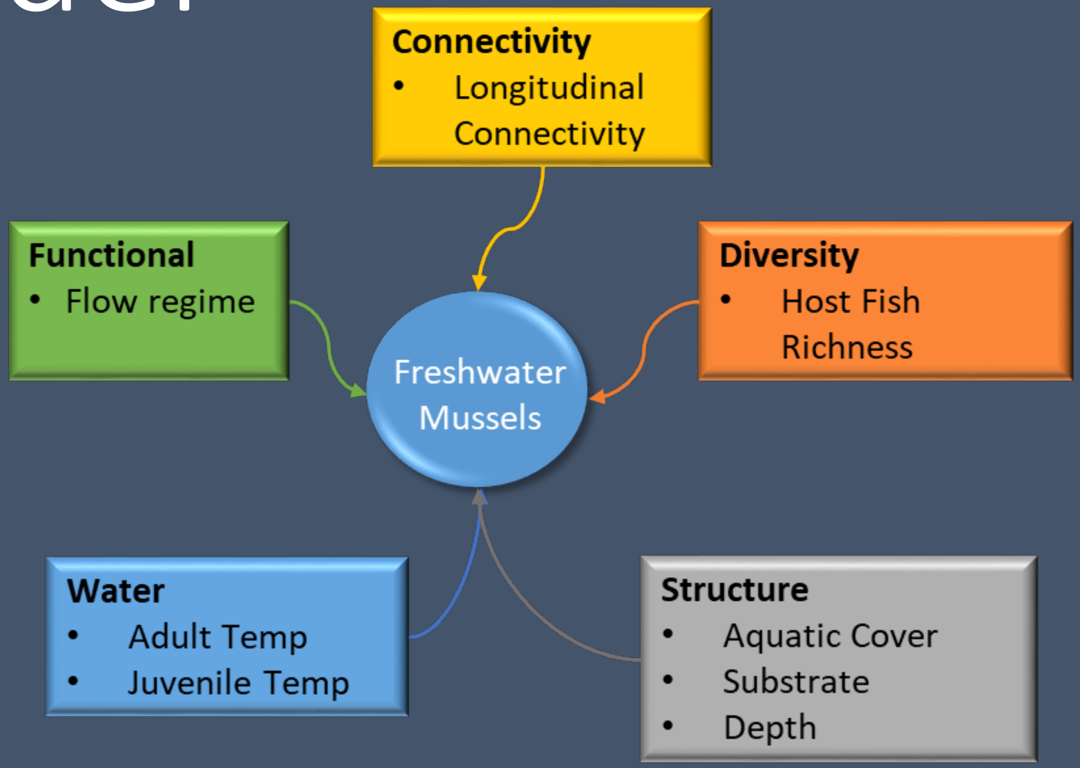
Overview of the Development of the General Freshwater Mussel Habitat Model

EMRRP Webinar

Dr. Todd Slack

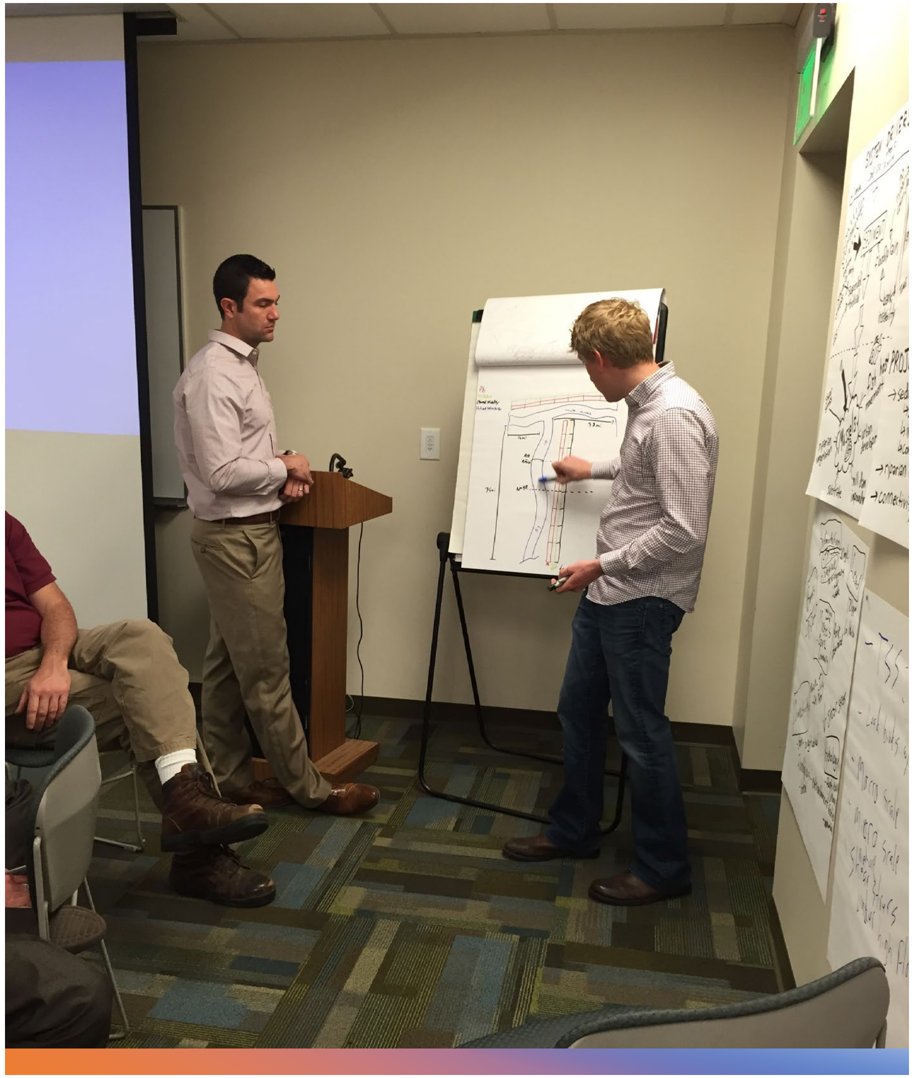
Dr. Brook Herman

February 7, 2024



Outline

- Review of Mussel Life History & Environmental Requisites
- Model Development Team
- Objectives
- Timeline
- Development
- Testing & Case Study

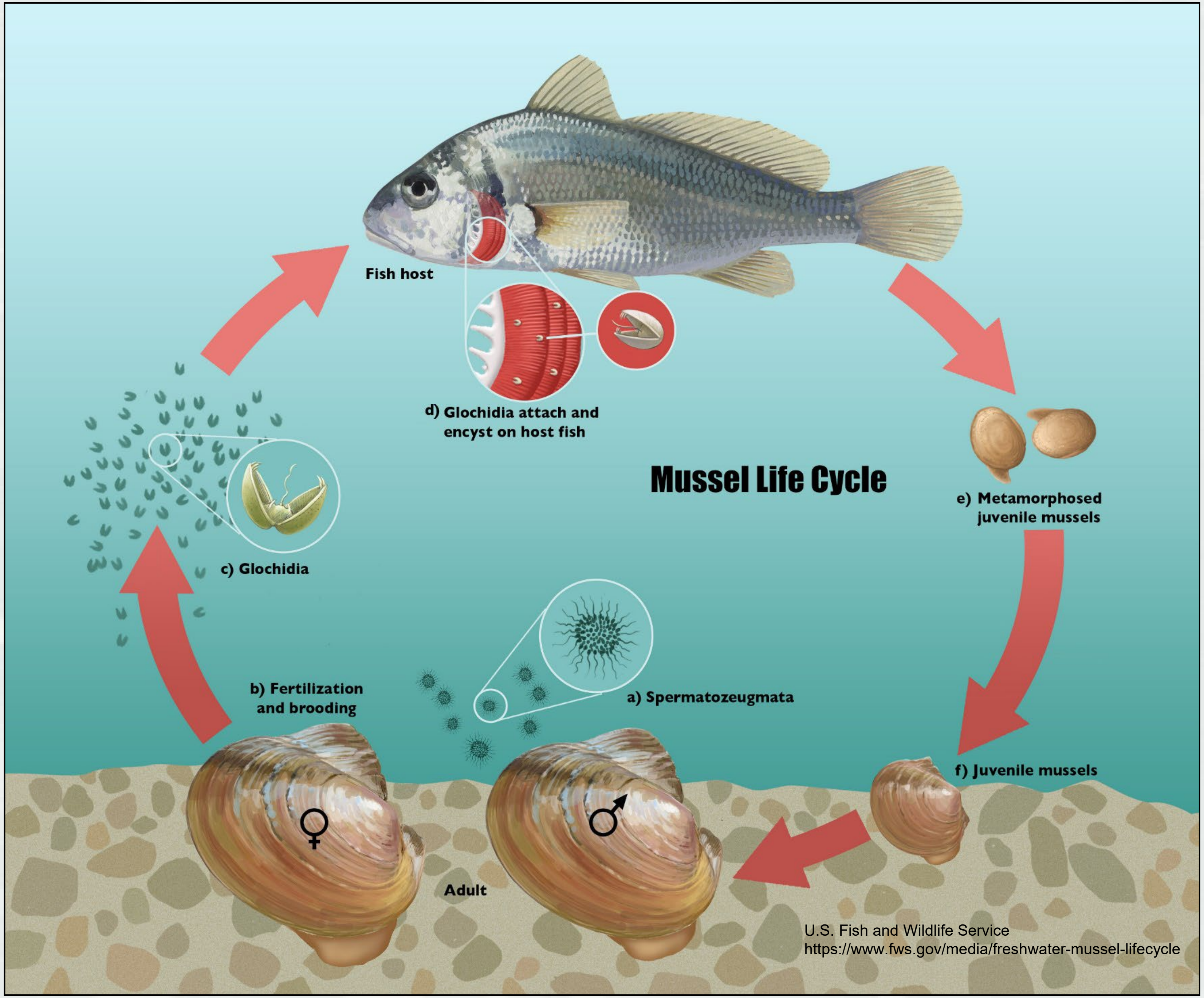


Importance

- Nearly 300 species within USA
- SE region highest species richness
- Mississippi ranks 5th

Ecological attributes

- excellent indicators of water quality
- provide important ecosystem services
- indicative of stable substrate
- stable position (degree of mobility: vertical/horizontal)
- sessile
- generally long-lived
- long-term trend (IBI)


Mussel Life Cycle
Fish host
d) Glochidia attach and encyst on host fish
e) Metamorphosed juvenile mussels
f) Juvenile mussels
Adult
a) Spermatozeugmata
b) Fertilization and brooding
c) Glochidia
U.S. Fish and Wildlife Service
https://www.fws.gov/media/freshwater-mussel-lifecycle

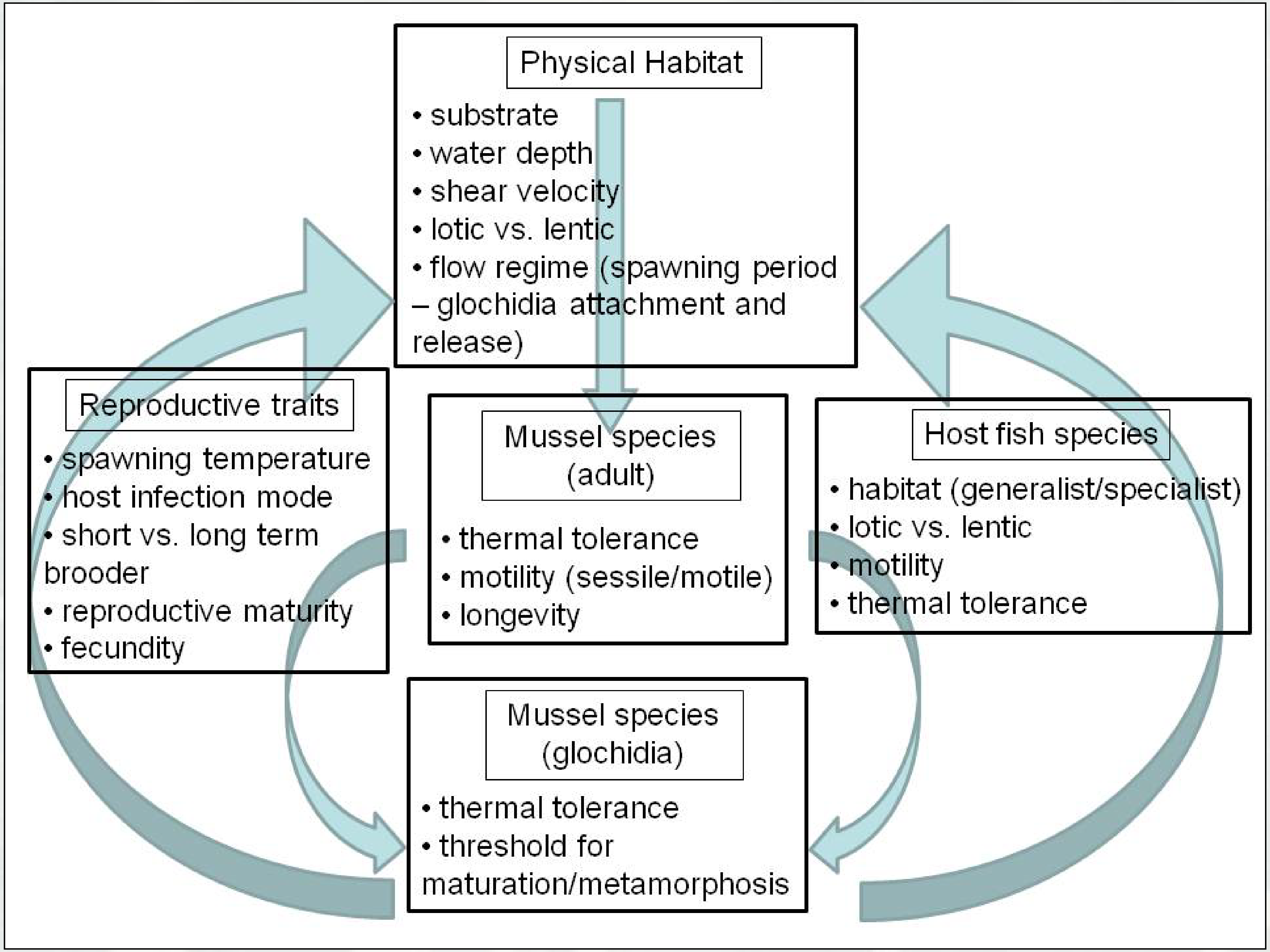
Mantle luring species

Louisiana fatmucket (*Lampsilis hydiana)*

Plain pocketbook (*Lampsilis cardium)*

Fatmucket (*Lampsilis siliquoidea*)

Obermeyer, B.K, E.J. Miller and M.C. Barnhart. 2006. Life History of Kansas Freshwater Mussels. The Kansas School Naturalist 53(2):1-15.

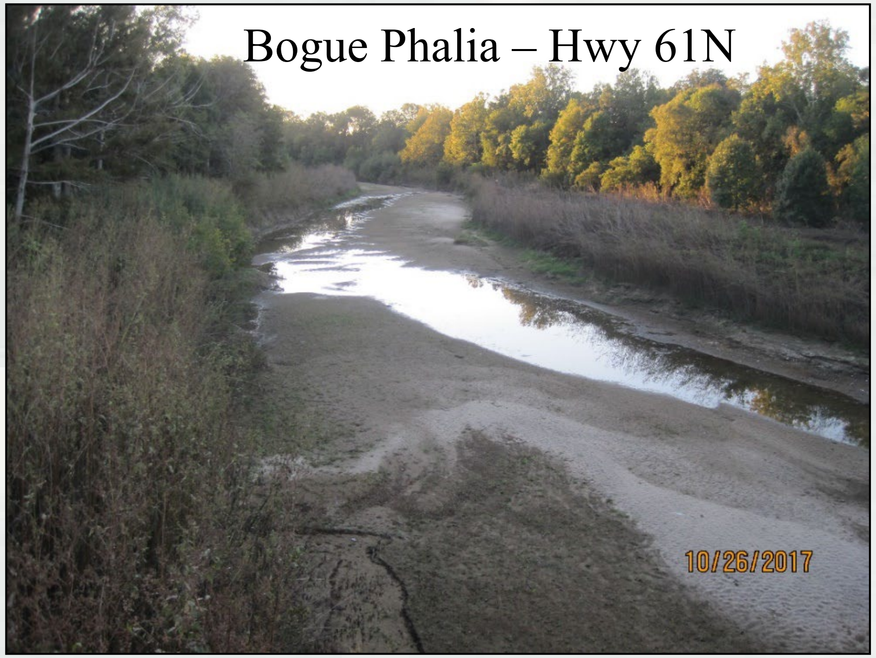

Physical Habitat
• substrate
• water depth
• shear velocity
• lotic vs. lentic
• flow regime (spawning period – glochidia attachment and release)
Reproductive traits
• spawning temperature
• host infection mode
• short vs. long term brooder
• reproductive maturity
• fecundity
Mussel species (adult)
• thermal tolerance
• motility (sessile/motile)
• longevity
Host fish species
• habitat (generalist/specialist)
• lotic vs. lentic
• motility
• thermal tolerance
Mussel species (glochidia)
• thermal tolerance
• threshold for maturation/metamorphosis

Impacts and Threats to Freshwater Mussels

- Commercial Harvest
    - pearl industry (1850-1900)
    - button industry (1890-1960)
    - cultured pearls (1950-2001)
- Dams
    - habitat conversion
    - aquatic corridors (connectivity)
    - alteration of flow regimes
- Channelization
    - substrate alteration/removal
    - Headcutting
- Pollution (water quality)
- Sedimentation/land use
- Invasive species

Freshwater Mollusk Conservation Society
Anthony and Downing (2001)

Need for water!



Sedimentation

Model Development Team

- **Integrated Ecological Modeling Team:**
  - Todd Swannack
  - Carra Carrillo
  - Brook Herman (formerly)
- **Subject Matter Expert:** Todd Slack
- **Meramec River Feasibility Team:** St Louis District, Lead - Kat McCain (now Eco-PCX)
- **Bartram's Gardens Feasibility Team:** Philadelphia District, Lead – Steve Allen
- **Reviewers:** Dan Kelner, Dave Potter, Joe Jordan, Aaron McFarlane (St Paul), Kat McCain (Eco-PCX, formerly St Louis), Audrey Harrison (ERDC-EL), Taylor Keyes (former ERDC-EL)
- **Eco-PCX:** Nate Richards (former), Kip Runyon

Timeline

2016

1st Model Development Workshop

- Meramec River Mussel Habitat Model – 2017 approved for single use

2017

Holistic Literature Review

- review of mussel life history requisites

2018

General Freshwater Mussel Habitat Model - conceptual model

- presented and reviewed at the Mississippi Chapter of the American Fisheries Society

2019

1st Independent Review:

- Kat McCain, Dan Kelner, Audrey Harrison, Taylor Keyes

2019

Submitted to Eco-PCX for Cert.

- suggested we evaluate general model with case studies working through modification/application

2020–2021

Case Study:

- Coordinated with Philadelphia District on their Bartram's Garden feasibility study

2022

Resubmitted to Eco-PCX:

- resubmitted model documentation/user's guide with case study

2022

2nd Independent Review (RPEDN):

- Dan Kelner, Dave Potter, Joe Jordan, Aaron McFarlane

2023

Certified for National Use

Model Objectives

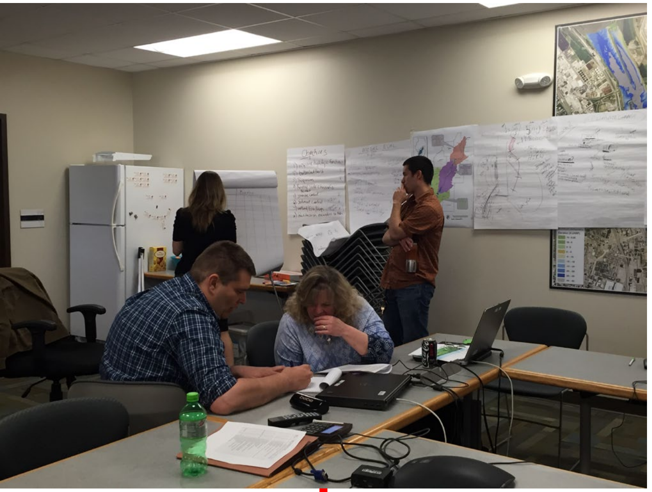
- be **sensitive** enough to distinguish relative differences between proposed freshwater mussel restoration actions or measures;
- contain parameters that reflect **system-level** functions, structures or processes that provide **suitable habitat** for freshwater mussels and;
- be applied in an **efficient** manner;
- be **flexible** enough to be applied throughout the range of the North American freshwater mussel species.

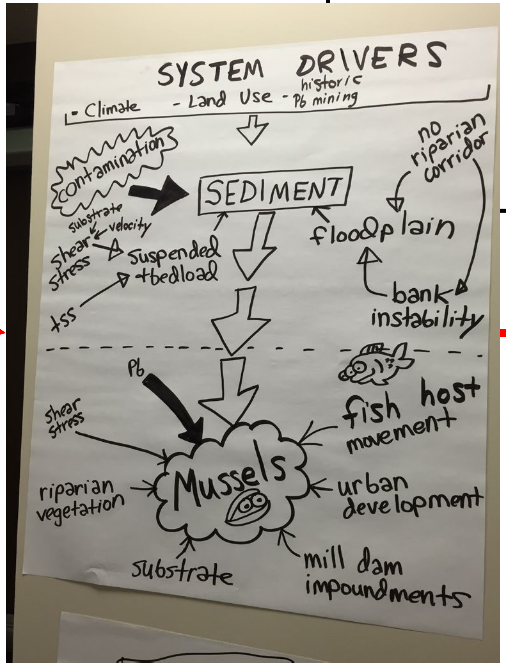
Model Limitations

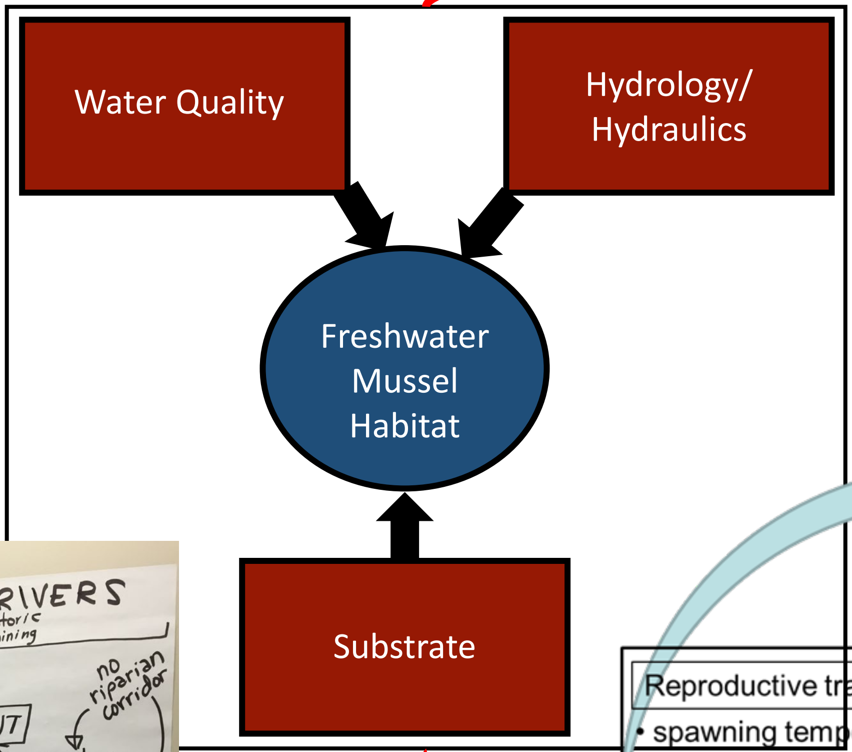
- • This model does not attempt to calculate **carrying capacity** or changes in absolute abundance for a population or a particular life stage. This model is intended to capture overall changes to the environment at the systems-level.

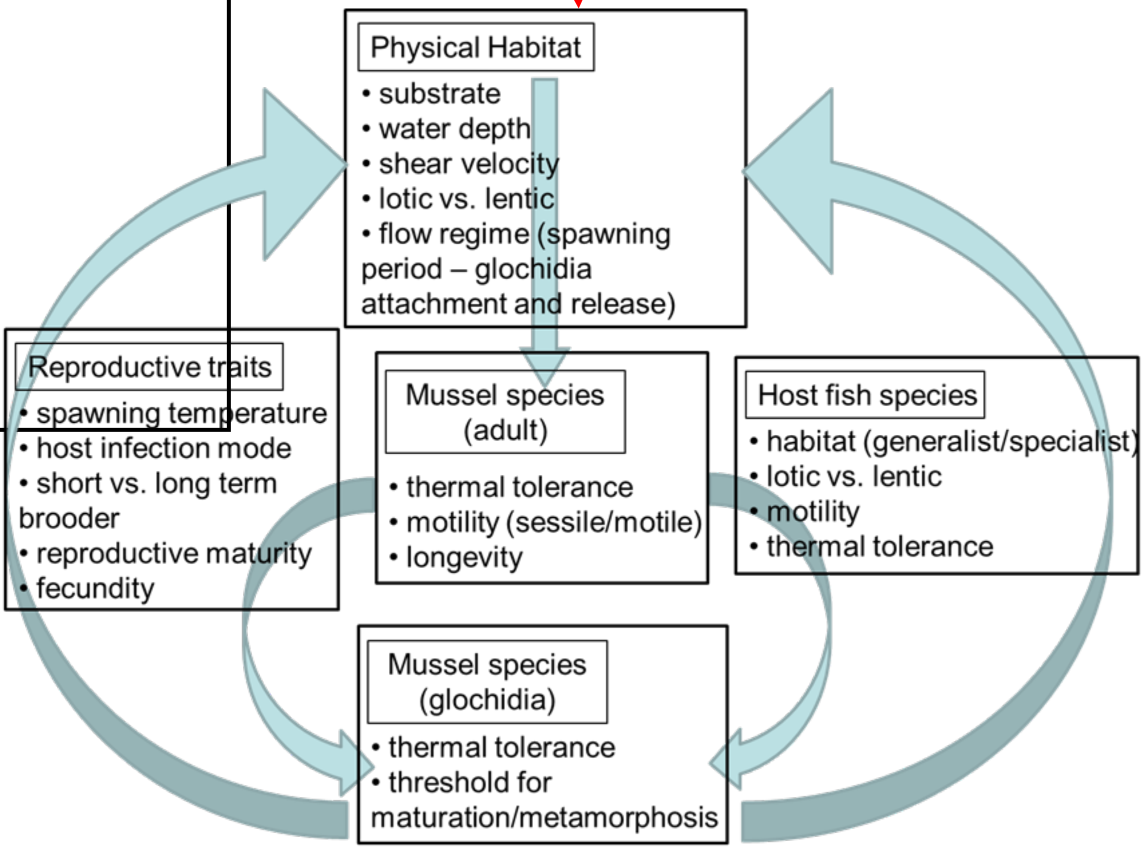
- • Affects of **pollution** to mussels were not explicitly accounted for in this model, however, a consideration during the restoration planning, design/construction and monitoring phases should be given if there are known sources of pollution (e.g., acid mine drainage, chlorination, heavy metals, etc.) in the system of interest. Elevated interstitial levels of chemicals affect juvenile mussels more severely because they have a much lower toxic response level (lower critical levels).

Conceptual Model Development









Model Quantification

Parameter	Unit of Measure	Data range
Aquatic Cover (V1)	% cover of aquatic veg/woody debris/etc.	0 – 100%
Substrate (V2)	Category based on mix of sediment types	Hard - Mix gravel/sand/ roots
Temperature (V3)	Mean daily summer water temperature (Celsius)	0 – 38° C
Flow Regime at Depth (V4)	Category based on range of appropriate flow (measured by velocity)	Cubic feet per second (cfs) or Meters per second (cms) or Flow Shear Stress (FSS)
Depth (V5)	Average depth of water in feet during normal water	-9 to 1 (ft)
Connectivity (V6)	% time accessible for fish hosts	0 – 100 %
Fish Species Richness (V7)	Number of fish species recorded from project area (Max=user defined)	0 – Max Diversity (#)
Habitat Suitability Index (HSI)	$HSI = \left(\prod_{i=1}^{n} V_i\right)^{1/n}$	

Model Quantification

Aquatic cover is defined as the associated structure that supports colonization of epifauna, substrate stability in lotic systems and provides cover for fish. Examples: cobble (riffles), rocks, entrained logs, woody debris, undercut banks, aquatic vegetation

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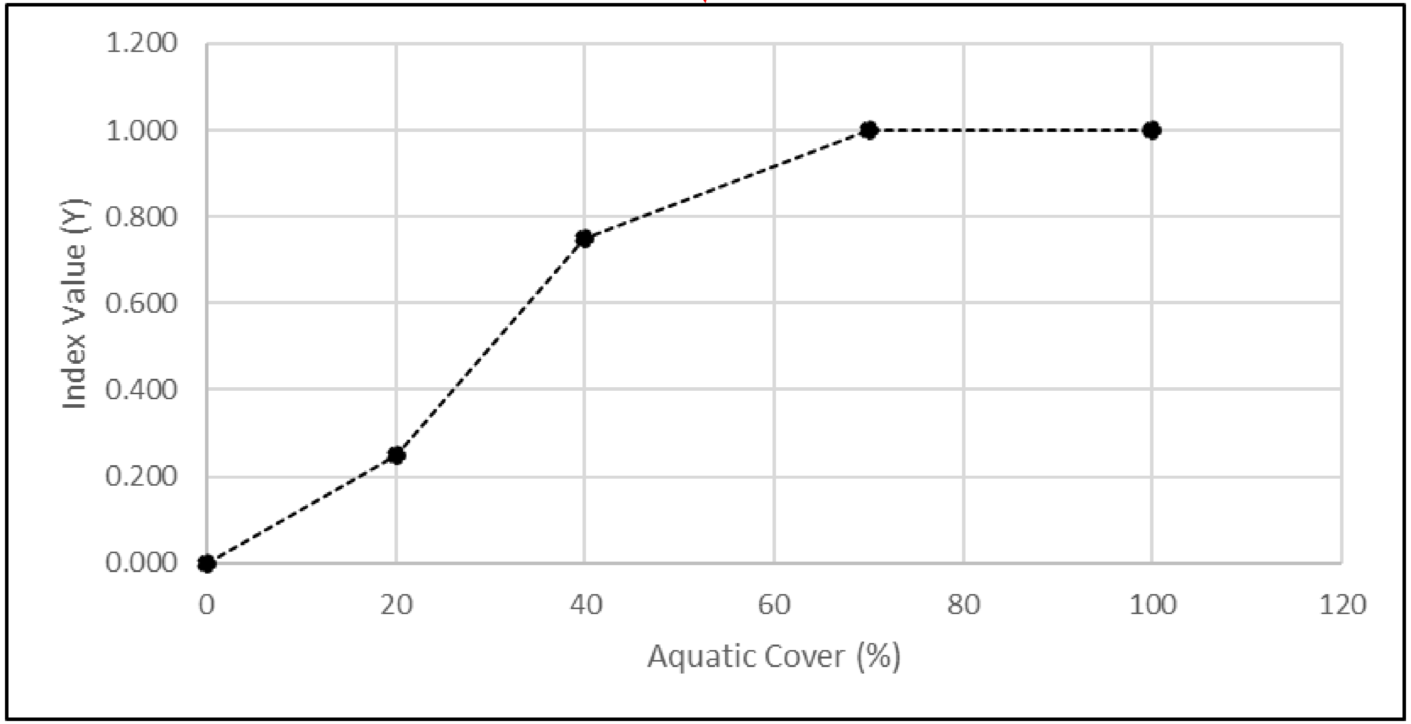
Fish Species Richness (V7)	Number of fish species recorded from project area	0 – Max Diversity (#)
Habitat Suitability Index (HSI)	**Geometric Mean of Parameter Outputs**	$HSI = \left(\prod_{i=1}^{n} V_i\right)^{1/n}$

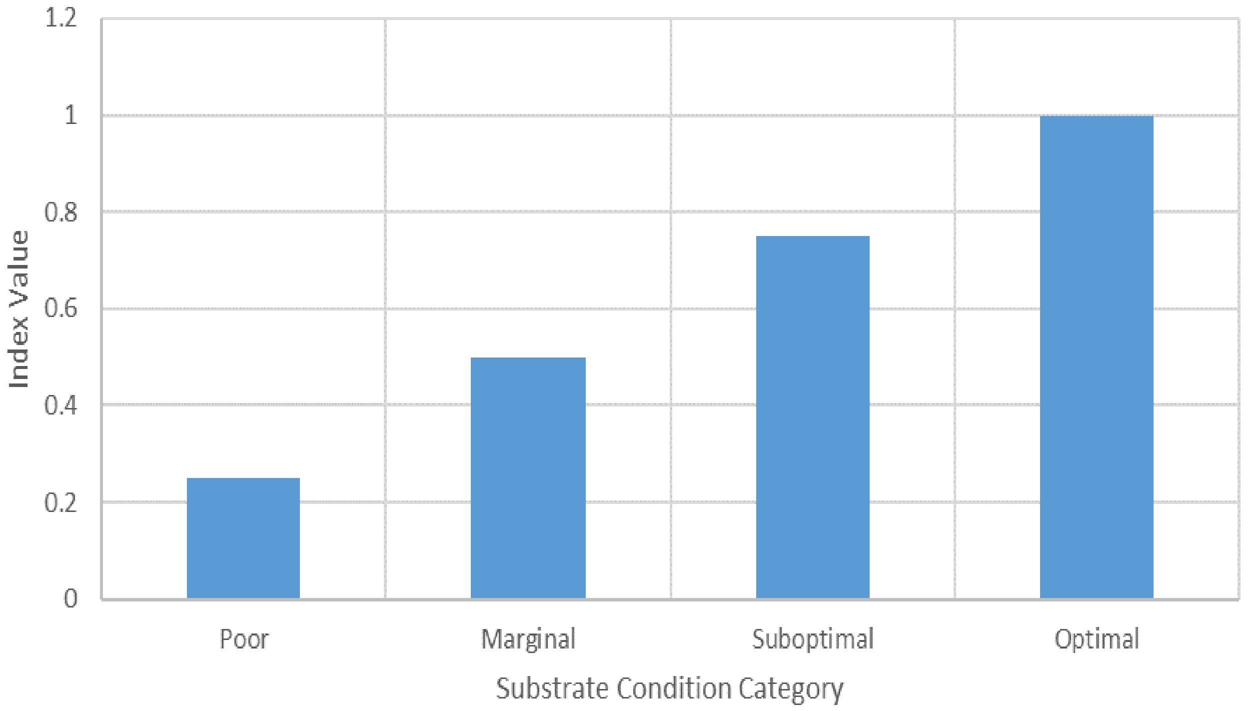
[1] USACE 2018

[2] Missouri Department of Conservation 1998

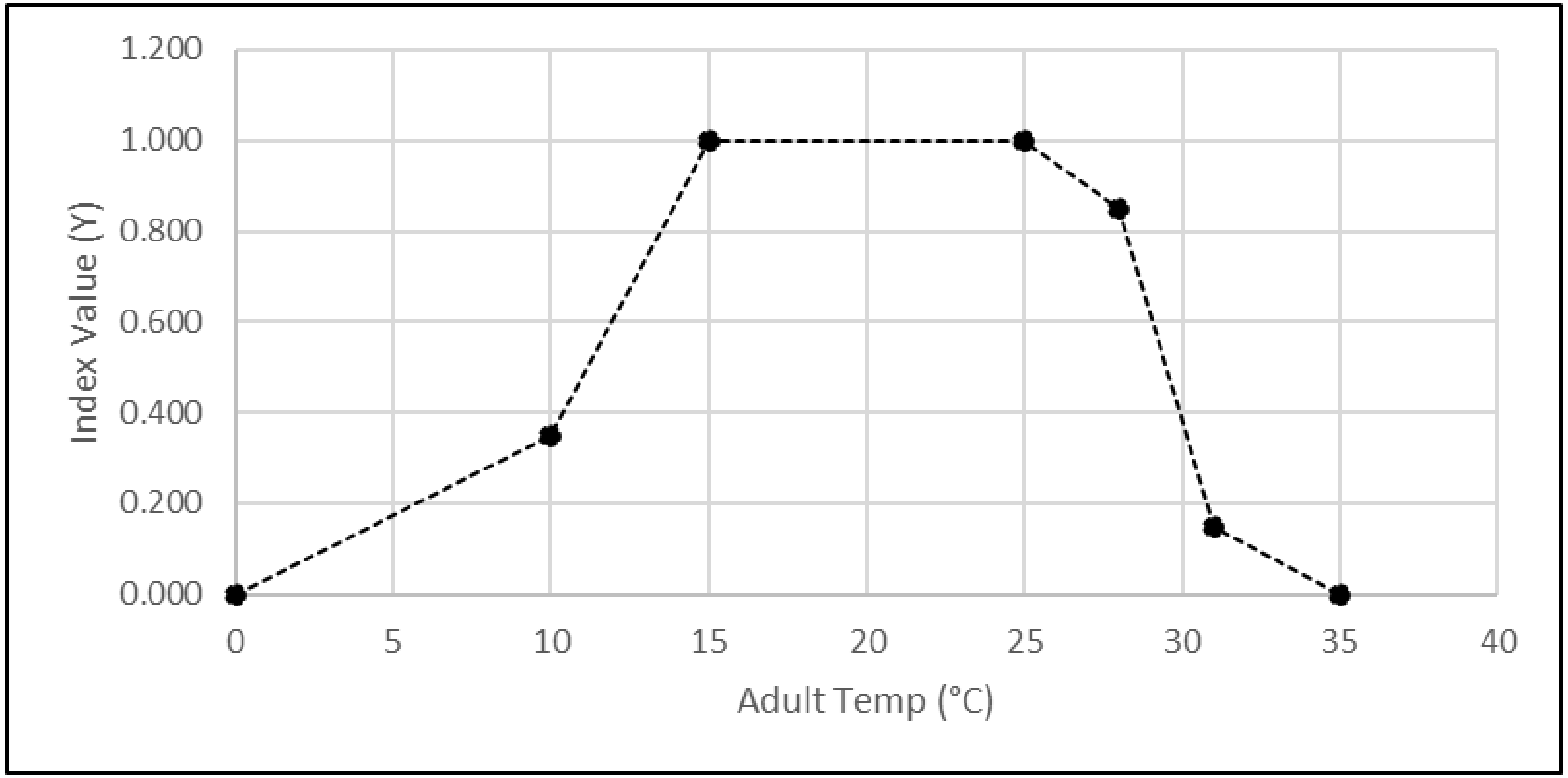


Substrate

Poor	Homogenous substrate of hard pan clay or bedrock, no root mat or submerged aquatic vegetation (SAV)
Marginal	All silt or mud bottom, little or no root mat, no SAV; marginal heterogeneous substrate
Suboptimal	Mixture of soft sand mud or clay, mud may be dominant some root mats and SAV present; suboptimal heterogeneity
Optimal	Mixture of substrate material, with gravel and firm sand prevalent; root mats and SAV; optimal heterogeneity; 50/50 mix

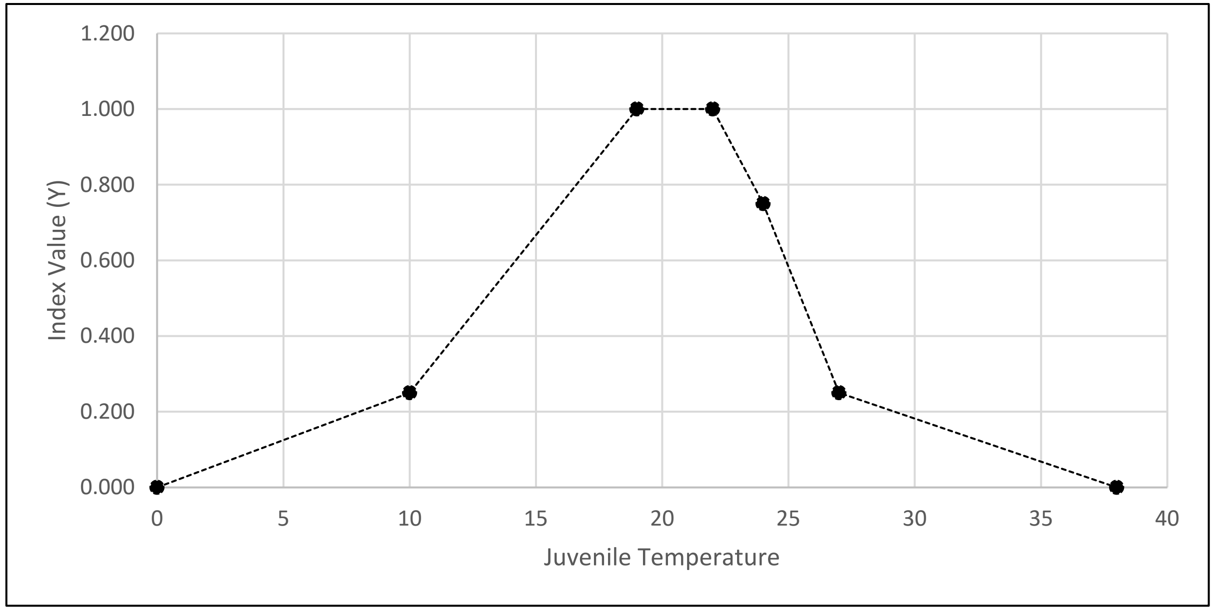


Temperature – mean daily summer temp



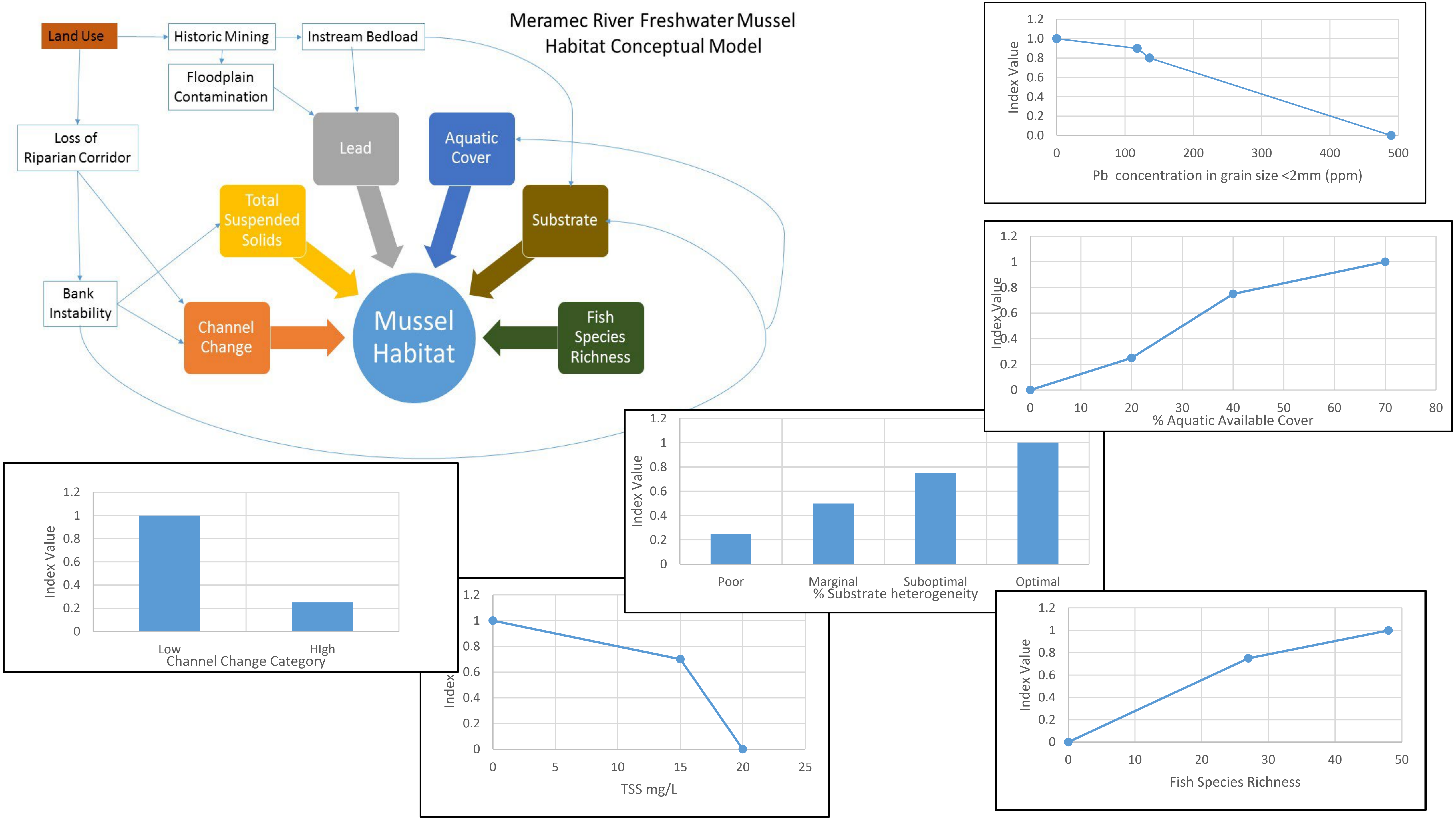
Values	Intercept	Slope	Equation
0 -10	0.00	0.0350	Y= 0 + (0.035 * Temp (°C))
10 -15	-0.95	0.1300	Y= -0.95 + (0.13 * Temp (°C))
15 -25	1.00	0.0000	Y= 1 + (0 * Temp (°C))
25 -28	2.25	-0.0500	Y= 2.25 + (-0.05 * Temp (°C))
28 -31	7.38	-0.2333	Y= 7.38 + (-0.2333 * Temp (°C))
31 - 35	1.31	-0.0375	Y= 1.31 + (-0.0375 * Temp (°C))
35 -	0.00	0.00	Y= 0 + (0 * Temp)

~~Juvenile Temperature – mean daily summer temp~~



Values	Intercept	Slope	Equation
0 -10	0.00	0.0250	Y= 0 + (0.025 * Temp)
10 -19	-0.58	0.0833	Y= -0.58 + (0.0833 * Temp)
19 -22	1.00	0.0000	Y= 1 + (0 * Temp)
22 -24	3.75	-0.1250	Y= 3.75 + (-0.125 * Temp)
24 -27	4.75	-0.1667	Y= 4.75 + (-0.1667 * Temp)
27 -38	0.86	-0.0227	Y= 0.86 + (-0.0227 * Temp)
38 -	0.00	0.0000	Y= 0 + (0 * Temp)

Removed after Case Study and 2nd Independent Review because of redundancy with Adult Temp


Meramec River Freshwater Mussel Habitat Conceptual Model
Land Use
Historic Mining
Instream Bedload
Floodplain Contamination
Loss of Riparian Corridor
Lead
Aquatic Cover
Total Suspended Solids
Substrate
Bank Instability
Channel Change
Mussel Habitat
Fish Species Richness
Index Value
Pb concentration in grain size <2mm (ppm)
% Aquatic Available Cover
% Substrate heterogeneity
Poor
Marginal
Suboptimal
Optimal
Channel Change Category
Low
HIgh
TSS mg/L
Index
Fish Species Richness

Project Evaluation/Modification for Steps and Case Study:

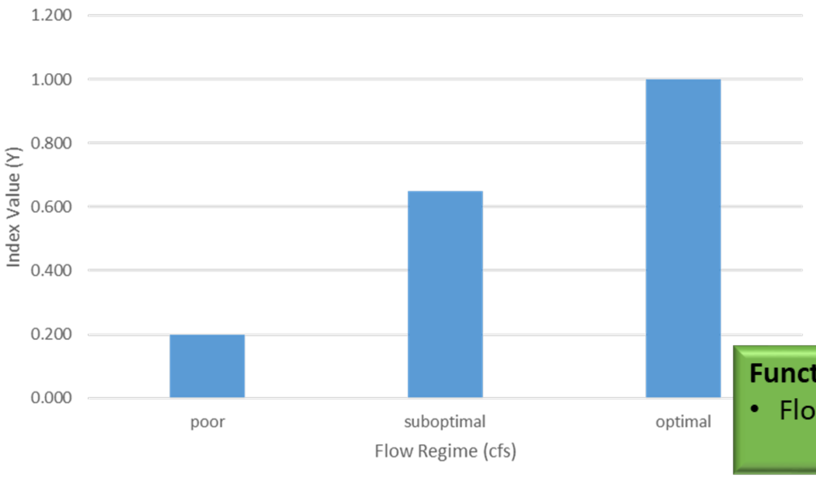
Bartram's Garden

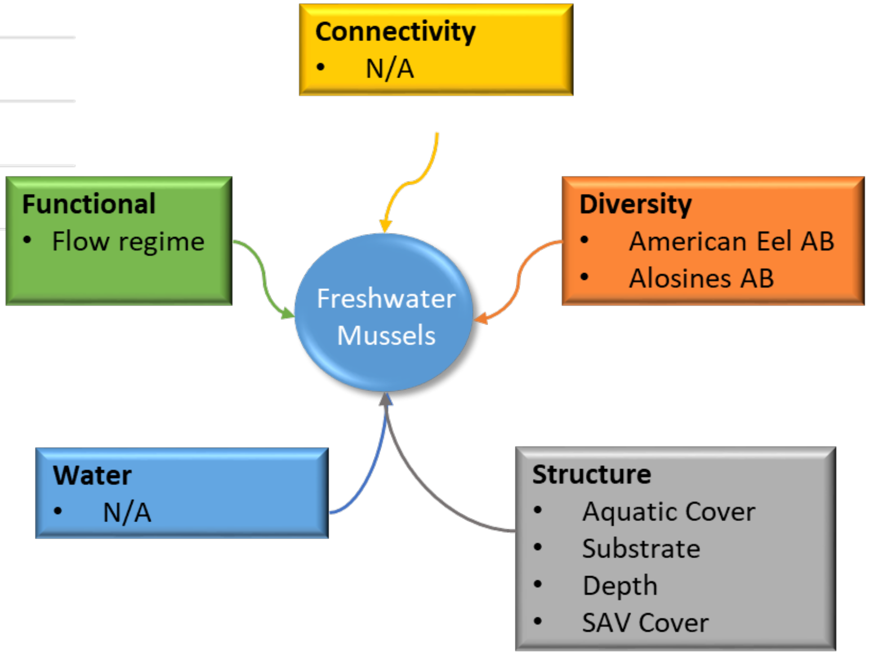
- **Determine** if the General Freshwater Mussel Habitat Model is appropriate for meeting project objectives and is system appropriate;
- **Review** generalized parameters against system specifics, does parameter(s) need to be rescaled to reflect system thresholds/ranges;
- **Determine** if important parameters are missing that are indicative of suitable habitat for mussel community of interest (e.g., levels of specific pollutant);
- **Evaluate** relationship between new parameters and suitable mussel habitat;
- **Modify** and **test** parameters to better represent system specifics.

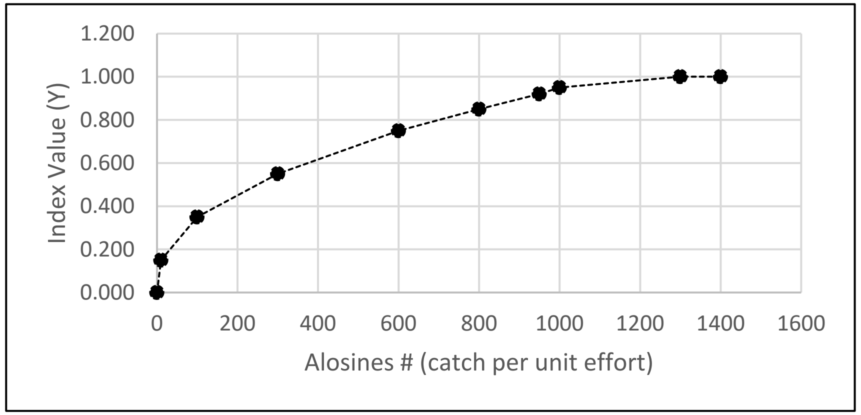
Bartram's Garden Expert Evaluation of the General Mussel Model

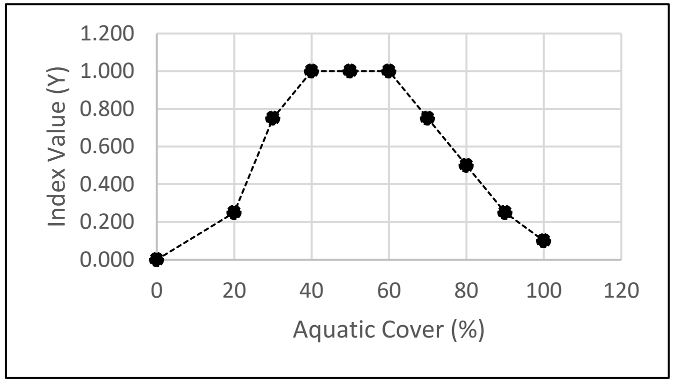
Parameters	General Unit of Measure	Evaluation	Notes
Aquatic Cover	% cover of aquatic veg/woody debris/etc.	Retained - Modified	Rescaled to indicate optimal habitat is between 40-60% cover. Less than 40% does not offer as much refuge and moderation of high flow events, greater than 60% becomes too much coverage and starts to reduce available substrate for mussels to use. SAV is no longer measured with this parameter.
Substrate	Category based on mix of sediment types	Retained	No change. Representative of system.
~~Temperature~~	Mean daily summer water temperature (Celsius)	Removed	Not a limiting factor to target guild of mussel or sensitive to proposed restoration actions.
Submersed Aquatic Vegetation	% cover of aquatic vegetation	Additional	New parameter to reflect important function of SAV in project area, acts as a refuge for host fish species, provide habitat structure for substrate and moderate high flow events. Relationship to habitat suitability very similar to aquatic cover parameter.

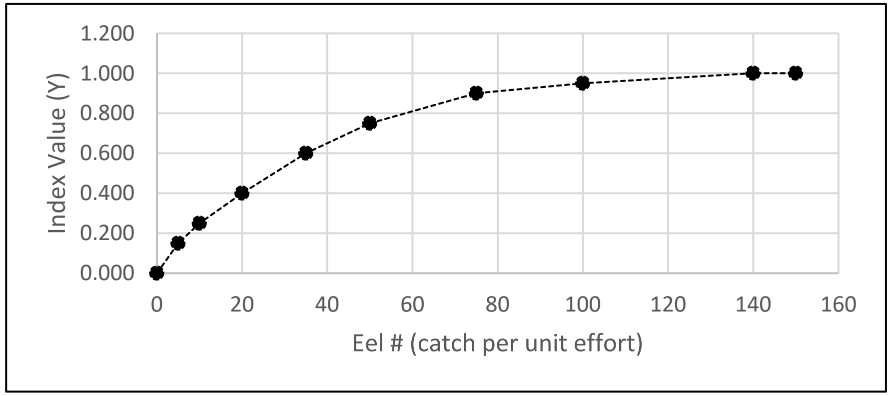
Bartram’s Gardens Mussel Habitat Model

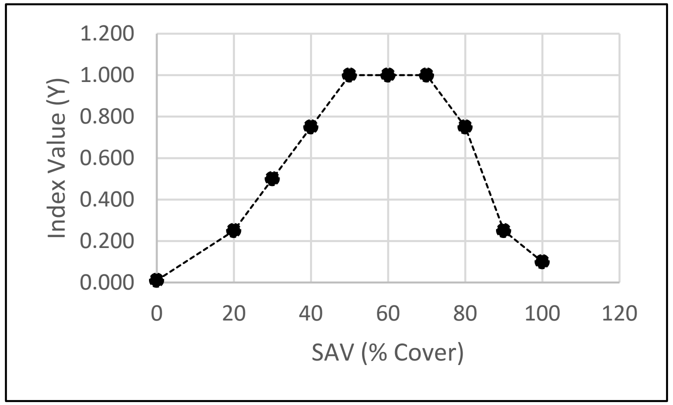


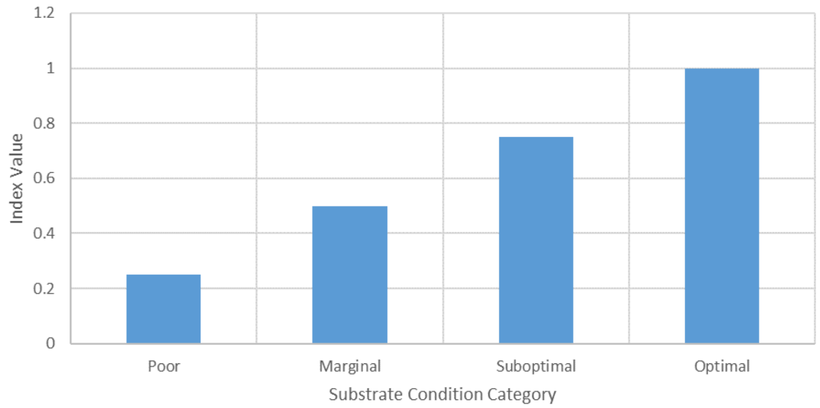


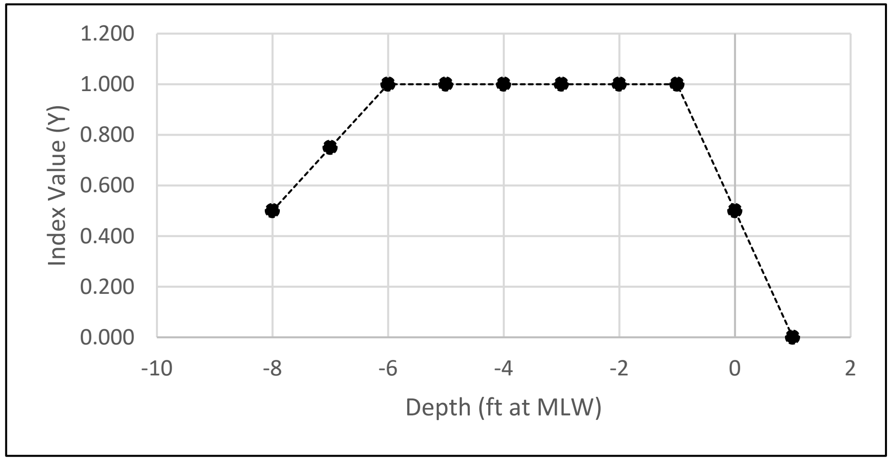






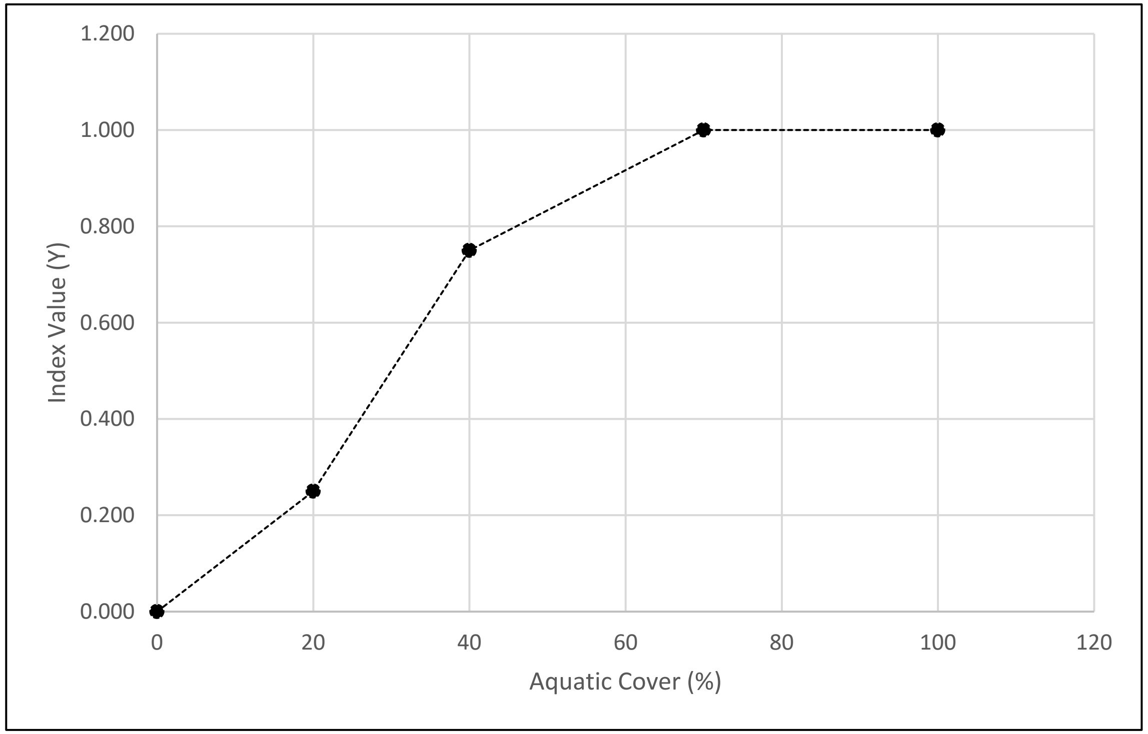




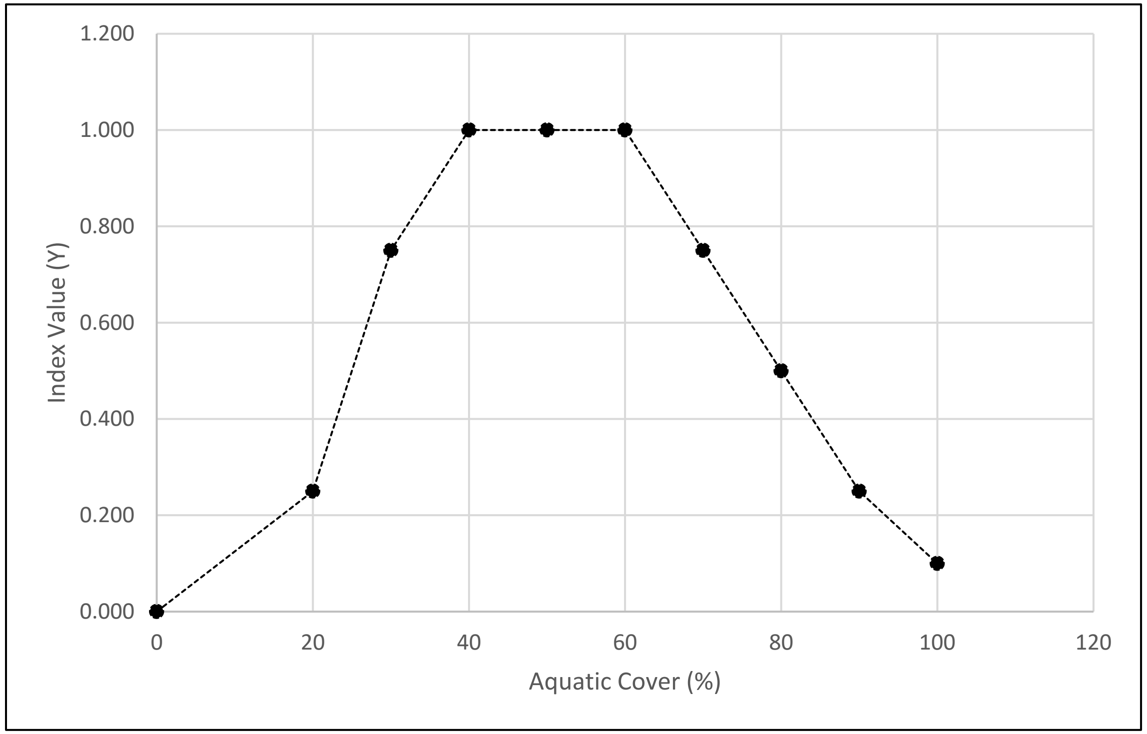


Comparison of Modified Habitat Suitability Curves

General Freshwater Mussel Habitat Model



Bartram's Garden Mussel Habitat Model



Model Considerations

- Local or regional mussel experts should be on the project delivery team or consulted so they can review and verify each component of the model.
- Consult the supporting guide (http://dx.doi.org/10.21079/11681/46146) that provides specific life history and environmental requirements of different guilds of mussel species.
- Although there is strong evidence of temperature effects on adults and juveniles, it is worthwhile to consider that fish host species may also experience stress/mortality under high summer temperatures.
- The ability to modify and add new parameters is a key capability of this general model.
- Planners should consult with the model developers (contact Int. Ecological Modeling Team at ERDC) and must consult the U.S. Army Corps of Engineers ECO-PCX, especially if a change is needed.

Documents

- Tech Note: Developing Conceptual Models for Assessing Benefits and Impacts of USACE Activities on Freshwater Mussel Communities
- Model Documentation and User's Guide (Final Draft Tech Report)
- Model Spreadsheet Calculator and User's Guide
- Model Reviewer's Comments and Responses (White Paper)
- Website: searchable database of Native Mussel Guilds life history:
    - http://dx.doi.org/10.21079/11681/46146

Input data example for testing purposes: Meramec River Feasibility Study Area, Missouri.

Enter: Maximum Fish Species Richness (#) →→ 30

	Baseline	0	Year	1	Year	5	Year	10	Year	25	Year	50	
Description	Data	HSI	Data	HSI	Data	HSI	Data	HSI	Data	HSI	Data	HSI	Comments
Aquatic Cover (V1)	20	0.25	50	0.83	75	1.00	100	1.00	15	0.19	110	1.00	
Substrate (V2)	Poor	0.10	Marginal	0.50	Suboptimal	0.75	Optimal	1.00	Poor	0.10	Poor	0.10	
Temperature (V3)	35	0.00	29	0.62	28	0.85	15	1.00	5	0.18	35	0.00	
Flow at Depth (V4)	Optimal	1.00	Suboptimal	0.65	Poor	0.10	Optimal	1.00	Poor	0.10	Optimal	1.00	
Depth (V5)	-20	0.20	-2	0.85	-1	0.40	-6	1.00	-9	0.20	-20	0.20	
Connectivity (V6)	0	0.00	14	0.14	45	0.45	55	0.55	65	0.65	15	0.15	
Fish Richness (V7)	5	0.15	140	1.00	80	1.00	45	1.00	55	1.00	250	1.00	
Suitability Score		**0.00**		**0.57**		**0.53**		**0.92**		**0.24**		**0.00**	
Quantity	0		0		0		0		0		0		
Habitat Unit(s)		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**	

Key Take-aways

- Freshwater mussels are the most imperiled taxa in North America with over 70 mussels listed on the Endangered Species List with over 180 identified as imperiled or threatened.
- A generalized freshwater mussel habitat suitability model was developed to quantify potential impacts and benefits of USACE project actions on mussel habitat.
- The model was thoroughly evaluated and tested and is certified for Nation-wide use.