration benefits. This study examines a variety of ecological modeling approaches that would help USACE improve decision-making and better “tell the story” of its restoration programs.

### **Project Purpose & Objectives**

This project will compile and demonstrate ecological modeling tools in the context of USACE studies and actions, specifically:

- Provide recommendations that may improve the use of ecological models in project planning
- Review key modeling approaches and demonstrate techniques with ongoing USACE restoration projects.
- Provide advanced ecological modeling training.

### **Value of Research and Development (Payoff)**

The USACE state-of-practice for ecological models undeniably emphasizes habitat models applied in a static environment with traditional approaches for documentation. This project looks to provide recommendations to improve ecological modeling practices within USACE, provides concrete examples of applications of these tools, and gives USACE practitioners guidance on application of novel methods and techniques. The study not only develops methods that may improve USACE modeling but also provides methods for more directly

measuring ecological outcomes associated with USACE projects.

## Products and Deliverables

### Journal Articles (JAs)

Irving K., R. Mathwin, C. Kotalik, J.A. Webb, D.M. Walters, S.E. Lovett, S.K. McKay, C. Torrens, J. Olson, and El Z. Jack. Adaptive modeling to inform environmental management. Submitted to *Frontiers in Ecology and the Environment*.

Quintana, V.M., J. Galaitsi, A. Jacobs, A. DuPuy, S.K. McKay, K. Huguenard, and T. Swannack. 2024. *Weaving Traditional Ecological Knowledge into Ecological Modeling*. Manuscript in preparation.

Quintana, V.M. *Journal Paper: Participatory Science from Workshop*. (Manuscript 50% drafted; anticipated FY26)

Stowe, S.G. 2025. *Rio Grande Silvery Minnow Recruitment Model*. (Manuscript drafted; anticipated FY26)

Stowe, E. Machine Learning for Ecological Modeling: Upper Mississippi River Restoration Case-Study. (anticipated FY26)

### Technical Reports

Stowe, S.G., D.D. Hernandez-Abrams, A.E. Harris, T.M. Swannack, K.E. Buenau, K. Irving, S. Jumani, M.D. Porter, V.M. Quintana, M.P. Dougherty, K.N.S. McCain, K.R. Runyon, D.L. Smith, and S.K. McKay. *Exploring the Application of Novel Ecological Modeling Approaches and a Path to Future USACE Practice: RoadMap*. Technical Report. U.S. Army Engineer Research and Development Center, Vicksburg MS. In management review.

Quintana, V.M., K. Huguenard, J. Stevens, J. Galaitsi, A. Jacobs, and S.K. McKay. 2024. *River Herring Habitat in the Eastern United States*. In preparation.

### Other Reports/Models/Tools/Datasets

McKay, S.K., D.D. Hernández-Abrams, and K.C. Cushway. *Package 'ecorest'*. Version 2.0.1. CRAN Reference Manual, 2025.

Stowe, E., D.D. Hernández-Abrams, A.E. Harris, T.M. Swannack, and S.K. McKay. 2024. *Emerging Ecological Modeling Approaches to Benefit USACE Projects*. White paper. U.S. Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory.

## *Models*

2D Hydraulic models for San Acacia, Isleta and Angostura Rio Grande reaches. Model purpose: outcomes used for hydrological and flow augmentation scenarios in Silvery Minnow Population model. Hydraulic models lead by Harris. (100% completed; certification not required)

*Stowe, E. 2025. Rio Grande Silvery Minnow Recruitment/Population Model.* Model purpose: to estimate Rio Grande Silvery Minnow recruitment under different hydrologic, restoration and management scenarios. (100% completed; not certified)

Quintana, V. Habitat model: Contamination Risk Across Anadromous Fish Life Stages (100% completed; not certified)

Quintana, V. Habitat model: River Herring. (90% completed)

Quintana, V. Agent-Based Model: Anadromous Fish Mercury Exposure Pathways. (50% completed)

Quintana, V. Github/Netlogo model library Anadromous Fish Behaviors and Processes (50% completed)

## *Interactive Modeling Web-tools*

Quintana, Vanessa, Katie Huguenard, John Stevens, James Galaitsi, Andrew Jacobs, and Kyle McKay. *River Herring Ecological Modeling*. Shiny web application (Under THPO review).

*Stowe, S. G. 2025. Rio Grande Silvery Minnow Recruitment Model.* Shiny web application. <https://wrises.shinyapps.io/rqsm-recruit/>

## *Online Training Material*

Quintana, Vanessa. 2025. *GitHub Skill Building Tutorials for Students & Researchers.* <https://usace-wrises.github.io/USACE.EcoMod.Training/>

Stowe, S. G. 2025. *USACE Ecological Modeling Training.* <https://usace-wrises.github.io/USACE.EcoMod.Training/>

## Conference Presentations/Webinars/Workshops/Demos

Emerging Modeling Approaches and the USACE. 2023. Workshop, ERDC, Vicksburg, MS

Quintana, V. 2025. River Herring Population Model: Developing ecological models for adaptive management in Aquinnah, Martha's Vineyard. EMRRP Webinar.

Quintana, V. 2025. Agent-Based Modeling Workshop. University of Maine.

Stowe, E. 2024. Rio Grande Fish Modeling: Integrating hydraulic analyses and population models to predict ecological effects of floodplain restoration for the Rio Grande Silvery Minnow. EMRRP Webinar.

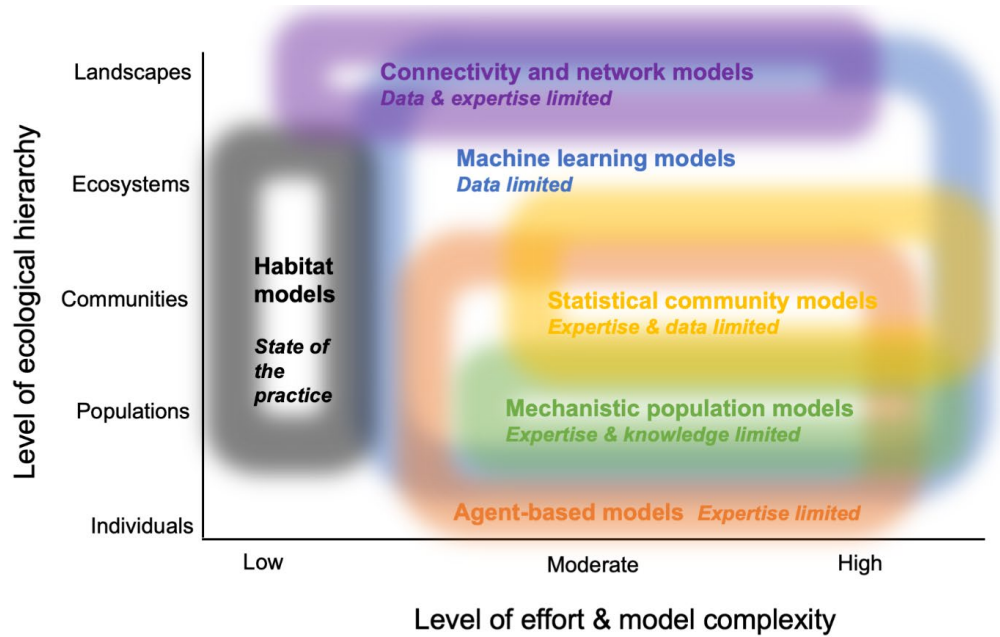
Stowe, E. Machine Learning for Ecological Modeling: Upper Mississippi River Restoration Case-Study. EMRRP Webinar (anticipated FY 2026).

Stowe, E. Machine Learning for Ecological Modeling: Upper Mississippi River Restoration Case-Study. Demo (anticipated FY 2026; 75% completed; practice run demonstrated to WRISES Team Oct FY26).

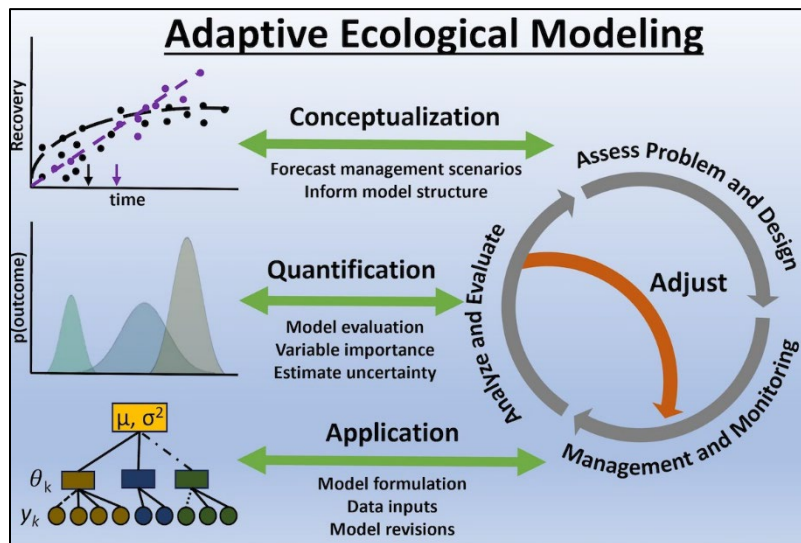
## Images



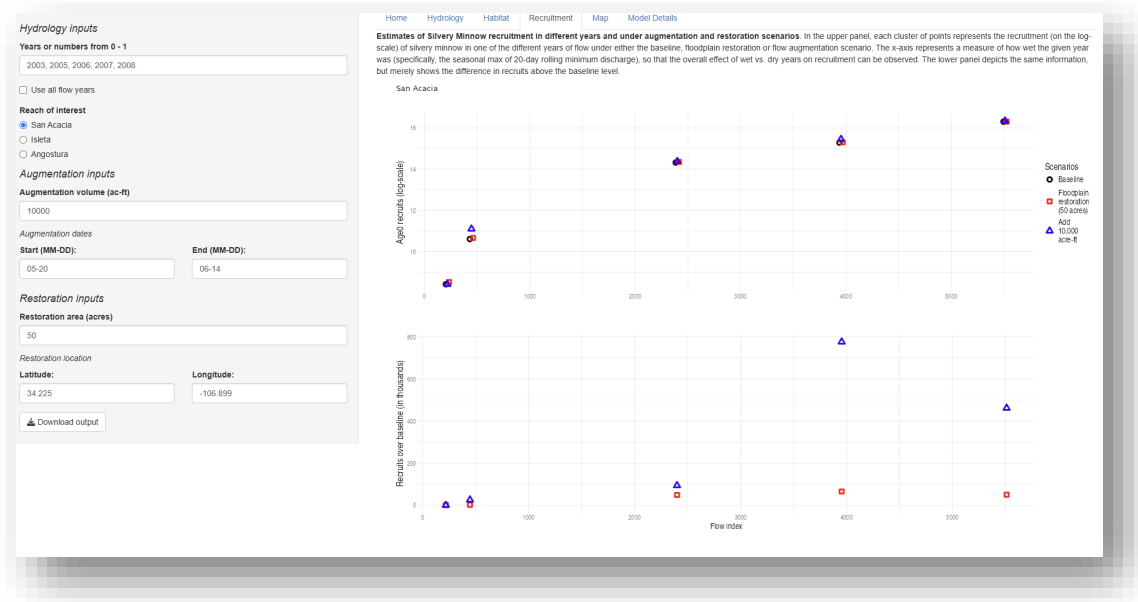
Virtual and in-person workshop participants discussing topics on advancing ecological modeling in September 2023 in Vicksburg, MS. Attendees (grouped by affiliation): Darixa Hernandez-Abrams, Kyle McKay, Aubrey Harris, Todd Swannack, Christina Saltus, Samantha Wiest, David Smith (ERDC-EL), Kip Runyon, Kat McCain (ECO-PCX), Edward Stowe, Suman Jumani, Vanessa Mahan, Rosamar Ayala, Nina Zamani (ORISE), Katie Irving (SCCWRP), Kate Buenau (PNNL), Jesse Ray (Rock Island), Mick Porter (Albuquerque), Jesse Miller (New York), Michael Dougherty (Rock Island), and Angie Sowers (Baltimore).



Families of ecological models arrayed relative to levels of effort and points in an ecological hierarchy (from Stowe et al. in review).



Conceptual model showing the integration of adaptive ecological modeling throughout the adaptive management cycle (from Irving et al. 2025).



Rio Grande Silvery Minnow Recruitment Tool Shiny App (<https://wises.shinyapps.io/rgsm-recruit/>)

Using R for ecological modeling in USACE

Search

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**Course overview**

Required set-up for the course

Basic Training on R and RStudio

- 1 Introduction to R and RStudio
- 2 Data Visualization with ggplot2
- 3 Exploring and understanding data
- 4 Manipulating Tabular Data

Ecological Modeling in R

- 5 Conceptual Ecological Models
- 6 Background on habitat models in USACE
- 7 Habitat Suitability Index models with ecorest
- 8 Ecorest Web App
- 9 Sensitivity and uncertainty analysis for habitat suitability index (HSI) models
- 10 Spatial Habitat Models

Linear Models

- 11 Linear Models
- 12 Generalized Linear Models
- 13 Random Effects

## Course overview

### Motivation

Ecological modeling within USACE is primarily a spreadsheet-based activity featuring deterministic habitat models. However, the ecological modeling capacity of USACE biologists can be greatly improved by incorporating modern data science practices, especially the uptake of R, a programming language that is used in the majority of ecological research being conducted today. R promotes research that is well-documented, reproducible, interdisciplinary, and extensible. This course works on all kinds of data, is easy to learn, and is supported by a large community of users, and is designed to help you teach USACE biologists and other practitioners how to use R for ecological modeling.

### Intended audience

- Modeling experience: Those considering themselves "modelers" on projects, with some familiarity with ecological modeling, or wanting to expand their modeling toolbox. Those open to learning how to use code.
- Career trajectory: USACE biologists and geospatial analysts; this course may also benefit ecological/environmental engineers.
- Institutional context: USACE team members; partners working closely with USACE.
- Pre-requisites: None! Although some familiarity with ecological models and how to use spreadsheets for numerical analyses is required.

### Learning objectives

- Become familiar with R coding basics, the RStudio environment, and the benefits of using R for conducting analyses.

## 2 Data Visualization with ggplot2

This module will teach you how to use the `ggplot2` package in R to efficiently generate customizable and complex plots like this:

## 9 Sensitivity and uncertainty analysis for habitat suitability index (HSI) models

This module will teach you how to assess the sensitivity and uncertainty of HSI models using the `sensobol` package in R.

Graphical output of a sensitivity analysis using `sensobol`.

Authors: Kiana Cushman, Ed Stone, Todd Swannack, Kyle McKay  
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Ecological modeling training hub <https://usace-wises.github.io/USACE.EcoMod.Training/>