

TOOLS FOR INDEX-BASED MODELING

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ERDC Environmental Laboratory

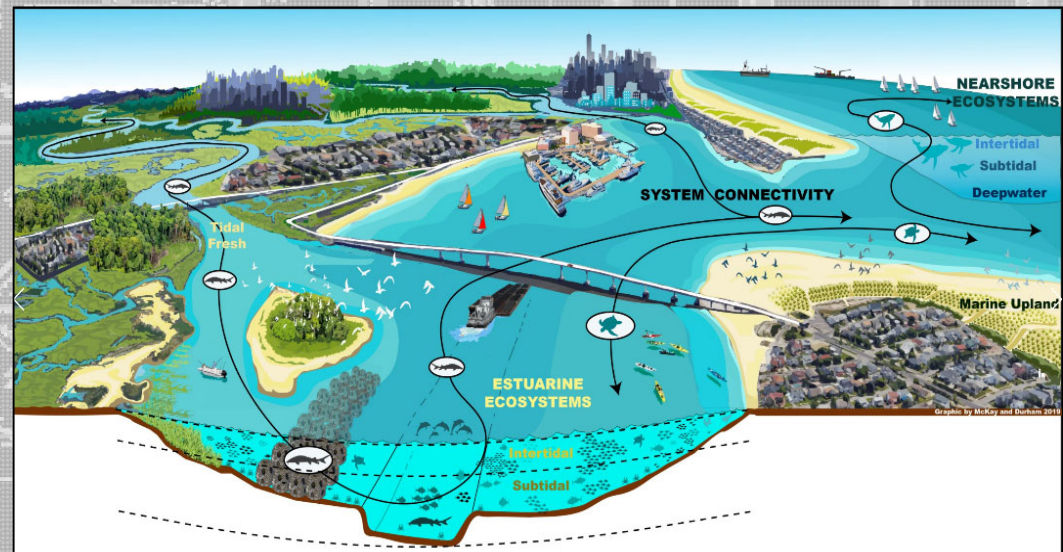
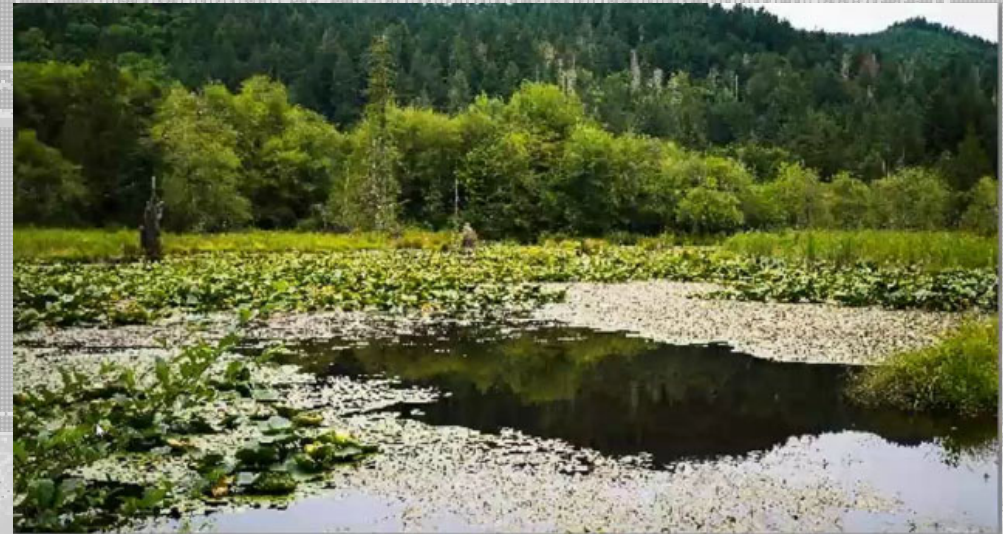
with Special Guests

*Kyle McKay, Nate Richards, Candice Piercy,
Molly Reif, Christina Saltus, Darixa
Hernandez-Abrams, Carra Carillo, Brook
Herman, Safra Altman, Meghan McCormack,
Tyler Keys, Mindy Simmons,*

18 March 2020



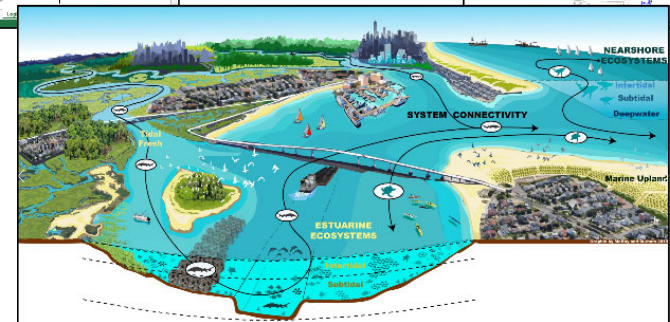
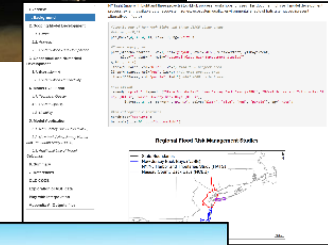
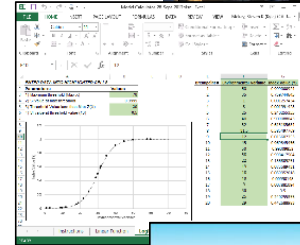
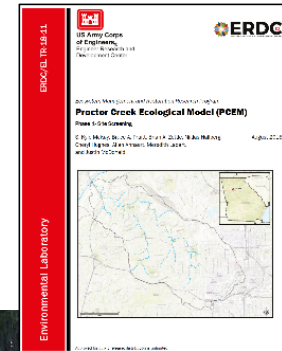
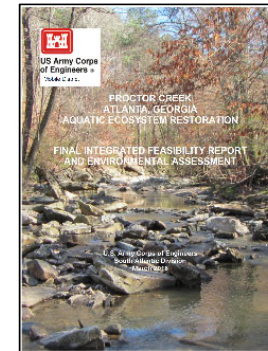
US Army Corps
of Engineers





OVERVIEW

- Over the last four years, EMRRP has funded an effort to improve ecological modeling across the USACE
- Work has been focused on two main topics:
 - Building expertise and developing good-practice ecological model development for restoration planning
 - Tools for rapid model development and application
- This presentation will cover some of the tools/approaches we've developed during this project.



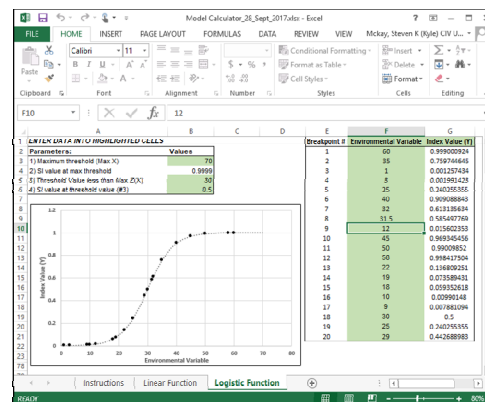
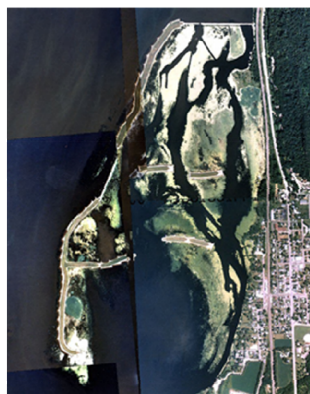


INDEX-BASED MODELS

3



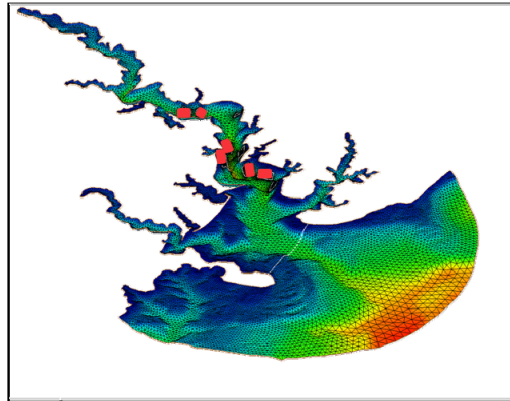
- Used a lot in restoration planning
 - *These models are designed to correlate species distribution to physical/environmental factors*
 - *General quantitative approach: develop correlations on a 0 to 1 scale for an environmental parameter and species “viability” with 0 being terrible for the species and 1 being perfect*
 - *Can be based on data, expert opinion or both*
 - *Can be developed rapidly*
 - *Blue book models (all certified)*
 - *For many projects, new models need to be developed to answer USACE-specific questions or for new habitats not covered under existing models*



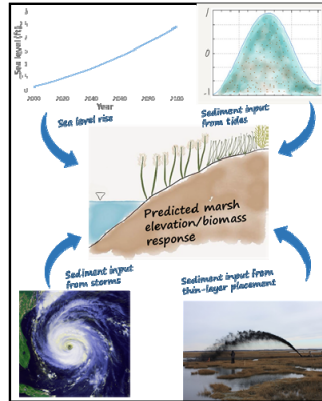


INDEX MODELS ARE GREAT TOOLS FOR, BENEFIT ANALYSIS, SCENARIO ANALYSIS AND DECISION-MAKING

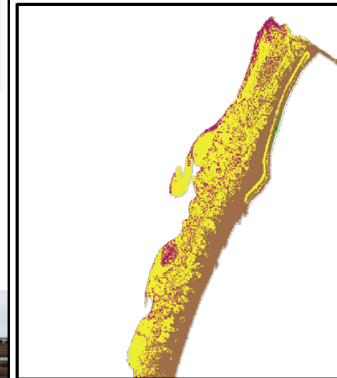
4



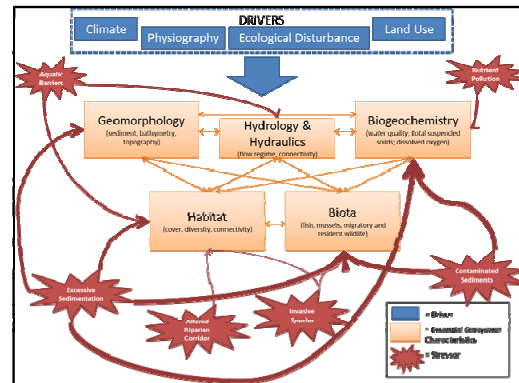
Oyster modeling: USACE-NAN & ERDC



Beneficial use:
USACE-NAP & ERDC



NNBF and EGS: ERDC



ER Project: USACE-MVS & ERDC



ER Project: USACE-SPL & ERDC



HABITAT MODELS IN PRACTICE

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HSI BLUEGILL MODEL WORKSHEET INSTRUCTIONS:					
Riverine 1. Please Choose Riverine or Lacustrine from the box at left 2. Enter Data Values below which are highlighted green					
Enter Condition:		FWOP (216 acres)	Enter Year:	0	
Variable	Habitat	Description	DATA	HSI	Comments
V1	R	% Pool Area	53.4%	0.89	
V2	R and L	% Cover (logs & brush)	10.9%	0.64	
V3	R and L	% Cover (vegetation)	14.3%	0.95	
V4	L	% Littoral Area			
V5	L	Avg. Total Dissolved Solids (TDS) (in ppm)			
V6	R and L	Avg. Turbidity (ppm)	64	0.93	
V7	R and L	pH Range	A	1.00	
V8	R and L	Min. Dissolved Oxygen (DO) - Summer	A	1.00	
V9	R and L	Salinity (ppt)	-1	nf	
V10	R and L	Max. Midsummer Temp. (Adult) (C)	29.1	0.30	
V11	R and L	Avg. Water Temp. (Spawning) (C)	22.4	1.00	
V12	R and L	Max. Early Summer Temp. (Fry) (C)	24.2	0.94	
V13	R and L	Max. Midsummer Temp. (Juvenile) (C)	29.8	0.99	
V14	R	Avg. Current Velocity (cm/s)	5.01	1.00	
V15	R	Avg. Current Velocity (Spawning) (cm/s)	5.59	1.00	
V16	R	Avg. Current Velocity (Fry) (cm/s)	5.59	0.61	
V17	R	Avg. Current Velocity (Juvenile) (cm/s)	6.8	0.79	
V18	R	Stream Gradient (m/km)	0.1	1.00	
V19	L	Reservoir Drawdown during spawning (m)			
V20	R and L	Substrate Composition	B	0.70	
		Food (Cf)		0.81	
		Cover (Cc)		0.79	
		Water Quality (Cwq)		0.87	
		Reproduction (Cr)		0.89	
		Other (Cot)		0.90	
		Summer HSI		0.86	
WITH WINTER HSI MODIFICATIONS					
Variable	Description				
Va	R and L	% of Backwater > 4 Feet in Depth	0.9%	0.21	
Vb	R and L	Min. Dissolved Oxygen (DO) - Winter	B	0.70	
Vc	R and L	Water Temperature (C)	1.4	0.57	
Vd	R and L	Current Velocity (cm/s)	1.4	0.24	
		Winter Cover (Cw-c)		0.21	
		Winter Water Quality (Cw-wq)		0.66	
		Winter Other (Cw-ot)		0.24	
		Winter HSI		0.39	
		Overall HSI with Winter Modifications		0.39	

Ad hoc spreadsheet models for:

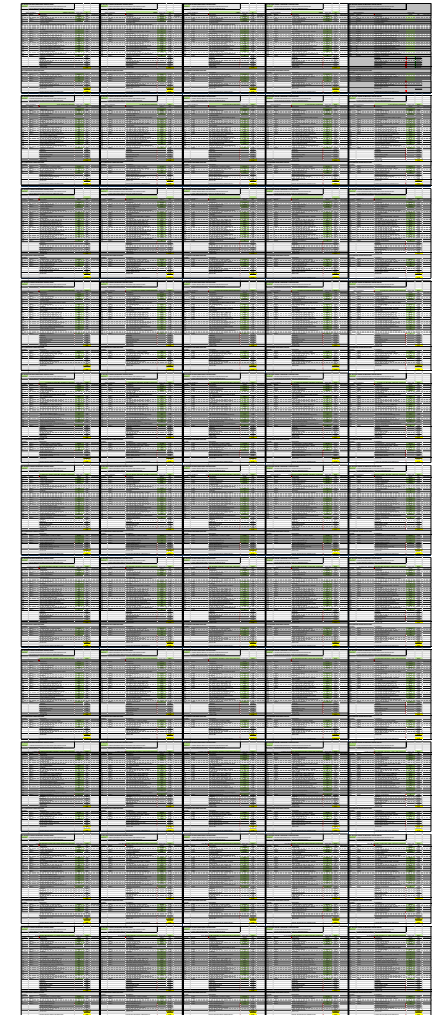
- a single taxa
- one location
- one restoration alternative
- one point in time

NO PROBLEM!

Ad hoc spreadsheet models for:

- a single taxa
- one location
- multiple restoration alternatives
- multiple points in time

WELL...





COLLABORATIVE MODEL DEVELOPMENT



- Model development, application, and certification can overwhelm project teams
- Coupling ERDC tech and District expertise reduces model development time while introducing new tech
- Developed a short course (1.5 days) to work through models
 - USACE and agency partners can attend
 - Series of lectures and labs on good modeling practice in USACE
 - Hands-on, problem-specific curriculum for a district to work through from concept to application
 - Model development is interactive and in real-time
 - Create index models within the workshop to be used for project development
 - *Best of both worlds*



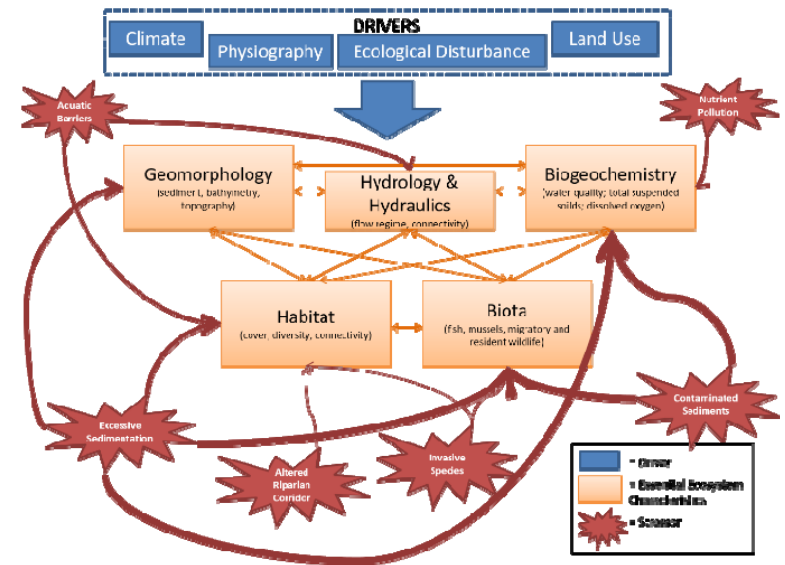
COLLABORATIVE MODEL DEVELOPMENT

7



Collaborative modeling streamlines project life cycle by:

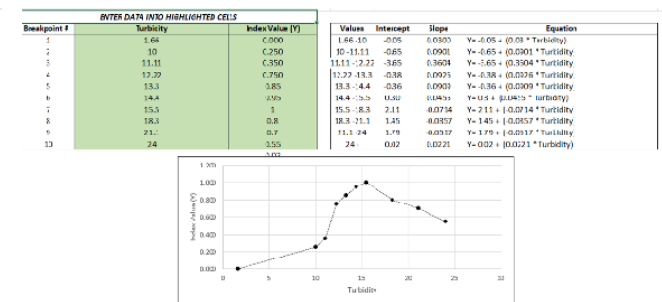
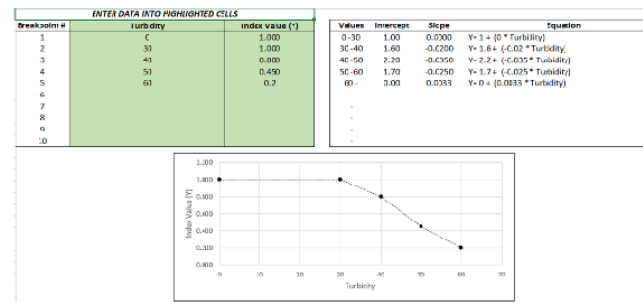
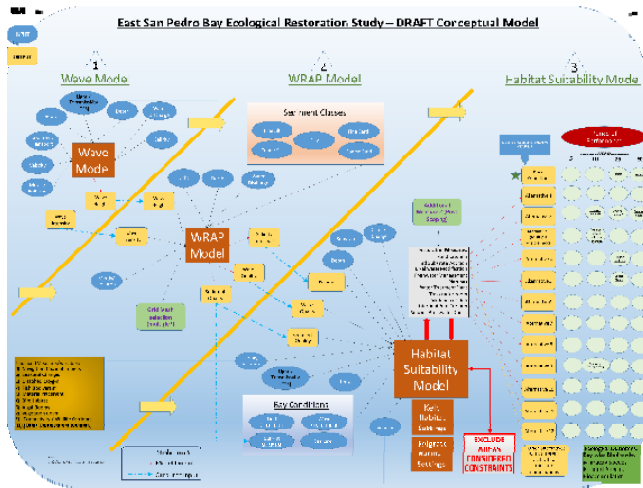
1. being a natural mechanism to facilitate interagency interactions and buy-in,
2. providing a framework for documentation and transparency,
3. reducing risk by providing more details upon which to base decisions, and
4. introducing emerging ERDC tools and models for project planning and operations while introducing ERDC to district needs and issues





TOOLKIT FOR INTERACTIVE MODELING (TAM)

- Facilitated modeling develops model in real time (certified for national use)
- Increases transparency by demystifying modeling
- Catalyzes PDT, so they can focus on integrating relevant input data and models
- Increases critical thinking





TOOLKIT FOR INTERACTIVE MODELING (TAM)

B

C

D

E

F

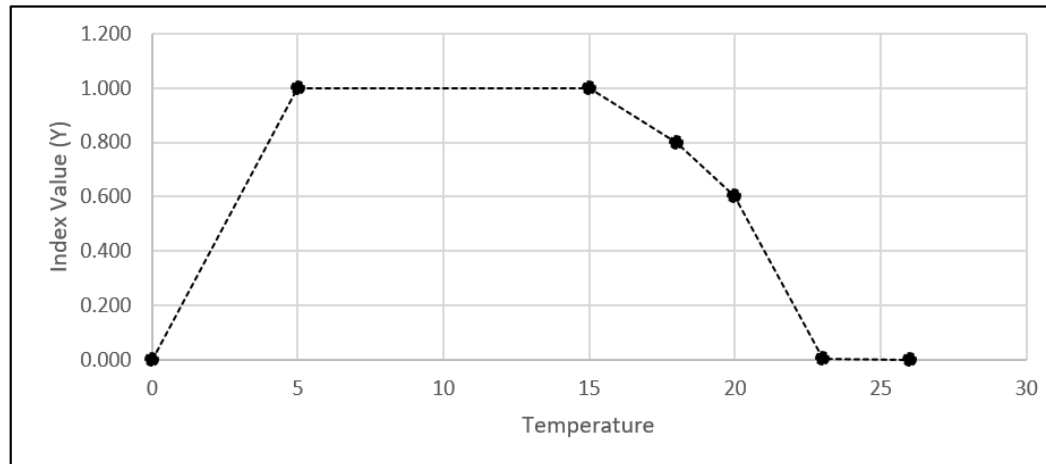
G

H

ENTER DATA INTO HIGHLIGHTED CELLS

Temperature	Index Value (Y)
0	0.000
5	1.000
15	1.000
18	0.800
20	0.6
23	0.001
26	0.00001
27	

Values	Intercept	Slope	Equation
0 -5	0.00	0.0667	$Y = 0 + (0.0667 * \text{Temperature})$
5 -15	1.00	0.0000	$Y = 1 + (0 * \text{Temperature})$
15 -18	2.80	-0.1000	$Y = 2.8 + (-0.1 * \text{Temperature})$
18 -20	2.13	-0.0667	$Y = 2.13 + (-0.0667 * \text{Temperature})$
20 -23	5.19	-0.1997	$Y = 5.19 + (-0.1997 * \text{Temperature})$
23 -26	0.03	-0.0010	$Y = 0.03 + (-0.001 * \text{Temperature})$
26 -27			
-			
-			



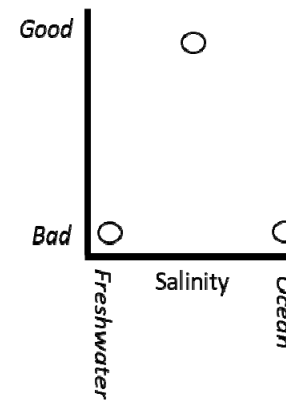
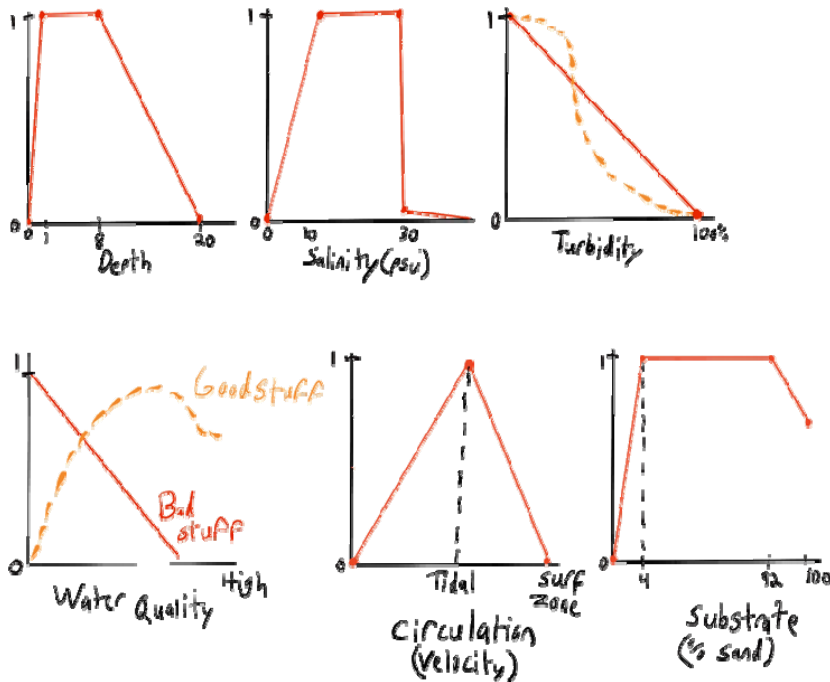
Auto-documenting!



BIGGEST CHALLENGE IN MODEL DEVELOPMENT

The Math

Modeling is viewed as a complex task that can only be completed by engineers & mathematicians. Index based models are great tools to overcome that issue.





ECOREST R PACKAGE: HABITAT DATA

- Compiled 100+ habitat suitability models from USFWS (with 500+ sub-models)
- All models and metadata loaded into the package
- Generic data structure for user-defined models

pl.area.avg.summer.flow.pct	pl.area.avg.summer.flow.SIV	cov.pls.litt.area.summer.pct	cov.pls.litt.area.summer.SIV	cov.aq.veg.pct	cov.aq.veg.SIV
0	0	0	0.2	0	0
60	1	20	1.0	15	1
100	1	60	1.0	30	1
NA	NA	100	0.2	100	0
NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA

model	submodel	species	geography	ecosystem	documentation	note	HSI.equation
bluegillRiv	RIVERINE Food Component	Lepomis machrochirus	Wherever bluegills occur in North America	Fish Passage, Fresh Wetland, Lake, Large River, Stream	Stuber, R.J, G Gebhart and OE Maughan. 1982. Habitat Suitability Index Models: Bluegill. USFWS Report FWS/OBS- 82/10.8. 26pp.		$\text{ifelse}(\text{CWQ} \text{CR} \leq 0.4, \min(\text{CF}, \text{CC}, \text{CWQ}, \text{CR}), (\text{CFCC}(\text{CWQ}^2) * \text{CR})^{(1/5)})$
bluegillLac	LACUSTRINE Food Component	Lepomis machrochirus	Wherever bluegills occur in North America	Fish Passage, Fresh Wetland, Lake, Large River, Stream	Stuber, R.J, G Gebhart and OE Maughan. 1982. Habitat Suitability Index Models: Bluegill. USFWS Report FWS/OBS- 82/10.8. 26pp.	drop SVI19 in natural lake	$\text{ifelse}(\text{CWQ} \text{CR} \leq 0.4, \min(\text{CF}, \text{CC}, \text{CWQ}, \text{CR}), (\text{CFCC}(\text{CWQ}^2) * \text{CR})^{(1/5)})$



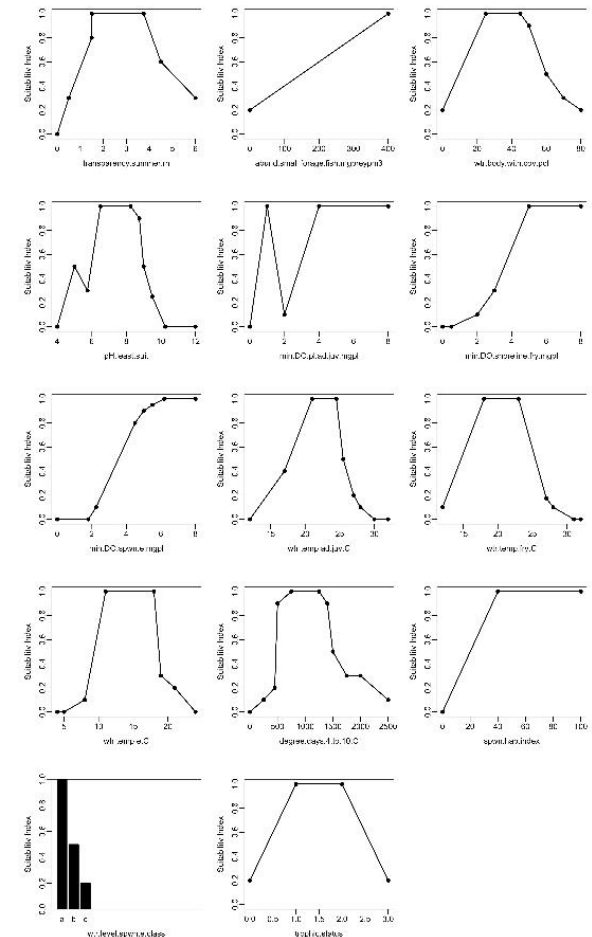
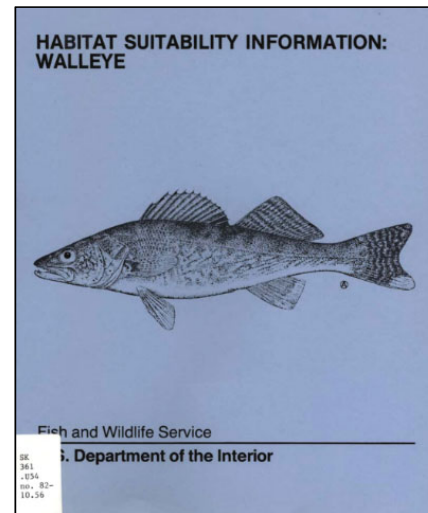
ECOREST R PACKAGE: HABITAT MODELING

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Key Functions:

- View habitat suitability index curves
- Compute suitability relative to multiple variables
- Compute overall patch quality by combining variables via:
 - USFWS equations
 - Arithmetic mean
 - Weighted arithmetic mean
 - Geometric mean
 - Minimum
- Compute habitat units





EcoRest HSI

13



Select model

Walleye Riv

Waleye Lac

Calculate SI

Calculate SI

Calculate HSI

Calculate HU

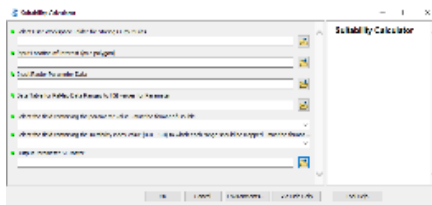
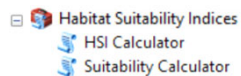
Alternative	Time	SIV1	SIV2	SIV3	SIV4	SIV5	SIV6	SIV7	SIV8	SIV9	SIV10	SIV11	SIV12	SIV13	SIV14	Quality	Quantity	Habitat Units
FWOP	0	0.24	0.30	0.232	1	1	1	1	0.5	1	0.3	0.908	0.250	1	1	0.238	1.5	0.357
FWOP	1	0.24	0.30	0.232	1	1	1	1	0.5	1	0.3	0.908	0.250	1	1	0.238	1.5	0.357
FWOP	10	0.24	0.30	0.232	1	1	1	1	0.5	1	0.3	0.908	0.250	1	1	0.238	1.5	0.357
FWOP	20	0.24	0.30	0.232	1	1	1	1	0.5	1	0.3	0.908	0.250	1	1	0.238	1.5	0.357
FWOP	30	0.24	0.30	0.232	1	1	1	1	0.5	1	0.3	0.908	0.250	1	1	0.238	1.5	0.357
FWOP	40	0.24	0.30	0.232	1	1	1	1	0.5	1	0.3	0.908	0.250	1	1	0.238	1.5	0.357
FWOP	50	0.24	0.30	0.232	1	1	1	1	0.5	1	0.3	0.908	0.250	1	1	0.238	1.5	0.357
BankProtection	0	0.24	0.30	0.232	1	1	1	1	0.5	1	0.3	0.908	0.250	1	1	0.238	1.5	0.357
BankProtection	1	0.24	0.38	0.680	1	1	1	1	0.5	1	0.3	0.908	0.775	1	1	0.300	1.5	0.450
BankProtection	10	0.24	0.42	0.680	1	1	1	1	0.5	1	0.3	0.908	0.775	1	1	0.300	1.5	0.450
BankProtection	20	0.24	0.42	0.680	1	1	1	1	0.5	1	0.3	0.908	0.775	1	1	0.300	1.5	0.450
BankProtection	30	0.24	0.42	0.680	1	1	1	1	0.5	1	0.3	0.908	0.775	1	1	0.300	1.5	0.450
BankProtection	40	0.24	0.42	0.680	1	1	1	1	0.5	1	0.3	0.908	0.775	1	1	0.300	1.5	0.450
BankProtection	50	0.24	0.42	0.680	1	1	1	1	0.5	1	0.3	0.908	0.775	1	1	0.300	1.5	0.450



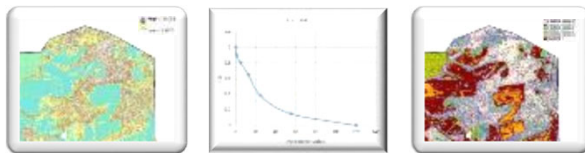
No R? No Problem!

Geospatial Toolbox

- ❖ An ArcGIS-based, python toolbox developed to create parameter suitability indices such as elevation, salinity, and slope based on species/habitat relationship and integrate multiple ecosystem parameter indices into a single raster layer representing relative environmental habitat suitability.



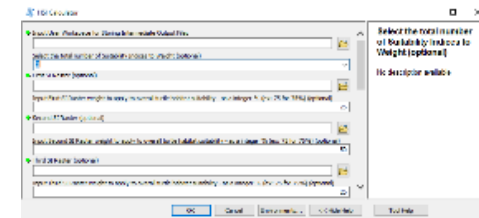
Calculate Parameter Suitability Index



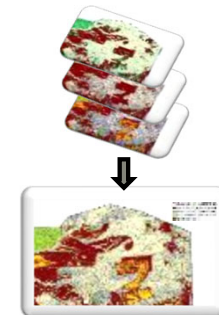
Tool Development:

- Raster/vector parameter input
- Predefined HSI curves (R-based index model)
- Habitat Suitability Index Calculator
 - Arithmetic mean
 - Geometric mean
 - Weighted mean
 - Minimum limiting factor

Multiple Parameter Suitability Indices



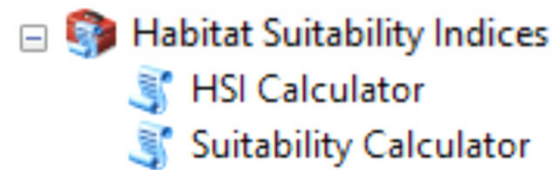
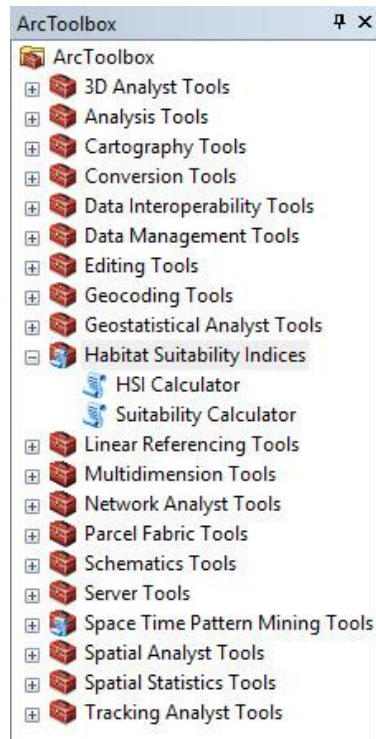
Calculate HSI





Habitat Suitability Index

Geospatial Toolbox



Tool Requirements:

ArcGIS 10.x

Spatial Analyst Extension

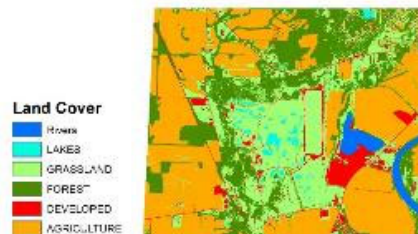
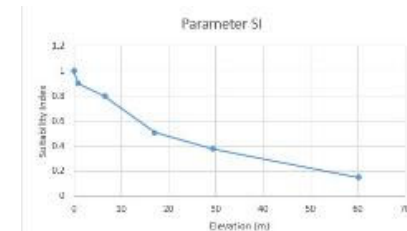
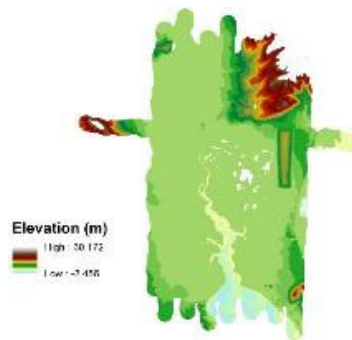
Python 2.7

Habitat Suitability Index

Suitability Calculator Tool Inputs

- ❖ Area of interest polygon
- ❖ Parameter raster (ie. elevation, land cover)
- ❖ CSV file of habitat suitability

Habitat Suitability Indices
 HSI Calculator
 Suitability Calculator



	A	B	C	D	E	F	G	H
1	PrjName	elev.value	elev.si	treehght.val	treehght.si	landcover.val	landcover.si	comments
2	Ohio	0	1	51.6	1	WATER	1	source: Smith et al 2016
3	Ohio	1	0.9	25.1	0.95	FORESTED	0.75	NA
4	Ohio	6.5	0.8	16.5	0.85	GRASS	0.5	NA
5	Ohio	17.1	0.51	12.2	0.59	AG	0.25	field tested
6	Ohio	29.4	0.38	8.12	0.265	URBAN	0	NA
7	Ohio	60.1	0.15	6.2	0.1			source: John and Kindle 2018
8	Ohio			1.5	0			NA
9								



Habitat Suitability Index

Suitability Calculator Tool – Numerical Input

Suitability Calculator

Select User Workspace Folder for Storing Output Files
E:\ERDC_Workspace\Projects\2019\EcoModels\HSI\ModelOutput

Output Project Name
ProjectArea

Input Location of Interest (as a polygon)
StudyArea

☐ Data is Categorical (eg. land use, species class) (optional)

Input Raster Parameter Data
E:\ERDC_Workspace\Projects\2019\EcoModels\HSI\TestData\elelevation

Select the field containing the parameter value (optional)

Data Table for ReMapping Data Ranges to HSI values for Parameter (.csv)
E:\ERDC_Workspace\Projects\2019\EcoModels\HSI\HSIvalueTables\HSIvalues.csv

Select the field containing the parameter categorized value (optional)

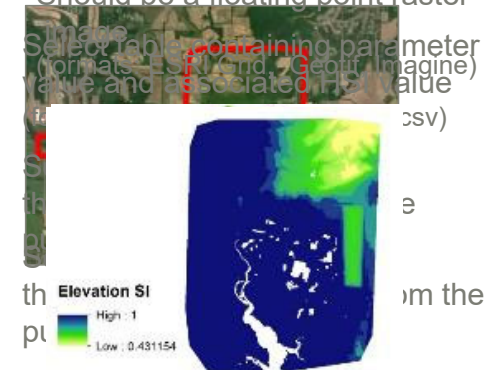
Select the field containing the parameter value (optional)

elev.value
elev.si
elev.value
elev.si
treehght.val
treehght.si
landcover.si

Output Parameter SI Raster
E:\ERDC_Workspace\Projects\2019\EcoModels\HSI\ModelOutput\elev_si

OK Cancel Environments... << Hide Help

Select User Workspace for storage of output files
The project name will be used as a prefix to the output feature layer, used to clip high names layer, project area, hsi.gdb
Select input parameter raster (formats: ESRI shapefile or geodatabase)
Should be a floating point raster



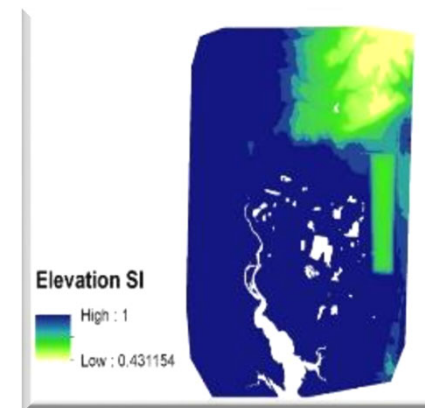
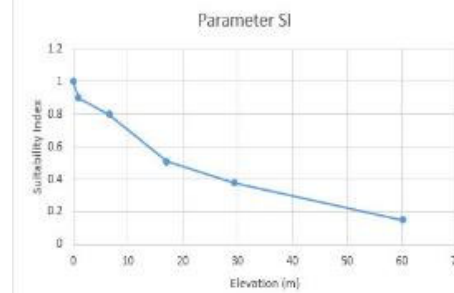
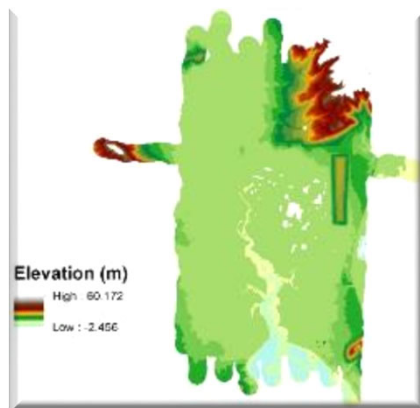
Select the location for Parameter SI output storage.
File formats (ESRI Grid is default)

PrName	elev.value	elev.si	treehght.val	treehght.si
1 Ohio	0	1	21.0	1
2 Ohio	1	0.9	25.1	0.95
3 Ohio	17.1	0.51	12.2	0.59
4 Ohio	0.38	8.12	0.265	
5 Ohio	0.15	6.2	0.1	



Habitat Suitability Index

Suitability Calculator Tool Numerical Output



Habitat Suitability Index

Suitability Calculator Tool – Categorical Input

Suitability Calculator

Select User Workspace Folder for Storing Output Files
E:\ERDC_Workspace\Projects\2019\EcoModels\HST\ModelOutput

Output Project Name
ThematicArea

Input Location of Interest (as a polygon)
StudyArea

☒ Data is Categorical (eg. land use, species class) (optional)

Input Raster Parameter Data
E:\ERDC_Workspace\Projects\2019\EcoModels\HST\TestData\landcover

Select the field containing the parameter value (optional)
CLASS

Rowid
VALUE
COUNT
CLASS

Select the field containing the suitability index value (0.0 - 1.0) to which each range should be mapped
landcover.si

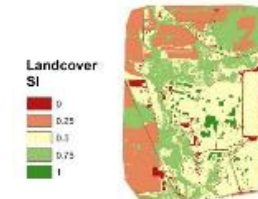
Select input parameter value to match to csv HSI table value (optional)

Parameter Value	CSV Value
AGRICULTURE	AG
	FORESTED
	GRASS
	URBAN
	WATER

E:\ERDC_Workspace\Projects\2019\EcoModels\HST\ModelOutput\landcover_si

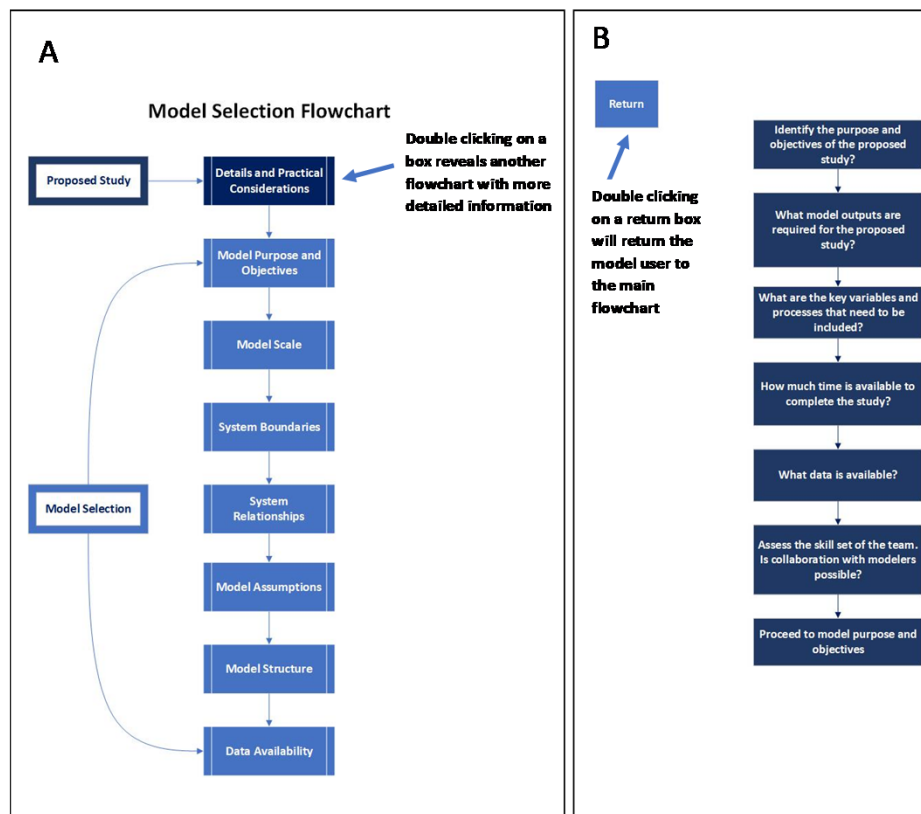
OK Cancel Environments... << Hide Help

Select checkbox if parameter raster is thematic
Select thematic raster such as (ie. land cover, vegetation type)
Select field from thematic raster (formats: ESRI, Gd, geotiff, imagine) containing the parameter value
Select the field containing the parameter value from the list
Select a parameter value from the raster thematic map, then match that value to the CSV parameter value from the pull down menu in the CSV Value column
Example of matched parameters





INTERACTIVE MODEL SELECTION TOOL

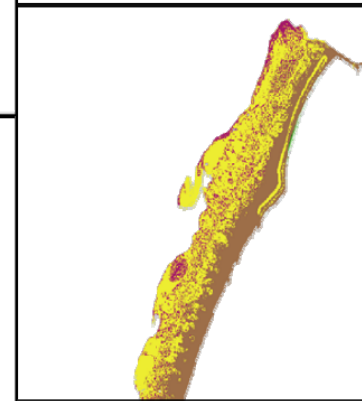
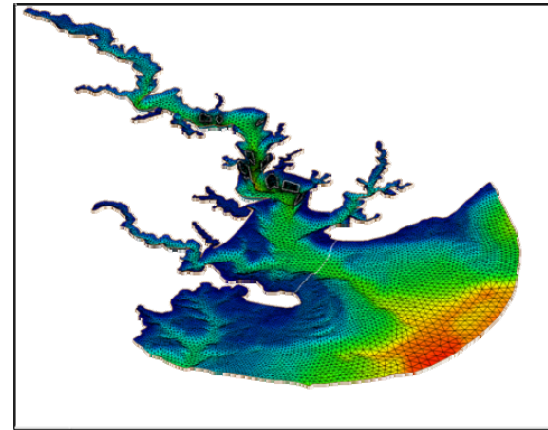


Developing an interactive flow chart to guide through model selection for existing models or new models



FUTURE DIRECTIONS

- Implementing ERDC technology and models across USACE
- The field of modeling has come a long way, ERDC is actively moving the needle, but there's more to be done
- Developing new tools
 - Multi-platform TAM
 - Model selection tool
 - Interactive spatial toolkits
 - Refining integrated modeling packages
 - Guidance for good modeling practices





QUESTIONS AND COMMENTS

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- Ecosystem Management and Restoration Research Program (EMRRP)
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- Water Operations Technical Support (WOTS) Program
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POTENTIALLY USEFUL RESOURCES



- McKay S.K., Richards N., and Swannack T. 2019. Aligning ecological model development with restoration project planning. *ERDC EMRRP-SR-89*. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Toolkit for interActive Modeling (TAM), Certified for National Use.
- ERDC Technical Note – Ecological model development: Toolkit for interActive Modeling (Forthcoming)
- Habitat Suitability Modeling Tools
 - Library of 500+ USFWS Habitat Suitability Models
 - EcoRest R package + Vignette / User Manual (Spring 2020)
 - EcoRest Shiny App (Summer 2020)
 - ArcGIS Toolbox + User Manual
- Best Practices in Model Development:
 - Herman B., McKay S.K., Altman S., Richards N.S., Reif M., Piercy C.D., and Swannack T.M. 2019. Unpacking the black box: Demystifying ecological models through interactive workshops and hands-on learning. *Frontiers in Environmental Science*, 7, 122.
 - McKay S.K., Kohtio D.M., Scarpa C.A., Tommaso D.M., Weppeler P.M., and Baron L.A. 2020. Incorporating multiple lines of evidence in urban stream restoration decision-making. Submitted to *Journal of the American Water Resources Association*.
 - Book Chapter – Encyclopedia of Ecology – Systems ecology
 - Book Chapter – Encyclopedia of Ecology – Model Types: Overview
 - Book Chapter – Encyclopedia of Ecology – Visualization as a tool for ecological analysis
 - ERDC Technical Note – Evaluation of system quality (Summer 2020)
 - ERDC Technical Note – Best practices for coding ecological models (Summer 2020)
 - ERDC Technical Note – Model application using scenario analysis (Spring 2020)
 - ERDC Technical Note – Conceptual modeling for large-scale regional projects (Spring 2020)
- Webinars: Models and SMART Planning (Proctor Creek), environmental flow modeling (Minnesota River), Incorporating secondary objectives to restoration planning (Hudson-Raritan Estuary), Data visualization,...
- Conferences: Ecological Society of America, Society for Freshwater Science, Symposium on Urban Stream Ecology
- Video series on key aspects of the model development process (Summer 2020)
- Facilitated modeling workshops: East San Pedro Bay, Cypress Valley, New York Bight, Swan Island, San Francisco Bay