Developing a Habitat Suitability Index (HSI) for Brown Trout in White Clay Creek Using Fuzzy Logic

BEN PLUMRIDGE & CATHY YU

LIAISON: VAL OUELLET

Our project

- Decide which abiotic parameters best explain the presence or absence of brown trout

- Develop a Habitat Suitability Index (HSI) with those parameters using fuzzy logic.

Habitat Suitability Index (HSI)

- Numerical index between 0 and 1
- Represents the capacity of a habitat to support a selected species
- Aids in decision making for management of species' habitats

Fuzzy Logic

Definition:

A knowledge-based method that recognizes more than simple true and false values.

History:

Fuzzy logic was first developed by Zadeh(1965) to represent imprecise or uncertain knowledge, for describing complex or ill-defined systems.

Applications:

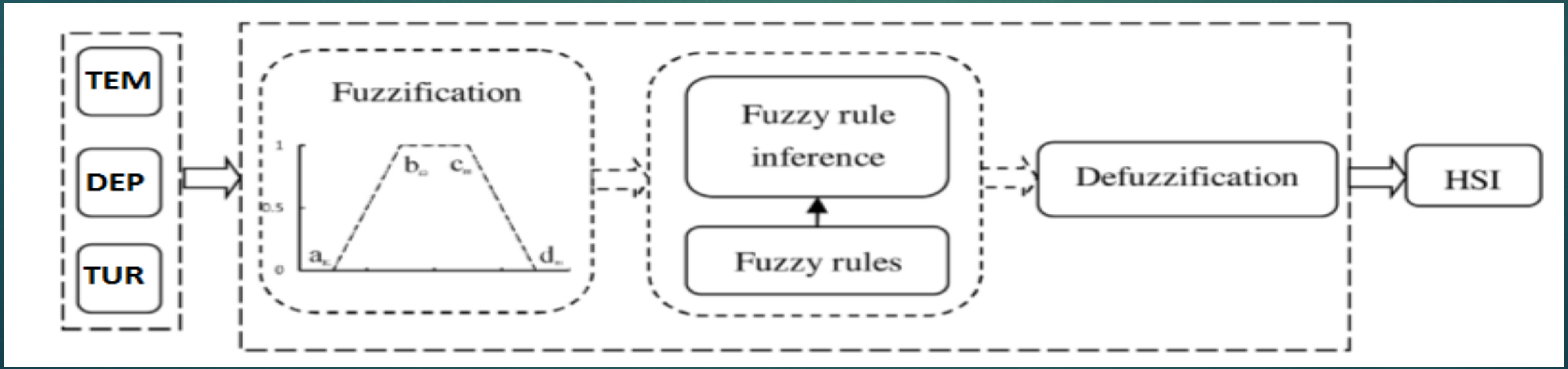
- Rice cookers
- Spell checker
- Automatic washing machines
- Refrigerators

Other Methods to generate HSI outputs:

- Regression Models

Fuzzy Logic

- A fuzzy logic system consists of:
- Fuzzy sets: fuzzy inputs, outputs and their associated membership functions.
- Fuzzy rules: that combine variables with one another to generate a consequence.
- Fuzzy inference method: which is used to process the sets of consequences to reach a conclusion.
- Defuzzifying the output distribution (Center of Gravity)



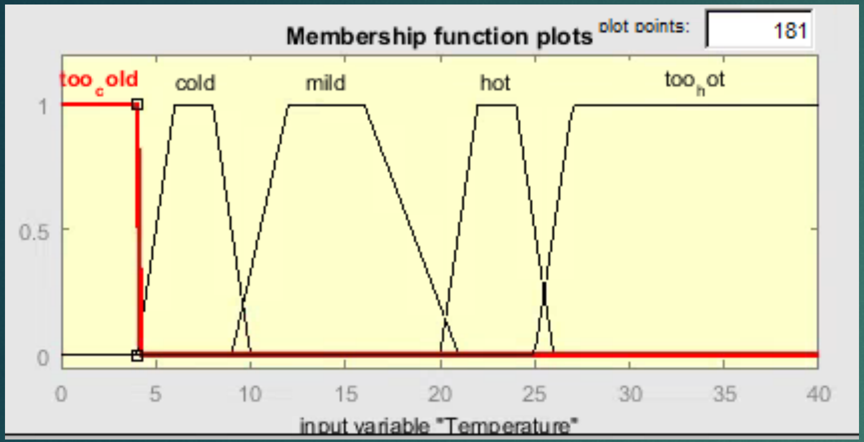
Correlation Procedure

Pearson Correlation Coefficients, N = 88 Prob > |r| under H0: Rho=0			
	temperature	depth	turbidity
temperature temperature	1.00000	-0.19584 0.0675	0.19346 0.0709
depth depth	-0.19584 0.0675	1.00000	0.23168 0.0299
turbidity turbidity	0.19346 0.0709	0.23168 0.0299	1.00000

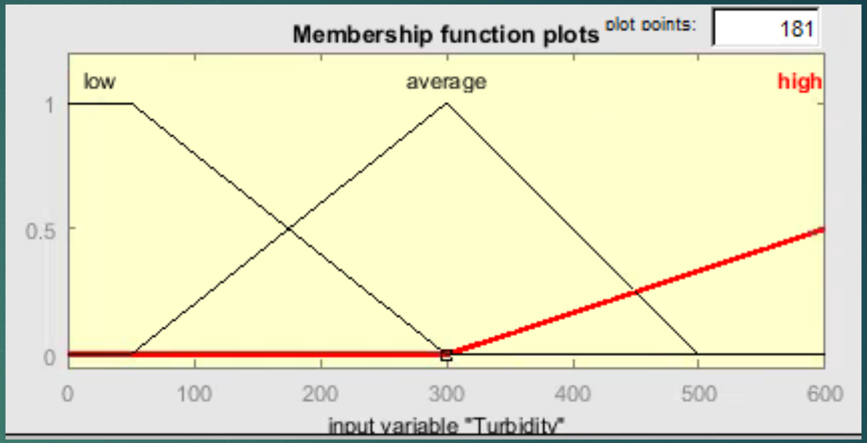
Data Mining

- SAS algorithms
- Output average values of each parameter over a day at each site
- Create new dataset to contain only: site, date, temperature, depth, turbidity
- Omit all observations with any missing values.

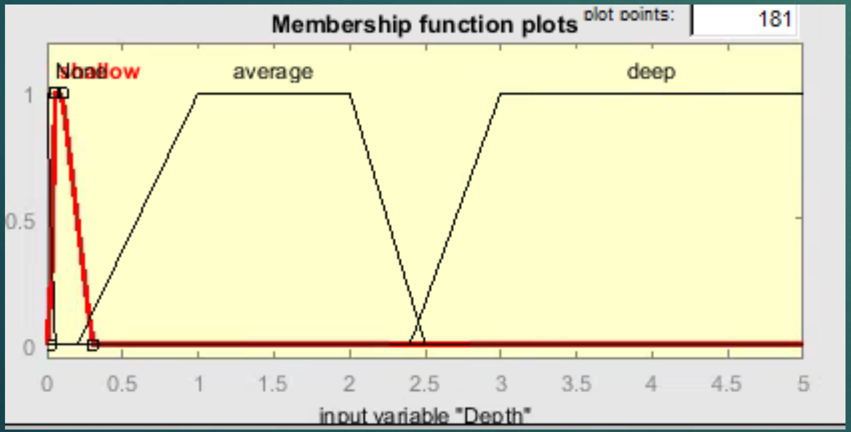
Our Fuzzy-logic Model – Membership Functions



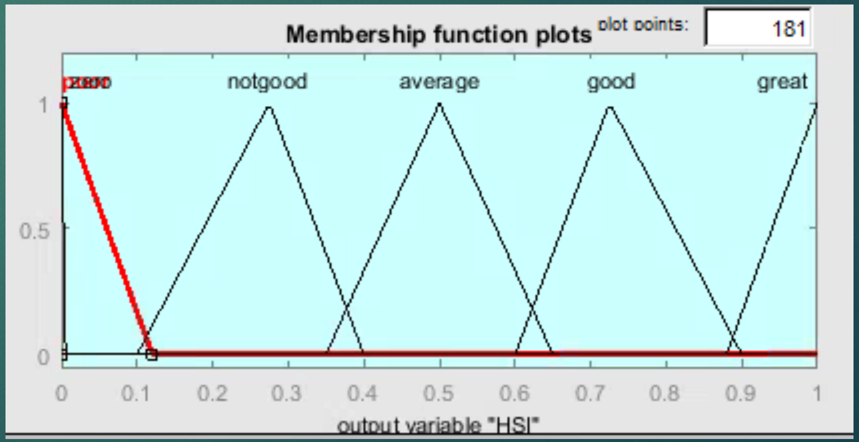
Temperature (input)



Turbidity (input)



Depth (input)



HSI (output)

Parameter values

Variables	Categories	Parameters [a1 a2 a3 a4]
Temperature (Input)	Very cold	[-infinity, -10, 4, 4]
	Cold	[4, 6, 8, 10]
	Mild	[9, 12, 16, 21]
	Hot	[20, 22, 24, 26]
	Too hot	[25, 27, infinity, infinity]
Depth (Input)	Low	[0.02, 0.05, 0.1, 0.3]
	Average	[0.2, 1, 2, 2.5]
	Deep	[2.4, 3, 4, infinity]
Turbidity (Input)	Low	[0, 0, 50, 300]
	Average	[50, 300, 500]
	Hight	[300, 900, infinity, infinity]
HSI (Output)	Poor	[0, 0, 0.12]
	Not good	[0.1, 0.275, 0.4]
	Average	[0.35, 0.5, 0.65]
	Good	[0.6, 0.725, 0.9]
	Great	[0.88, 1, 1]

Our Fuzzy-logic Model – Rules

Less-Conservative Model

12 rules

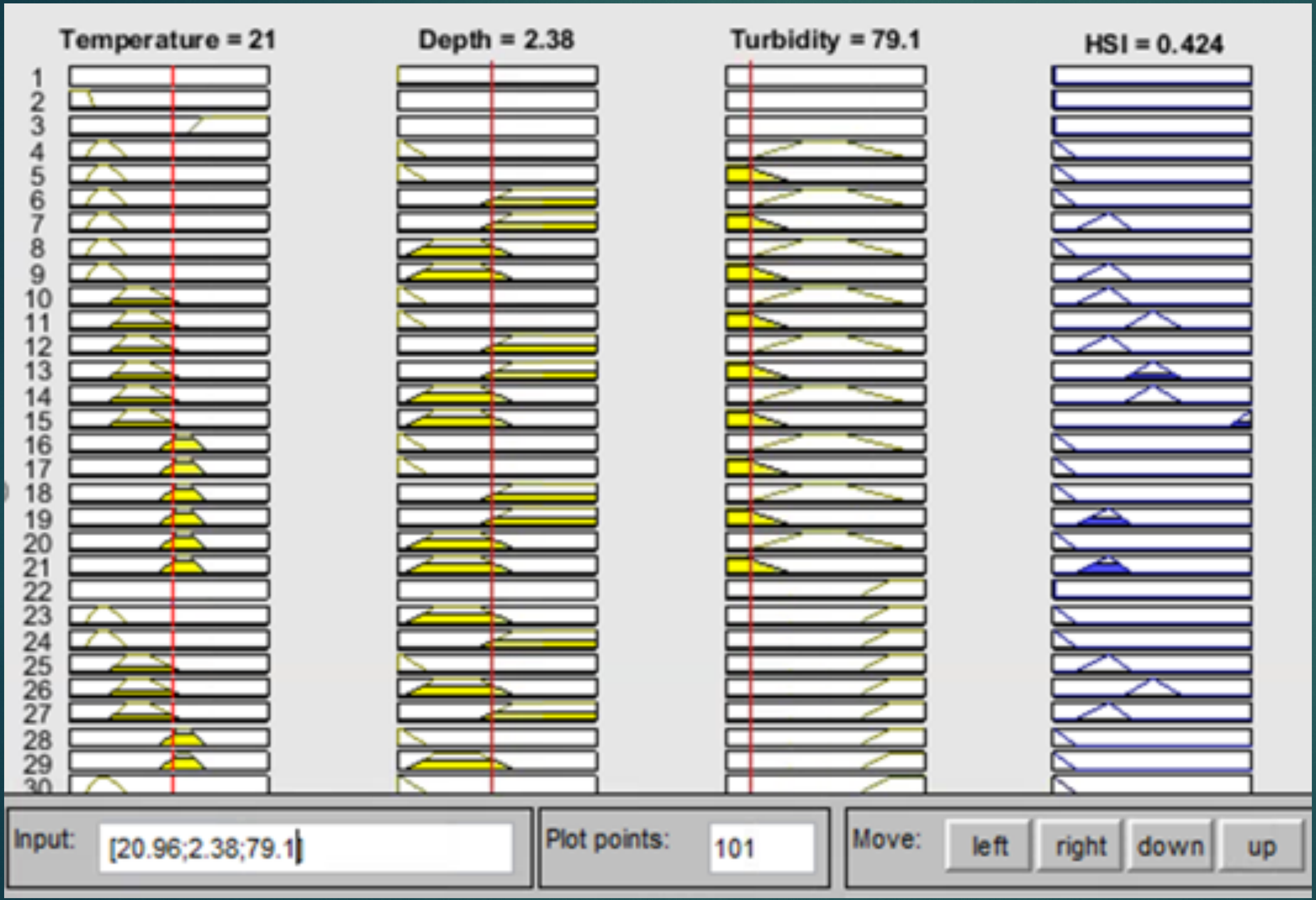
1. If (Temperature is cold) then (HSI is notgood) (0.001)
2. If (Temperature is mild) then (HSI is great) (0.001)
3. If (Temperature is hot) then (HSI is poor) (0.001)
4. If (Depth is shallow) then (HSI is notgood) (0.001)
5. If (Depth is deep) then (HSI is notgood) (0.001)
6. If (Depth is average) then (HSI is great) (0.001)
7. If (Turbidity is high) then (HSI is zero) (1)
8. If (Turbidity is low) then (HSI is great) (0.001)
9. If (Depth is None) then (HSI is zero) (1)
10. If (Temperature is too_cold) then (HSI is zero) (1)
11. If (Temperature is too_hot) then (HSI is zero) (1)
12. If (Turbidity is average) then (HSI is average) (0.001)

Conservative model

30 rules

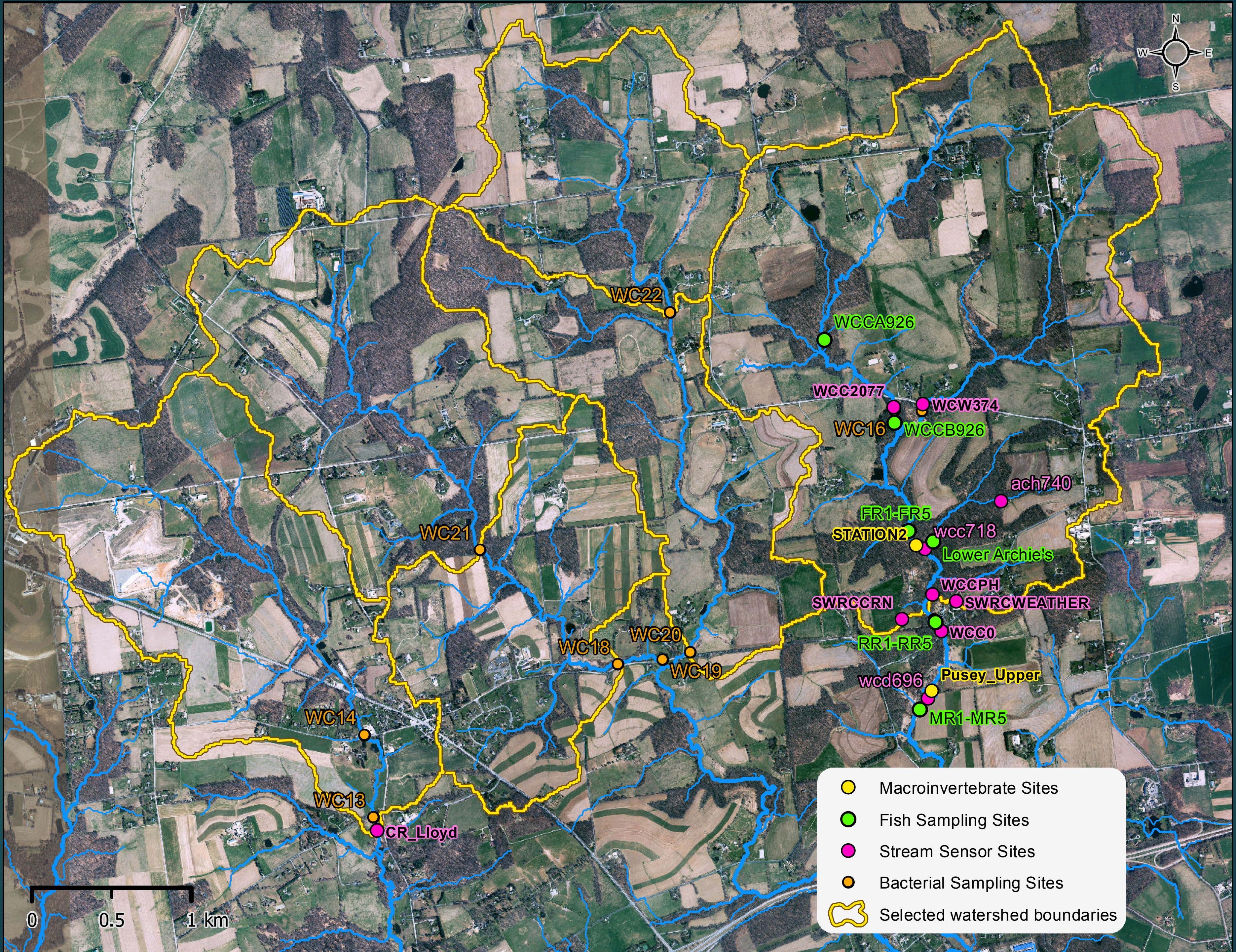
1. If (Depth is None) then (HSI is zero) (1)
2. If (Temperature is too_cold) then (HSI is zero) (1)
3. If (Temperature is too_hot) then (HSI is zero) (1)
4. If (Temperature is cold) and (Depth is shallow) and (Turbidity is average) then (HSI is poor) (1)
5. If (Temperature is cold) and (Depth is shallow) and (Turbidity is low) then (HSI is poor) (1)
6. If (Temperature is cold) and (Depth is deep) and (Turbidity is average) then (HSI is poor) (1)
7. If (Temperature is cold) and (Depth is deep) and (Turbidity is low) then (HSI is notgood) (1)
8. If (Temperature is cold) and (Depth is average) and (Turbidity is average) then (HSI is poor) (1)
9. If (Temperature is cold) and (Depth is average) and (Turbidity is low) then (HSI is notgood) (1)
10. If (Temperature is mild) and (Depth is shallow) and (Turbidity is average) then (HSI is notgood) (1)
11. If (Temperature is mild) and (Depth is shallow) and (Turbidity is low) then (HSI is average) (1)
12. If (Temperature is mild) and (Depth is deep) and (Turbidity is average) then (HSI is notgood) (1)
13. If (Temperature is mild) and (Depth is deep) and (Turbidity is low) then (HSI is average) (1)
14. If (Temperature is mild) and (Depth is average) and (Turbidity is average) then (HSI is average) (1)
15. If (Temperature is mild) and (Depth is average) and (Turbidity is low) then (HSI is great) (1)

Fuzzy rules

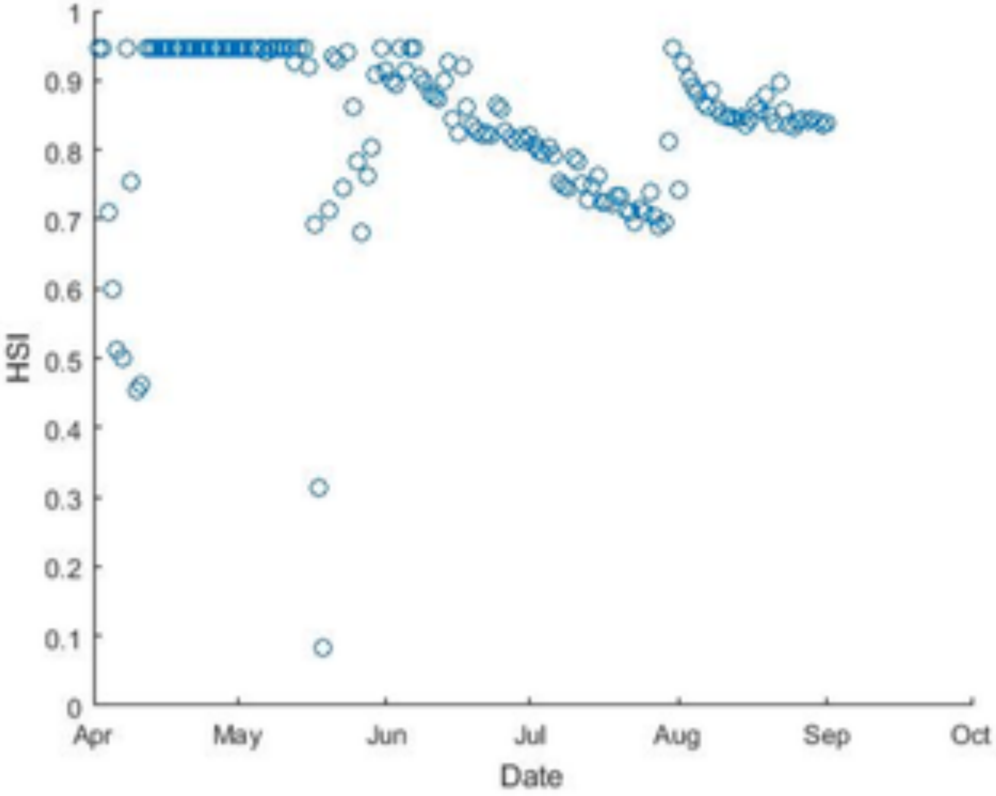


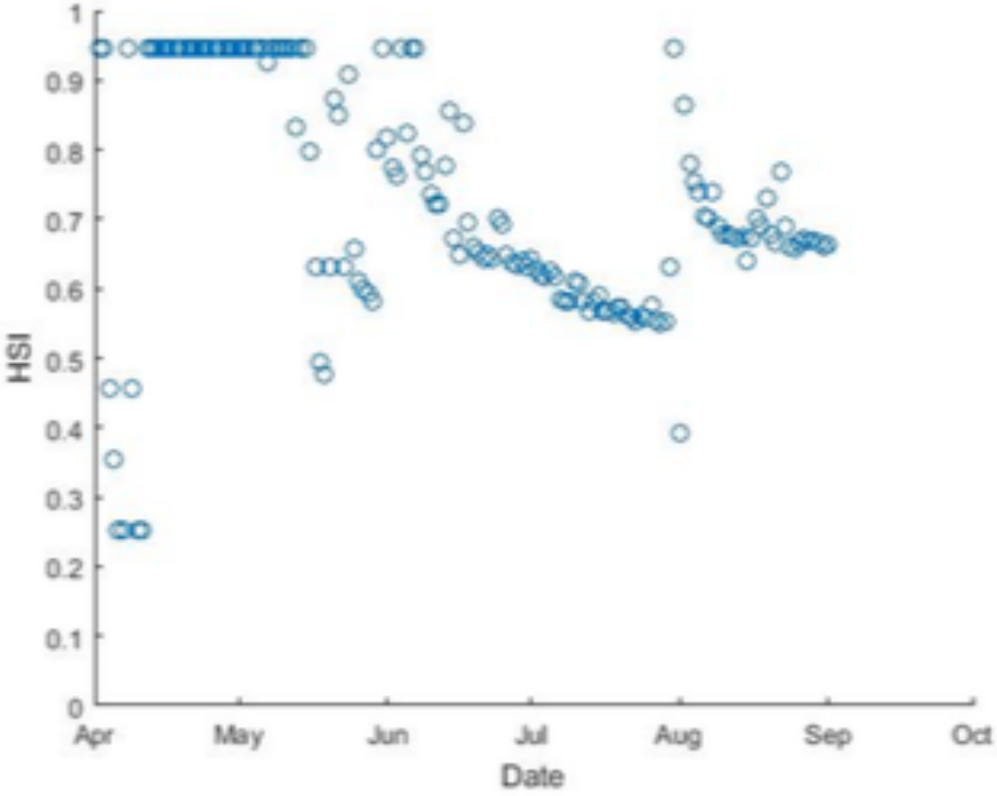
$$\mu_{A\cap B} = min(\mu_A(x), \mu_B(x))$$

$$\mu_{A\cup B} = max(\mu_A(x), \mu_B(x))$$


N
W
E
S
WC22
WCCA926
WCC2077
WCW374
WC16
WCCB926
ach740
FR1-FR5
STATION2
wcc718
Lower Archie's
WC21
WCCPH
SWRCCRN
SWRCWEATHER
WCC0
RR1-RR5
WC20
WC18
WC19
wcd696
Pusey_Upper
MR1-MR5
WC14
WC13
CR_Lloyd
0
0.5
1 km
Macroinvertebrate Sites
Fish Sampling Sites
Stream Sensor Sites
Bacterial Sampling Sites
Selected watershed boundaries

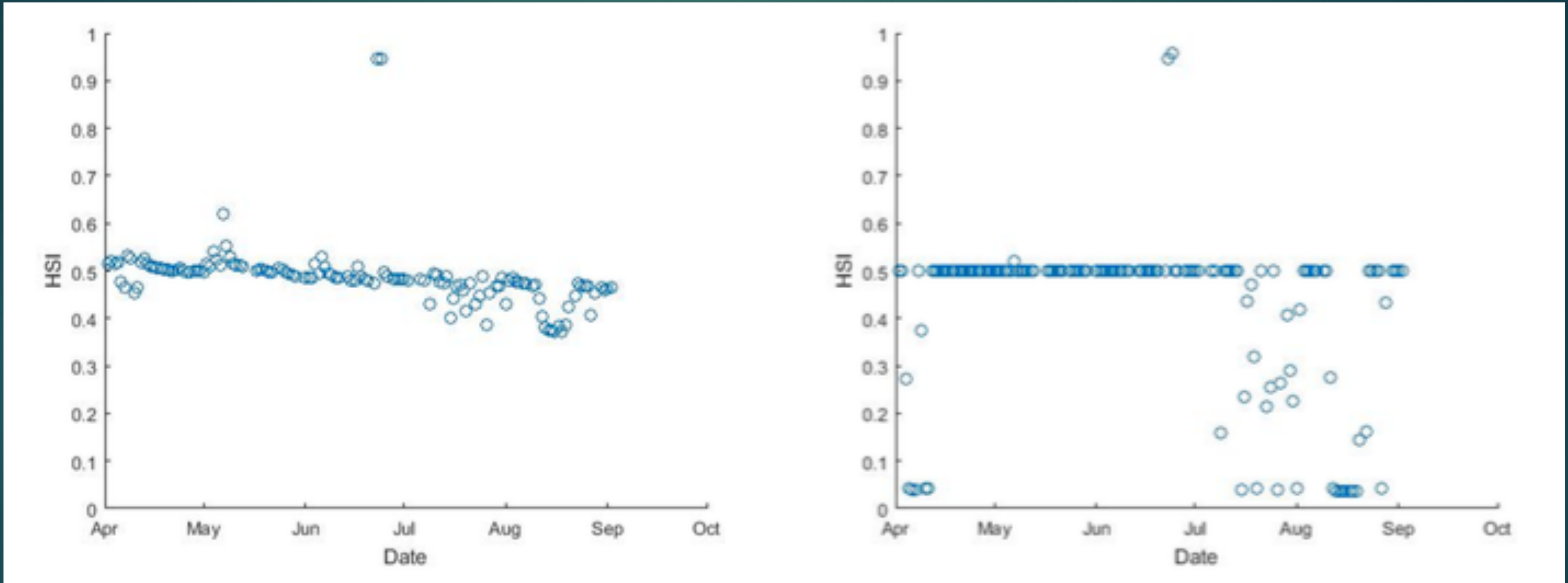
HSI outputs for Location 1 in White Clay Creek





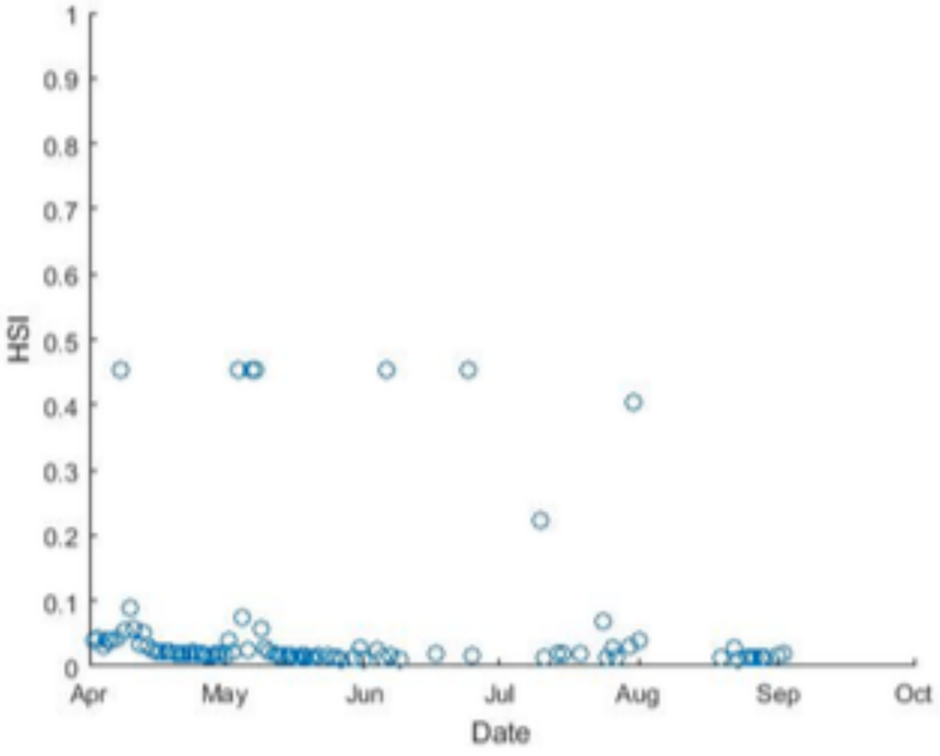
WCC2077

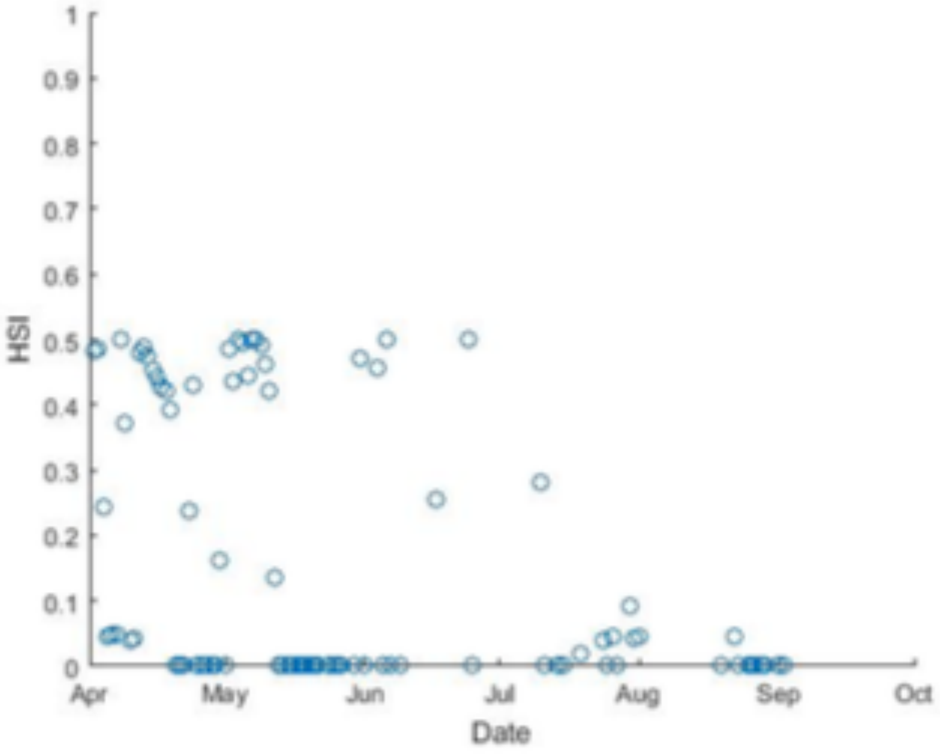
HSI outputs for Location 2 in White Clay Creek



WCC718

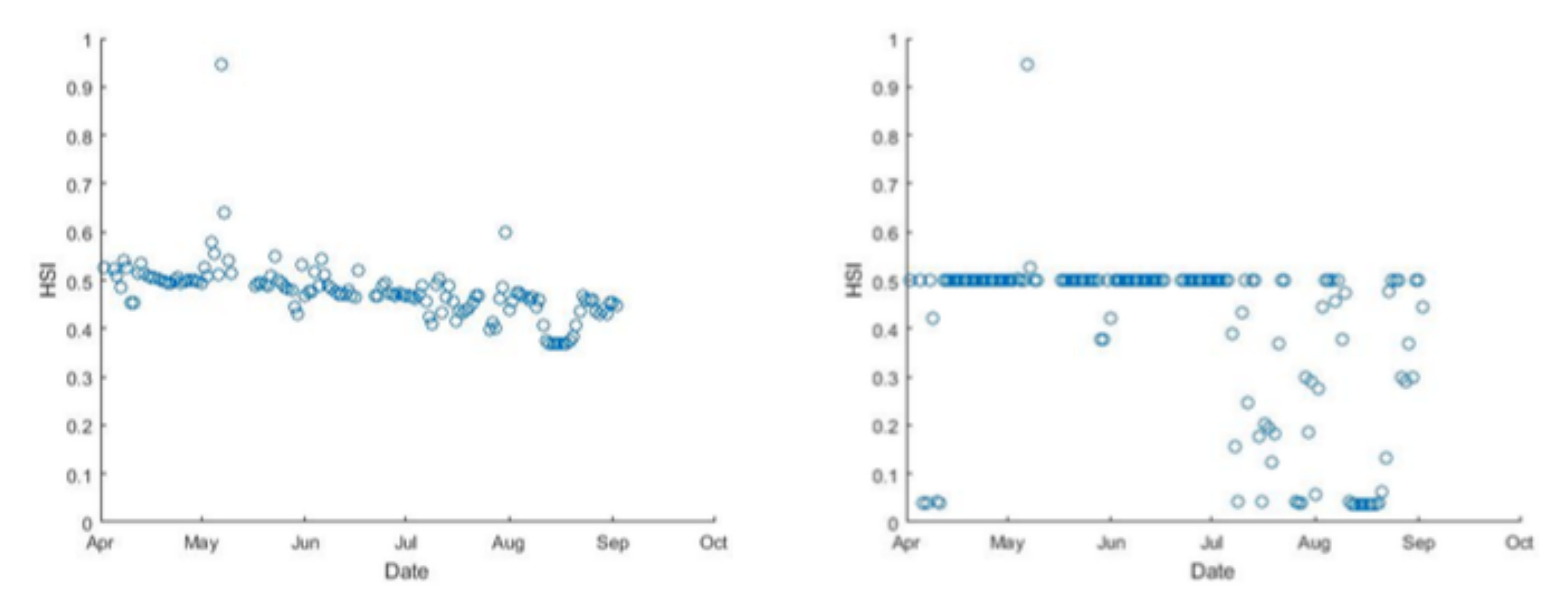
HSI outputs for Location 3 in White Clay Creek





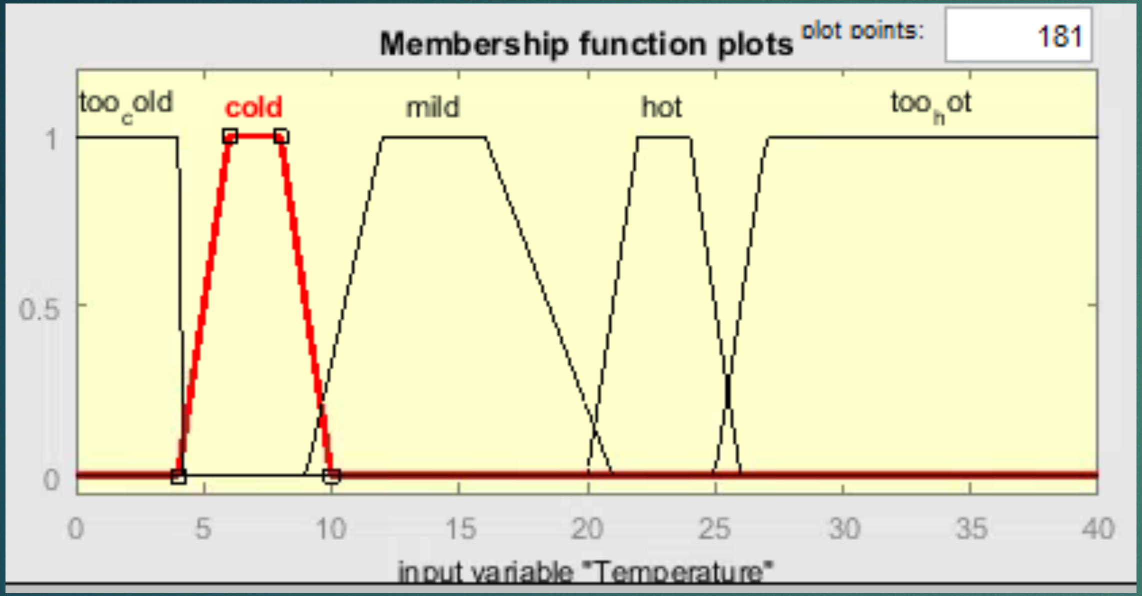
WCCPH

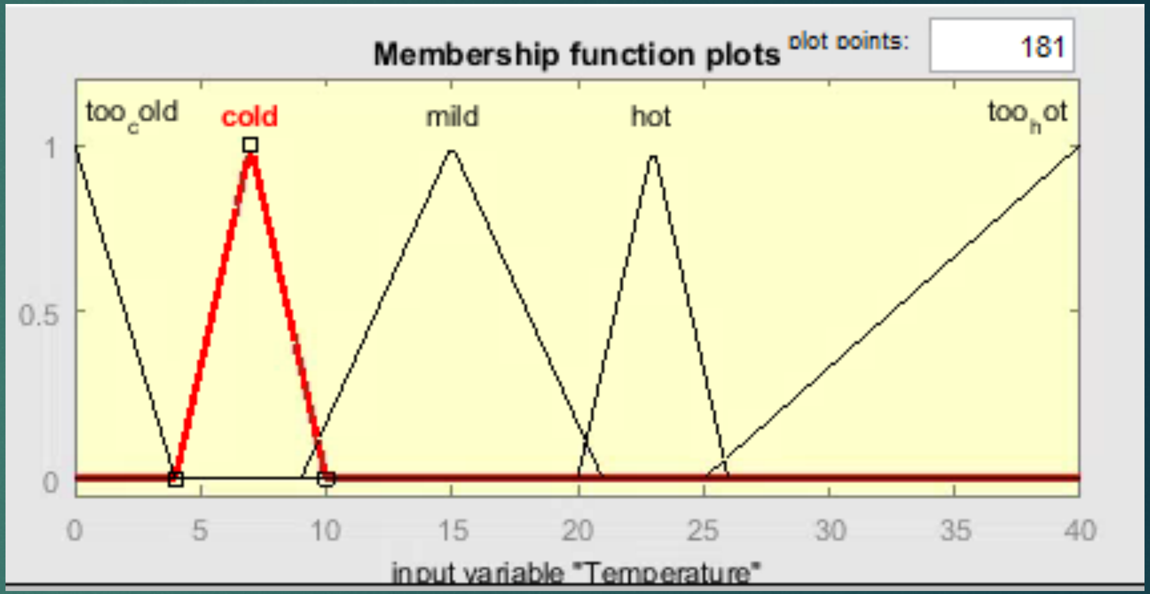
HSI outputs for Location 4 in White Clay Creek



WCD696

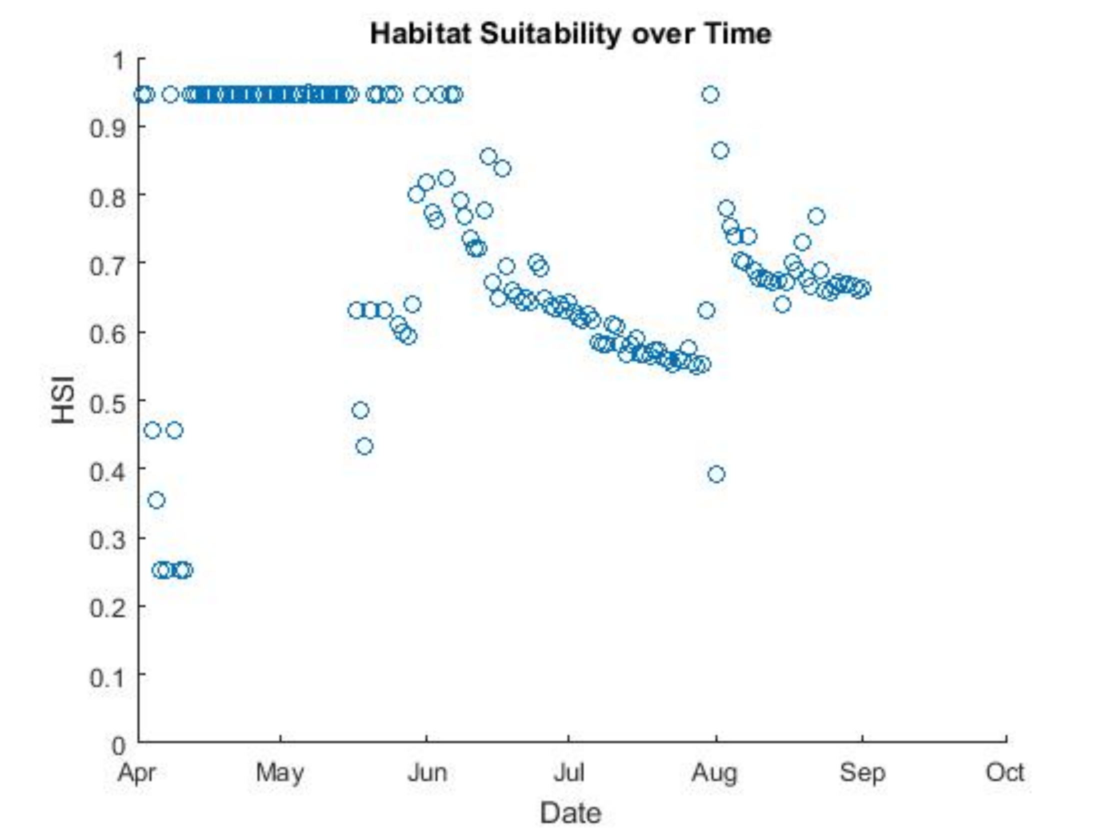
Comparison
Trapezoidal Model vs. Triangular Model

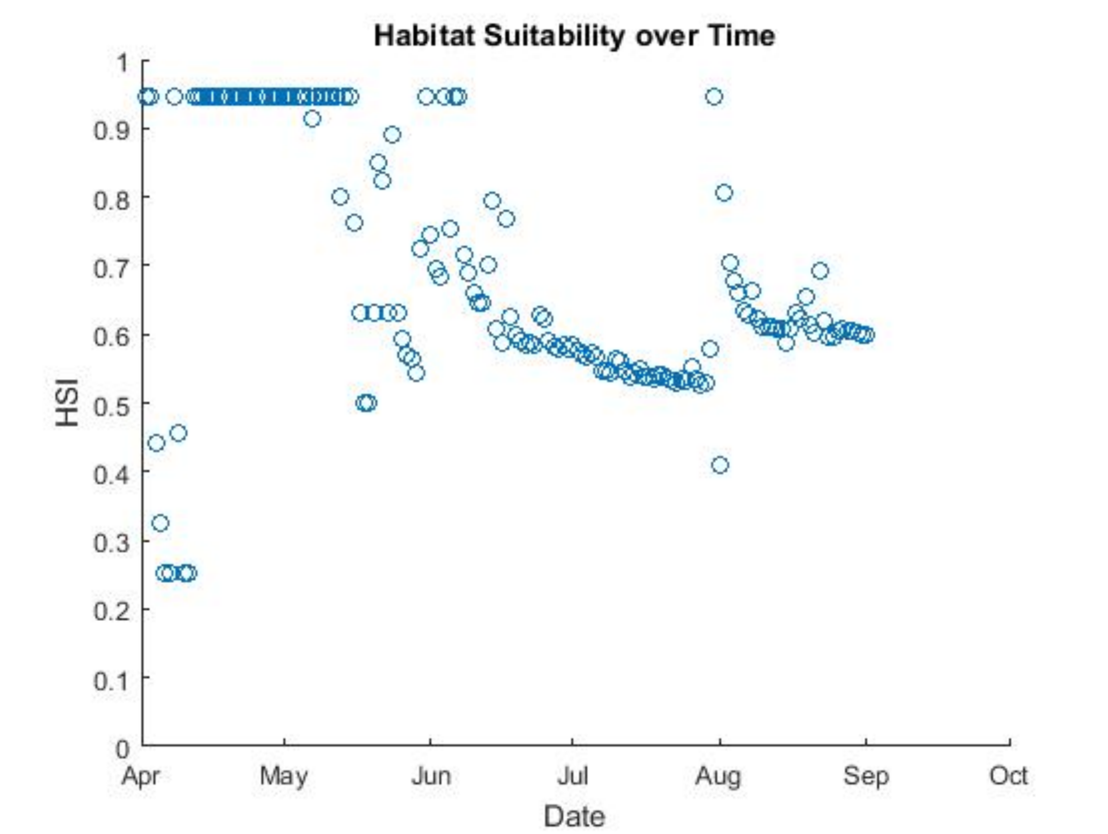




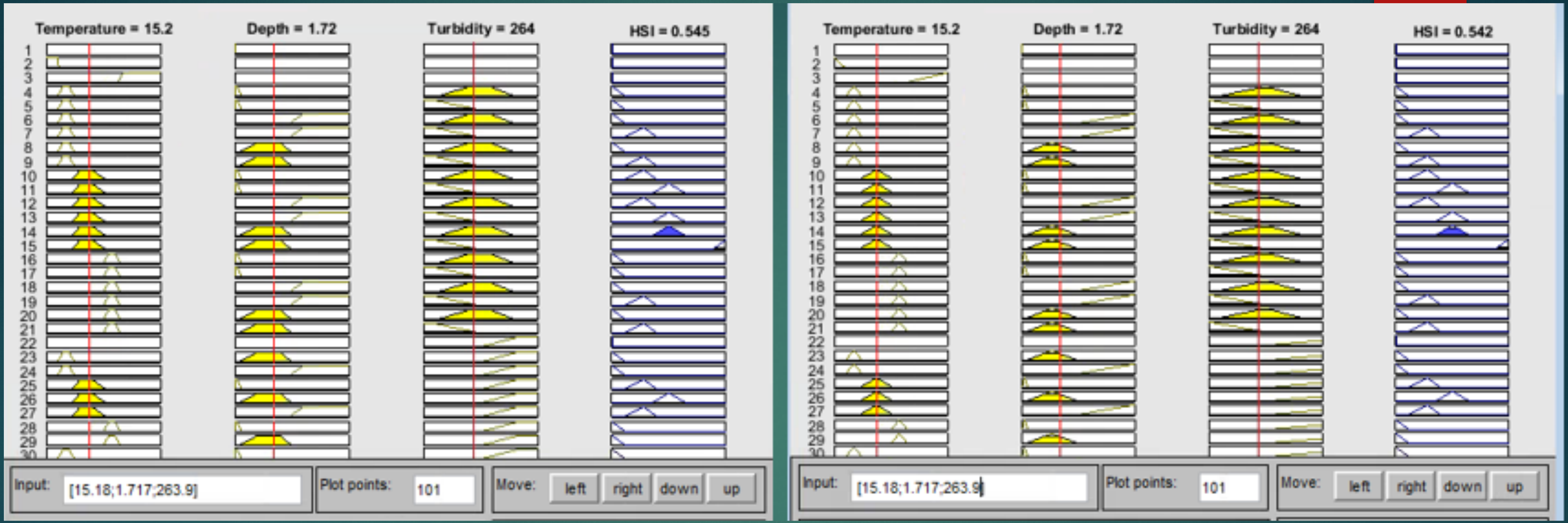
Location: WCC2077

Comparison
Trapezoidal Model vs. Triangular Model



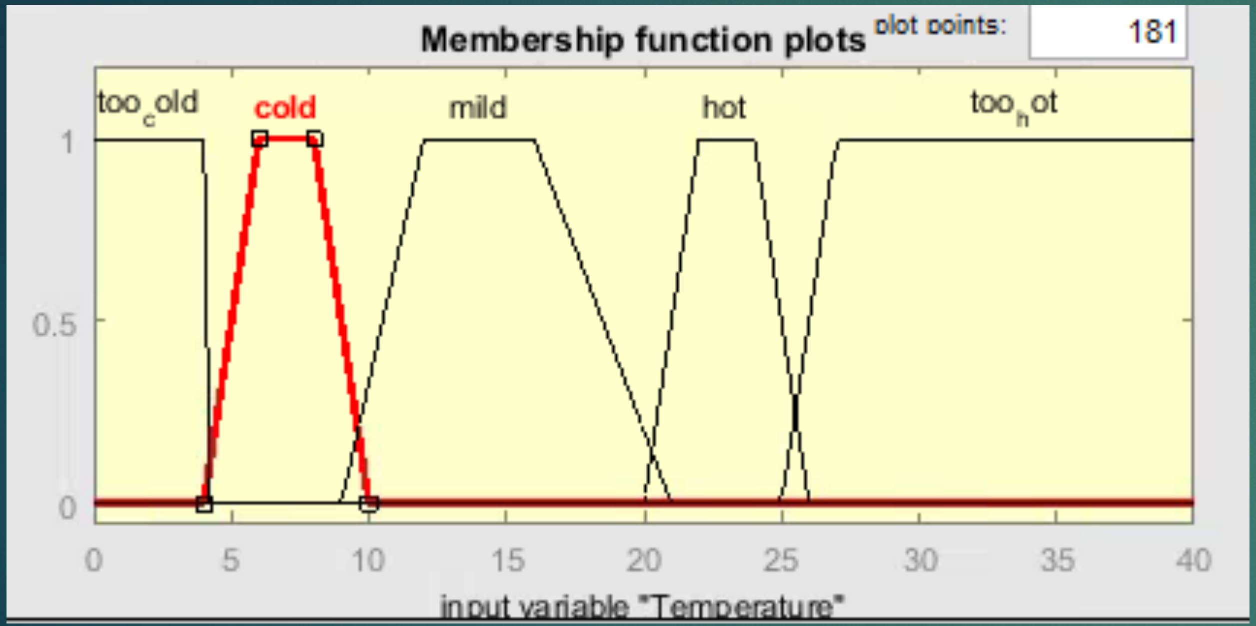


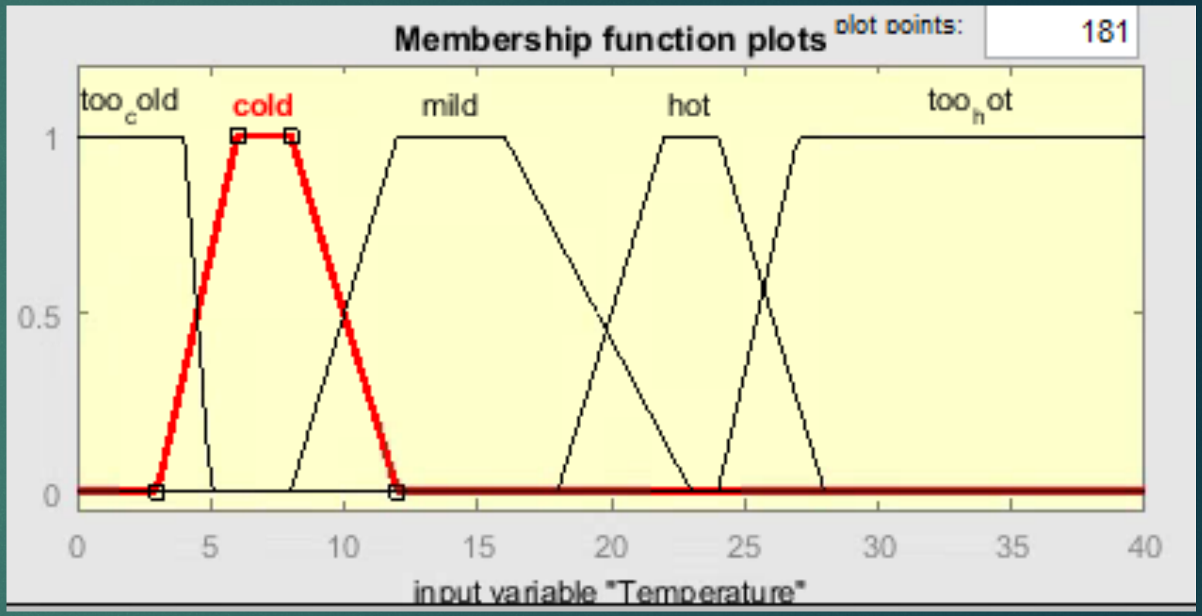
Location: WCC2077



HSI (Trapezoidal) > HSI (Triangular)

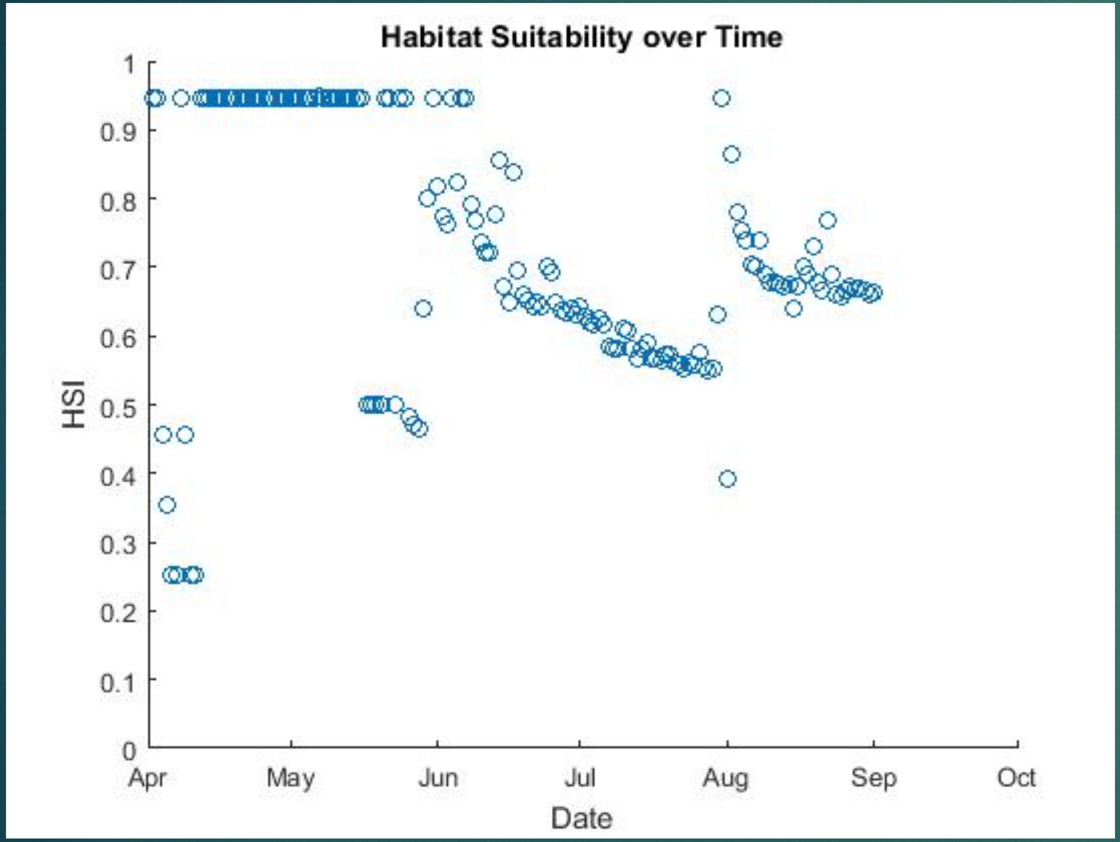
Comparison
Less overlap Model vs. More overlap Model

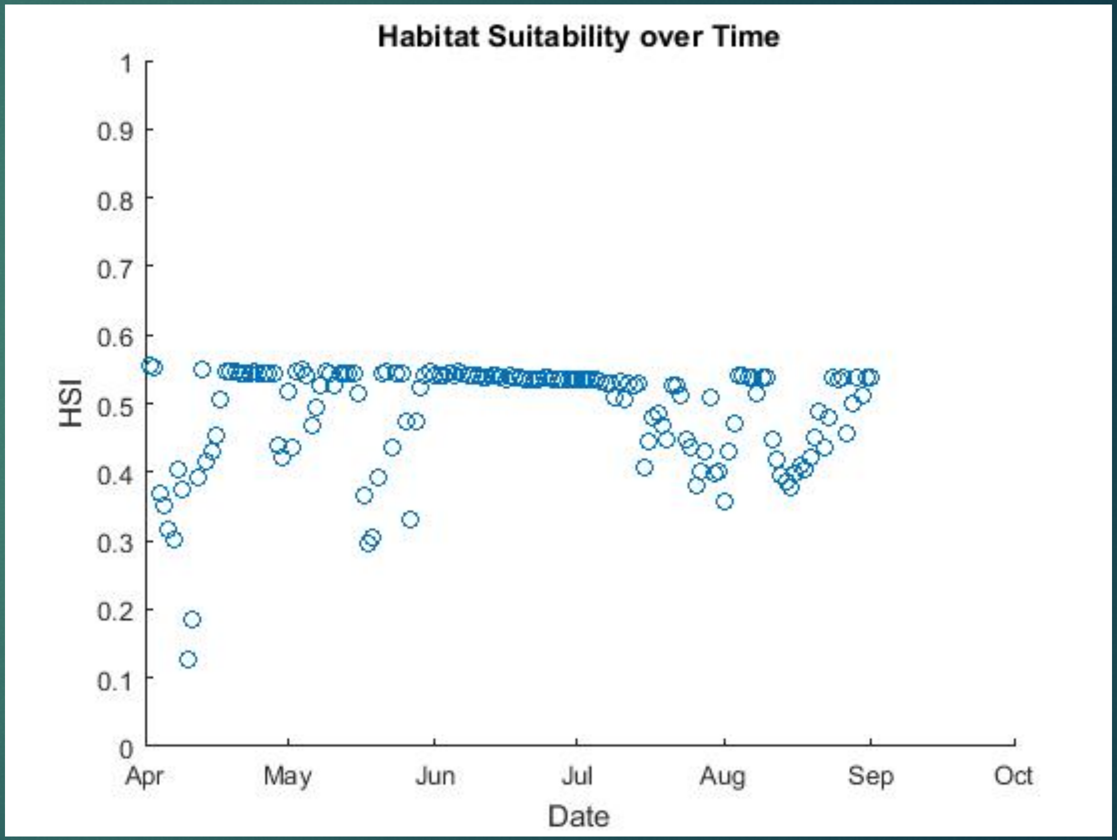




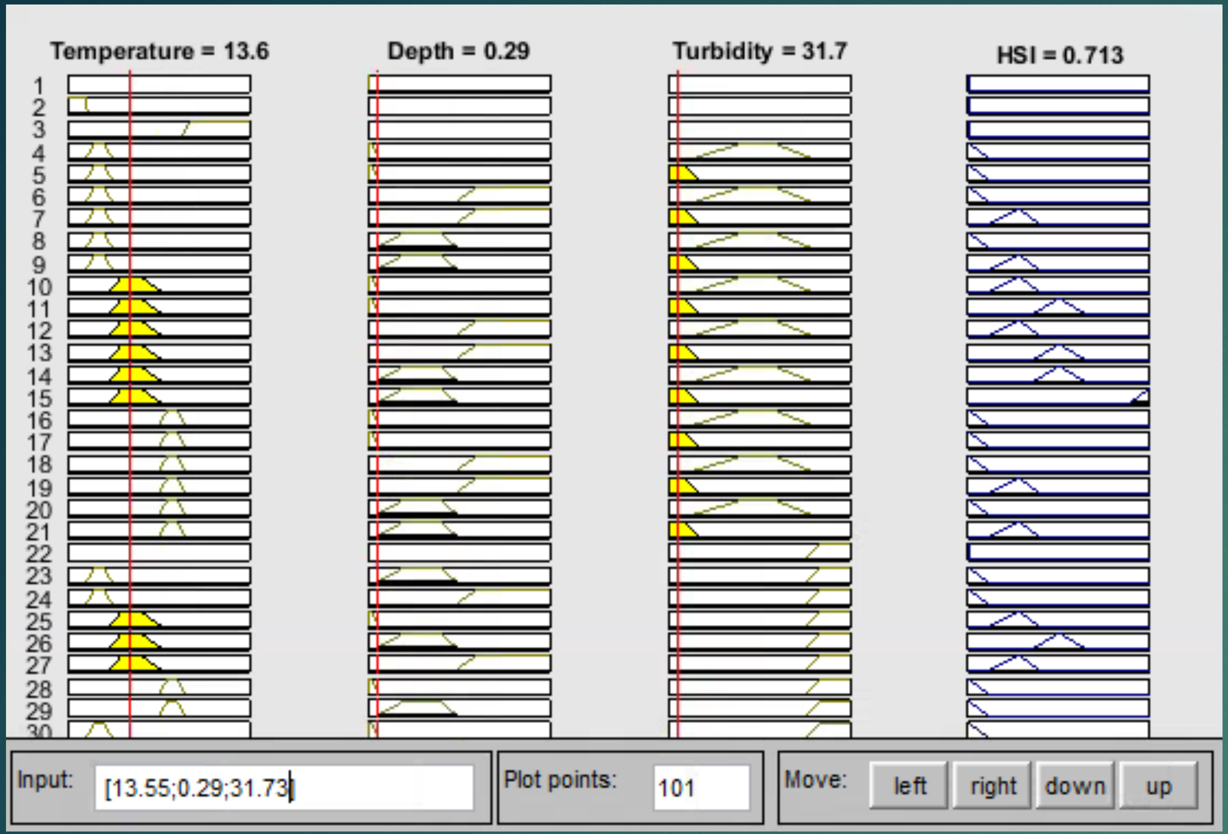
Location: WCC2077

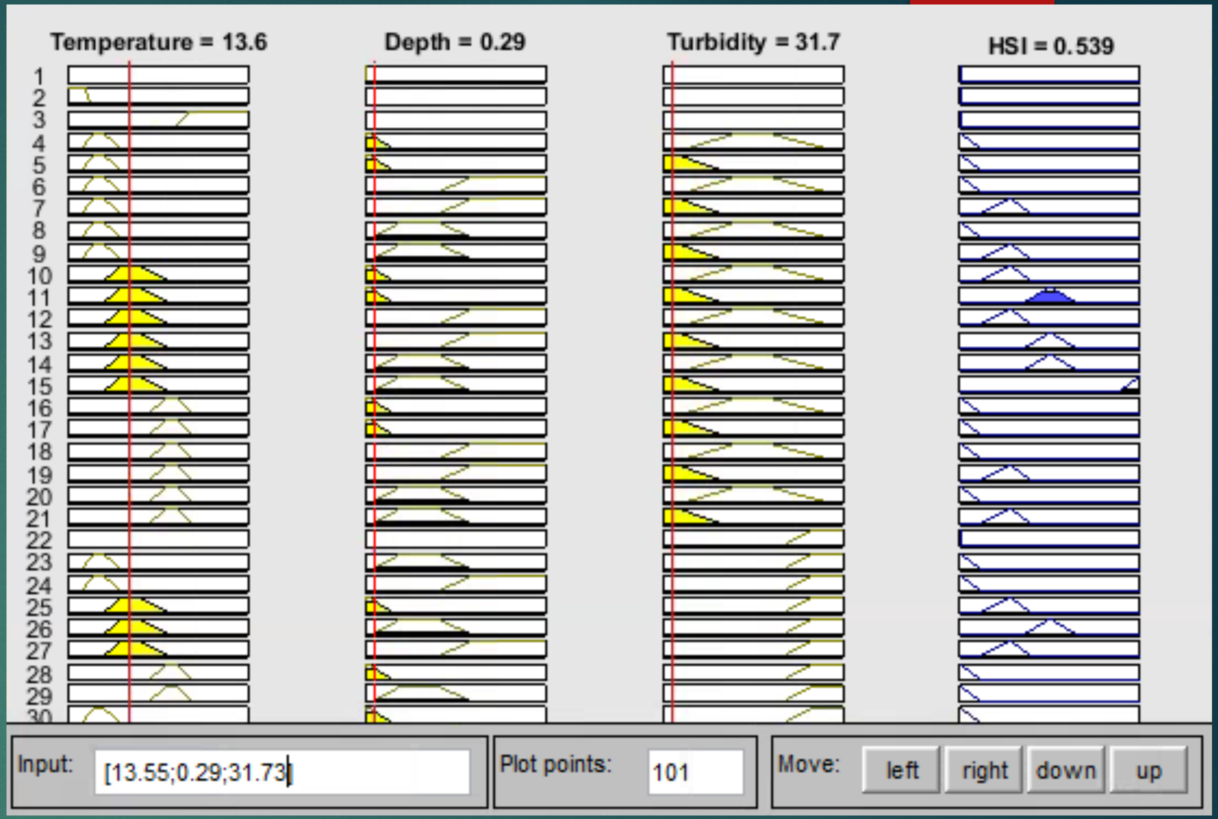
Comparison
Less overlap Model vs. More overlap Model





Location: WCC2077





HSI (Less overlap) > HSI (More overlap)

Conclusion

- Comprehensive platform to study HSI's in time
- The two approaches have similar results, validating the model
- Sensitivity analysis was conducted
  - Sensitive to parameter changes
  - Not as sensitive to membership function changes

Thank you!

Any questions?

Acknowledgements

- Val and Matt from Stroud
- Dr. Kolpas
- WCU Mathematics

References

Aggus [1] Aggus, L. R., and W. M. Bivin. 1982. Habitat suitability index models: Regression models based on harvest of coolwater and coldwater fishes in reservoirs. U.S. Dept. Int. Fish Wildl. Servo FWS/OBS-82/10.25. 38 pp.

defuzz [2] Defuzzification Methods (PID and Fuzzy Logic Toolkit)." Defuzzification Methods. National Instruments, n.d. Web. 21 Mar. 2017.

Fly [3] Fly Fishing in Rockies: Temperatures and Trout." Fly Fishing in Rockies: Temperatures and Trout. N.p., n.d. Web. 21 Mar. 2017.

Fuzzy [4] Fuzzy Sets and Pattern Recognition." Princeton University. The Trustees of Princeton University, n.d. Web. 21 Mar. 2017.

How [5] "How Rice Cookers Work." HowStuffWorks. N.p., 04 Apr. 2008. Web. 18 Apr. 2017.

Mocq [6] Habitat Suitability Index." EPA. Environmental Protection Agency, 20 Feb. 2016. Web. 20 Mar. 2017.

Mocq [7] Mocq, J., A. St-Hilaire, and R.a. Cunjak. "Assessment of Atlantic Salmon (Salmo Salar) Habitat Quality and Its Uncertainty Using a Multiple-expert Fuzzy Model Applied to the Romaine River (Canada)." Ecological Modelling 265 (2013): 14-25. Web.

Palm [8] Palm, Daniel, Eva Brannas, and Kjell Nilsson. "Canadian Journal of Fisheries and Aquatic Sciences." Predicting Site-specific Overwintering of Juvenile Brown Trout (Salmo Trutta) Using a Habitat Suitability Index - Canadian Journal of Fisheries and Aquatic Sciences. N.p., n.d. Web. 14 Feb. 2017.

Raleigh [9] Raleigh, R. F., L. D. Zuckerman, and P. C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout, revised. U.S. Fish Wildl. Servo Biol. Rep. 82(10.124). 65 pp. [First printed as: FWS/OBS-82/10.71 , September 1984]

Rouse [10] Rouse, Margaret. "What Is Fuzzy Logic? - Definition from WhatIs.com." WhatIs.com. TechTarget, n.d. Web. 21 Mar. 2017.

Xue [11] Xue, Sufeng, Tao Sun, Heyue Zhang, and Dongdong Shao. "Suitable Habitat Mapping in the Yangtze River Estuary Influenced by Land Reclamations." Ecological Engineering 97 (2016): 64-73. Web.