SEFA Model Development and Evaluation of Instream Habitat Metrics for Middle Econfina Creek Minimum Flows

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1.0 INTRODUCTION

Geosyntec Consultants, Inc., d/b/a ATM (ATM), has been tasked by the Northwest Florida Water Management District (NWFWMD or District) to develop a System for Environmental Flow Analysis (SEFA) model for the Econfina Creek system in support of Minimum Flows and Levels (MFL) development for the Middle Econfina Creek, including Gainer, Williford, and Sylvan spring groups. Environmental Science Associates (ESA) is working with ATM to satisfy the objectives of this project. The goal of this task was to examine the extent to which reductions in creek flow affect the habitat availability for relevant species within the Middle Econfina Creek MFL study area by employing the SEFA methodology. SEFA is a Windows-based program that was developed as a tool for use in studies that utilize the Instream Flow Incremental Methodology (IFIM). The Instream Flow Incremental Methodology described an impact assessment framework but did not create comprehensive software which would allow for a complete implementation of that framework. SEFA, System for Environmental Flow Analysis, is current software that implements the IFIM framework. Version 1.8 of the SEFA software was used in this project.

The SEFA methodology has been applied to support the development of environmental flow regimes as required by Florida's MFL statute. Specifically, SEFA has been applied to support MFL development for lotic ecosystems (i.e., rivers and creeks) by four of the Florida water management districts – Southwest, St. Johns River, Suwannee River, and most recently Northwest. SEFA applications can be found across many U.S. systems in Georgia (Evans, and England, 1995); Arkansas (Filipek et al. 1987). Texas (Mathews and Bao, 1991), and Oklahoma (Normandeau Associates, Inc. 2017). SEFA has also been applied in various international projects including France (Mattia Damiani et al., 2018); Australia (Hughes & James, 1989) and New Zealand (Jowett et al., 2008)

SEFA operates under the assumption that individual species or guilds of species in lotic systems display optimal habitat requirements (specifically, water velocity and depth), outside of which the health and survival of the species is reduced. SEFA allows the use of the HEC-RAS (Hydrologic Engineering Center River Analysis System) model output to calculate an Area Weighted Suitability (AWS) index that addresses habitat quality and quantity. Alternatively, field data collection at transects can provide the data used in SEFA. There are two issues that bear on whether field data or HEC-RAS output are employed. First, if field data are used then the data collection must be completed over a reasonably wide range of flow conditions allowing the capture of the seasonal variability in the stream condition. This approach is largely limited by the variability in rainfall and the response instream flows. Clearly, both the time necessary to complete the data collection and the associated costs are affected. In contrast, HEC-RAS output provides information about the stream hydraulics and bathymetry, in addition to providing consistency with other hydrologic models.

SEFA has been applied in several MFL in Florida development projects including the following:

Table 1. MFLs where SEFA was applied.	
Steinhatchee River	Minimum Flows and Levels for Steinhatchee River, Florida. Prepared for Suwannee River Water Management District. Prepared by ATM and Janicki Environmental, May 2018.
Lower Santa Fe and Ichetucknee Rivers and Priority Springs	Minimum Flows and Minimum Water Levels Re-Evaluation For The Lower Santa Fe and Ichetucknee Rivers and Priority Springs. Prepared for Suwannee River Water Management District. Prepared by HSW Engineering, January 2021.
Aucilla River, Wacissa River and Priority Springs	Minimum Flows and Levels for the Aucilla River, Wacissa River and Priority Springs. Prepared for Suwannee River Water Management District. Prepared by HSW Engineering, January 2021.
Little Manatee River	Recommended Minimum Flows for the Little Manatee River Final Draft Report. Prepared for the Southwest Florida Water Management District. Prepared by SWFWMD and Janicki Environmental, November 2023.
Horse Creek	Recommended Minimum Flows for Horse Creek Final Report. Prepared for the Southwest Florida Water Management District. Prepared by SWFWMD December 2023.

AWS can be modeled for an individual cross section, or in aggregate for any number of cross sections. SEFA relies on HEC-RAS cross sectional estimates of both the area of inundated channel at a particular HEC-RAS cross section as well as velocities at specific channel locations across the main channel, deriving a single AWS value for each flow in a time series that describes the relative suitability throughout the model domain. The model output is a curve relating flow to AWS, with each value of flow having a single corresponding AWS value. Therefore, a series of flow values can be converted into a series of AWS values for each taxon/life stage that comprise a given habitat suitability group. Alternative scenarios, for example time series of flows under baseline (unimpacted) conditions, can be compared to flow reduction scenarios to determine changes in habitat suitability associated with decreases in flows (Herrick, 2021).Additionally, the patterns ofAWS variation across time scales (monthly, seasonal, or annual time scales) can be modeled under differing flow scenarios.

The following describes the data/information used in the application of the SEFA model to Middle Econfina Creek.

2.0 DATA SOURCES

2.1 Econfina Creek Biota

Table 2 presents the fish species documented to occur in Econfina Creek. The data sources include the Florida Wildlife Commission and University of Florida fish collection library.

Table 2. Fish species and macroinvertebrates documented to occur in Econfina Creek. Data sources include the Florida Wildlife Commission and University of Florida fish collection library.

Taxon	Common Name	Taxon	Common Name
Ameiurus serracanthus	Spotted bullhead	*Lepomis gulosus*	Warmouth
Aphredoderus sayanus	Pirate perch	*Lepomis marginatus*	Dollar sunfish
Cyprinella venusta	Blacktail shiner	*Lepomis microlophus*	Redear sunfish
Cypreinella venusta	Blacktail shiner	*Lepomis punctatus*	Spotted sunfish
Elassoma evergladei	Everglades pygmy sunfish	*Lucania goodei*	Bluefin killifish
Enneacanthus gloriosus	Bluespotted sunfish	*Medionidus penicillatus**	Gulf moccasin shell
Erimyzon sucetta	Lake chubsucker	*Micropterus salmoides*	Largemouth bass
Esox americanus	Redfin pickerel	*Micropterus salmoides floridanus x*	Largemouth bass
Esoxamericanus x	Grass pickerel	*Minytrema melanops*	Spotted sucker
Esox niger	Chain pickerel	*Moxostoma poecilurum*	Blacktail redhorse
Etheostoma edwini	Brown darter	*Notropis harperi*	Redeye chub
Etheostoma swaini	Gulf darter	*Notropis longirostris*	Longnose shiner
Fundulus escambiae	Eastern starhead minnow	*Notropis petersoni*	Coastal shiner
Gambusio holbrooki	Mosquitofish	*Notropis texanus*	Weed shiner
Heterandria Formosa	Least killifish	*Noturus funebris*	Black madtom
Ichthyomyzon gagei	Southern brook lamprey	*Noturus gyrinus*	Tadpole madtom
Ictoalurus punctatus	Channel catfish	*Noturus leptacanthus*	Speckled madtom
Labidesthes sicculus	Brook silverside	*Percina nitrofasciata*	Blackbanded darter
Labidesthes sicculus vanhyningi	Silverside	*Pleurobema pyriforme**	Oval pigtoe
Lepisosteus oculatus	Spotted gar	*Pteronotropis hypselopoterus*	Sailfin shiner
Lepomis auratus	Redbreast sunfish	*Pteronotropis signipinnis*	Flagfin shiner
Lepomis gulosus	Warmouth	*Lepomis macrochirus*	Bluegill

Table 2. Fish species and macroinvertebrates documented to occur in Econfina Creek. Data sources include the Florida Wildlife Commission and University of Florida fish collection library.

Taxon	Common Name	Taxon	Common Name
Ephemeroptera	Mayflies	EPT Total (Ephemeroptera, Plecoptera, Tricoptera)	EPT
Plecoptera	Stoneflies	Low Gradient Macroinvertebrates	
Tricoptera	Caddisflies		

*Indicates macroinvertebrates.

2.2 Habitat Suitability Curves

As has been true for earlier approaches to habitat suitability modeling, habitat suitability curves (HSC) are applied in this project. A HSC is a graphical depiction that relates how well a species is likely to thrive in relation to a specific environmental factor, such as stream depth and water velocity These graphical depictions of depth, stream velocity, and stream substrate present a range of suitability that encompass the optimal condition (i.e., value =1) where the habitat is considered most suitable for the species, with values outside that range indicating decreasing suitability.

Figure 1 presents a simplified representation of a habitat suitability curve based on water depth. Similarly, curves for velocity present habitat suitability on the y-axis and velocity on the x-axis.

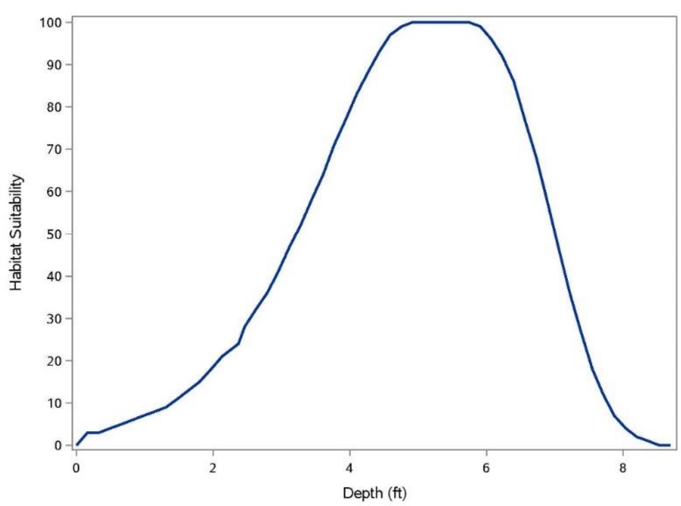


Figure 1. Example of a habitat suitability curve.

Habitat suitability curves have been identified for use in this study by cross referencing the species in Table 1 from a series of existing curves found in the following data sources:

Nagid, E.J. 2022a. Florida Handbook of Habitat Suitability Indices. Florida Fish and Wildlife Conservation Commission. Final Report to the Southwest Florida Water Management District, Brooksville, Florida. https://doi.org/10.6095/YQWK-P357.

Nagid, E.J. 2022b. Data from: Handbook of Florida Habitat Suitability Indices, Freshwater Streams [Data set]. Florida Fish and Wildlife Conservation Commission - Fish and Wildlife Research Institute. https://doi.org/10.6095/GJ9W-5H42.

Rouse Holzwart, Kym, Yonas Ghile, XinJian Chen, Gabe Herrick, Kristina Deak, Jordan Miller, Ron Basso, and Doug Leeper. 2023. Recommended Minimum Flows for the Little Manatee River Final Draft Report. Southwest Florida Water Management District Brooksville, Florida' Mike Wessel and Ray Pribble Janicki Environmental, Inc. St. Petersburg, Florida.

Sutherland, A.B., F. Gordu, J. Mace and A. Karama. 2024. Minimum Flows and Levels (MFLs) Reevaluation for the Wekiva River at State Road 46, Wekiwa Springs, Rock Springs, Palm Springs, Sanlando Springs, Starbuck Springs and Miami Springs; and MFLs Determination for the Little Wekiva River, Lake, Orange and Seminole Counties. Draft Technical Publication. St. Johns River Water Management District, Palatka, FL.

The curves used in the Little Manatee River and Wekiva River MFL evaluations were generally found in what has been reported as the Gore Library. Table 3 presents the species documented in Econfina Creek for which curves exist and the specific habitat suitability curve sources that have been identified. Inspection of the two sources shows that the curves were essentially the same. If both curve sources were available, the preference was given to the Nagid Curves as the Nagid curves were recently developed for use and accuracy in Florida and were based upon Florida specific best available information. For many species, multiple HSCs were available for a given species reflective of habitat preferences of different life stages. When available, curves for all life stages were utilized.

In addition, four HSCs were used for different general habitat guilds. Guilds refer to a given group of fish taxa that have similar characteristics. In this case, the taxa within guild have similar physical habitat requirements.

Table 3. Fishes and other taxa documented in Econfina Creek for which habitat suitability have been identified.	
ECONFINA TAXA	
Aphredoderus sayanus	Pirate perch
Ictoalurus punctatus	Channel catfish
Lepomis auratus	Redbreast sunfish
Lepomis macrochirus	Bluegill
Lepomis punctatus	Spotted sunfish
Micropterus salmoides floridanus x salmoides	Largemouth bass hybrid
Minytrema melanops	Spotted sucker
Notropis harperi	Redeye chub
Noturus leptacanthus	Speckled madtom
Percina nigrofasciata	Blackbanded darter
Generic darters	Darters
Habitat Guild – Deep Fast	
Habitat Guild – Deep Slow	
Habitat Guild – Shallow Fast	
Habitat Guild – Shallow Slow	
EPT Total (Ephemeroptera, Plecoptera, Tricoptera)	
Ephemeroptera	Mayflies
Low Gradient Macroinvertebrates	
Plecoptera	Stoneflies
Tricoptera	Caddisflies

Appendix A presents the habitat suitability curves used in this effort.

3.3 Hydrology and HEC-RAS Data

The HEC-RAS model that provided the depth and velocity data was developed by the District (NWFWMD, 2024 - Update and Calibration of the Hydrologic Engineering Center River Analysis System (HEC-RAS) Model Econfina Creek System. The HEC-RAS model was developed using bathymetric surveys and lidar to establish substrate elevations at each transect. These transects provided the basis for the SEFA model transect dimensions.

In addition to the habitat suitability curves and creek transect bathymetry, the SEFA application is based on flow data for the gages found in Econfina Creek and output from the HEC-RAS model used to simulate water depths and velocities as a function of creek flow. Flows at each transect in the SEFA model were derived from flows produced as a result of the HEC-RAS model simulated at each flow percentile. The creek flows are expressed as total river/creek flow. Table 4 presents the creek flow scenarios that were simulated by the HEC-RAS model, at the CR 388 gauge. These flows include a 1.78 cfs correction for historical water withdrawals to determine baseline flows. Figure 2 presents the HEC-RAS transects for which the SEFA modeling was completed. Figure 3 presents an example cross section included in the SEFA model depicting water depth and velocity at transect 7137.

Table 4. Baseline Creek Flows at CR 388 gauge – cfs.

Percentile	Baseline	Percentile	Baseline	Percentile	Baseline
1	302.8	34	467.8	67	561.8
2	318.8	35	470.8	68	563.8
3	327.8	36	473.8	69	567.8
4	337.8	37	476.8	70	571.8
5	346.8	38	478.8	71	576.8
6	355.8	39	480.8	72	579.8
7	363.8	40	483.8	73	583.8
8	369.8	41	486.8	74	588.8
9	375.8	42	487.8	75	593.8
10	381.8	43	490.8	76	598.8
11	388.8	44	492.8	77	602.8
12	393.8	45	495.8	78	608.6
13	398.8	46	498.8	79	613.8
14	403.8	47	500.8	80	619.8
15	407.8	48	503.8	81	626.8
16	412.8	49	506.8	82	632.8
17	416.8	50	507.8	83	639.8
18	420.8	51	511.8	84	647.8
19	423.8	52	514.7	85	655.8
20	427.8	53	516.8	86	663.8
21	428.8	54	519.8	87	673.8
22	432.8	55	521.8	88	683.8
23	435.8	56	524.8	89	695.8
24	438.8	57	528.8	90	708.8
25	441.8	58	531.8	91	722.8
26	444.8	59	534.8	92	737.3
27	447.8	60	537.8	93	756.8
28	450.8	61	539.8	94	780.8
29	453.8	62	543.8	95	807.8
30	455.8	63	546.8	96	843.0
31	459.8	64	549.8	97	890.8
32	462.8	65	553.8	98	968.0
33	465.8	66	557.8	99	1141.8

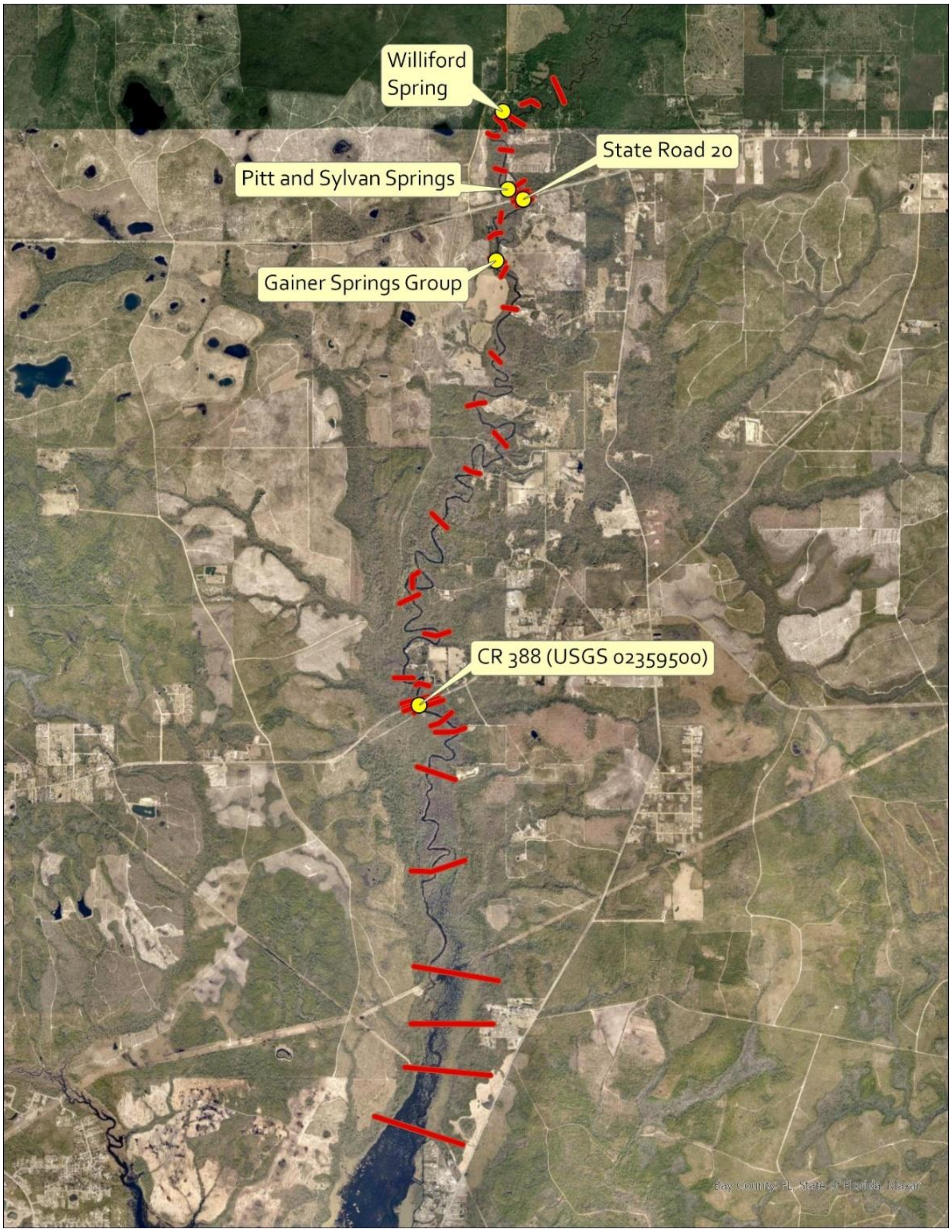


Figure 2. Econfina Creek HEC-RAS transects and CR 388 gage.

Figure 3 presents an example transect from which depth and velocities are calculated by the HEC-RAS model of Econfina Creek.

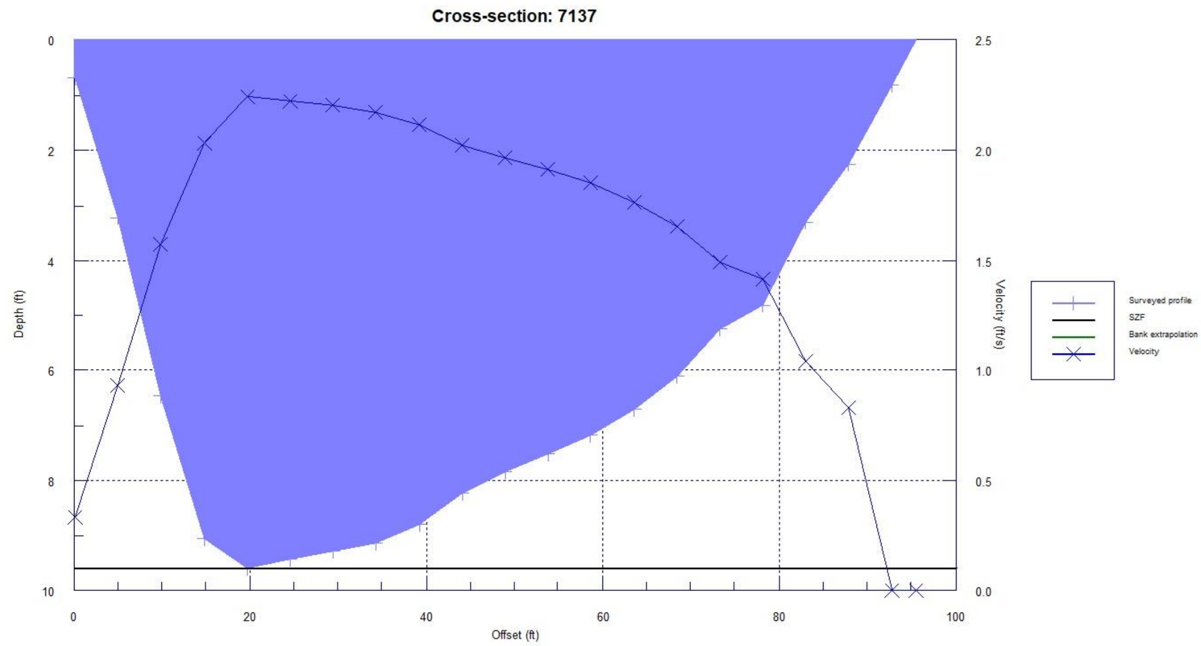


Figure 3. Example cross section (7137) and verticals from which depth and velocities are estimated by the HEC-RAS model.

3.0 SEFA MODEL RESULTS

The primary response metric employed in the SEFA analysis is the Area Weighted Suitability (AWS) which is often used in environmental studies, particularly when analyzing habitat for taxon where the size of suitable areas matters significantly. AWS is calculated for a given area by taking the mean of the suitability scores for each cross section and weighting by the area which essentially gives the habitat scores more weight to larger areas with high suitability scores. The resulting AWS model output is a curve relating flow to AWS, with each flow having a single corresponding AWS value.

Appendix B presents the SEFA results for the Baseline Scenarios. The mean, median, and maximum AWS and associated creek flow are shown. (Any model result that did not show a decrease in AWS with decreasing flows are shown as blanks, all of which were found for the mean and median metrics.)

4.0 APPLICATION OF SEFA RESULTS TO DEVELOPMENT OF THE MINIMUM FLOW FOR ECONFINA CREEK

Although significant harm is not specifically defined in statute, an allowable 15 percent reduction in WRV metrics has been implemented as the protection standard for multiple MFLs throughout Florida. This definition of significant harm was first proposed by Gore et al. (2002) during their review of the upper Peace River MFL report (SWFWMD 2002). The peer review panel stated, "In general, instream flow analysts consider a loss of more than 15 percent habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage." This definition of significant harm has been subsequently utilized and accepted by more than a dozen MFL peer review panels in the establishment of MFLs for springs and rivers (Munson and Delfino 2007, NWFWMD 2021, NWFWMD 2019, SJRWMD 2017, SRWMD 2005, SRWMD 2007, SRWMD 2013, SRWMD 2015, SRWMD 2016a, SRWMD 2016b, SRWMD 2021, SWFWMD 2008, SWFWMD 2010, SWFWMD 2011, SWFWMD 2012a. SWFWMD 2012b, SWFWMD 2017a, SWFWMD 2017b). The 15 percent threshold is also used in this assessment, recognizing that additional data collection and long-term research to confirm or refine this threshold for MFL assessments in Florida would be beneficial. Implementation will follow an adaptive management approach, with MFLs periodically reviewed and reevaluated by the District to reflect new data and information. As new data and information are developed regarding the definition of or threshold for significant harm, the District will consider this information in future MFL re-evaluations.

Given the common use of a 15% reduction to define an MFL in Florida and the similar range of habitat reduction suggested by Richter et al. (2011), consideration of the application of a 15% reduction in AWS is warranted.

Since the SEFA analysis provides an estimate for AWS for each flow found in Table 3 above, the relationship between flow and AWS can be defined and used to estimate the reduction in flows that would result in at least a 15% reduction in AWS. Figure 4 presents a conceptual depiction of the estimation of the critical flow that results in a 15% reduction in AWS.

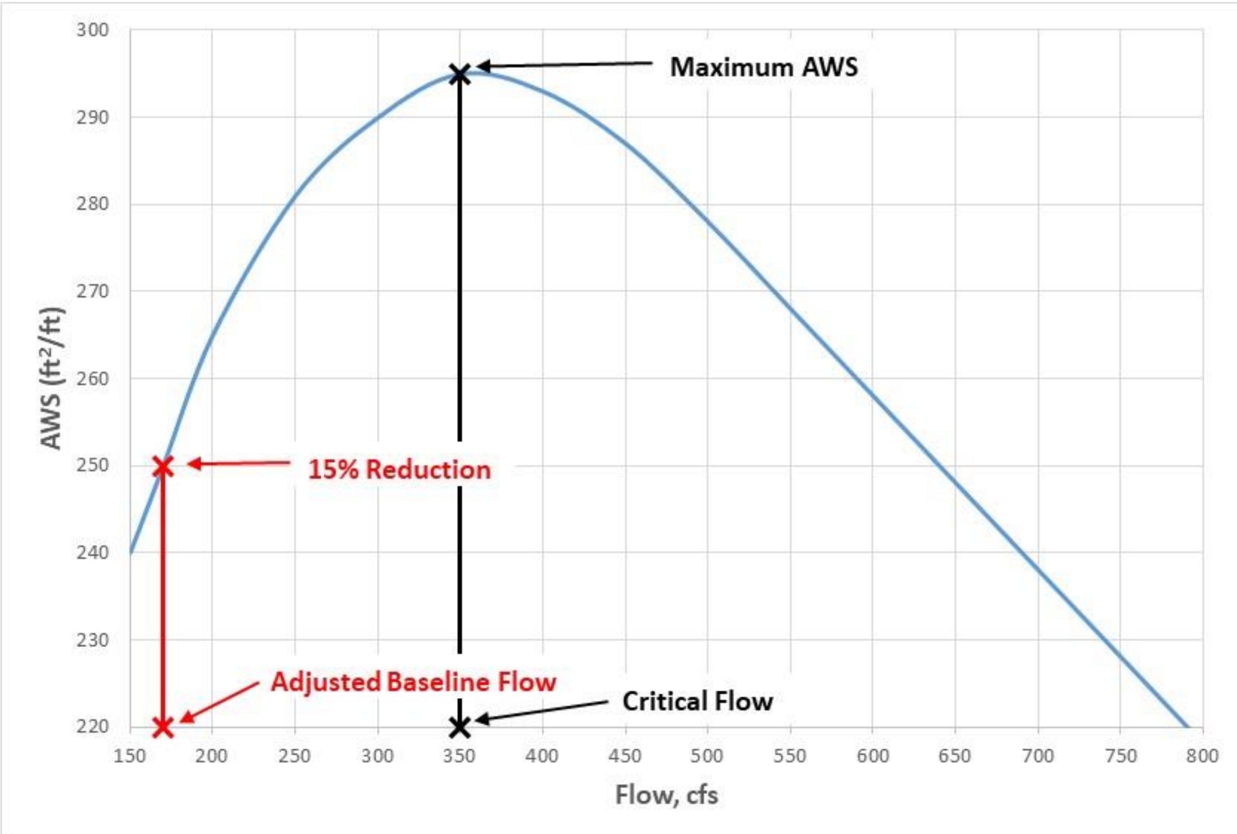
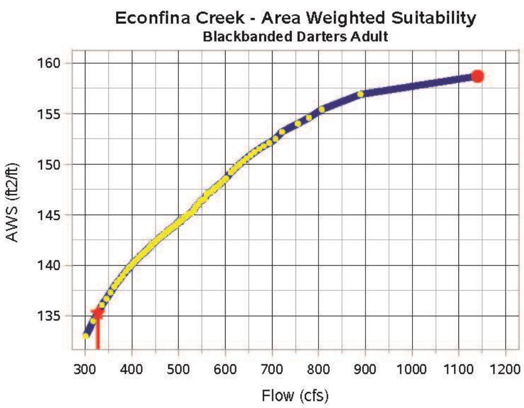
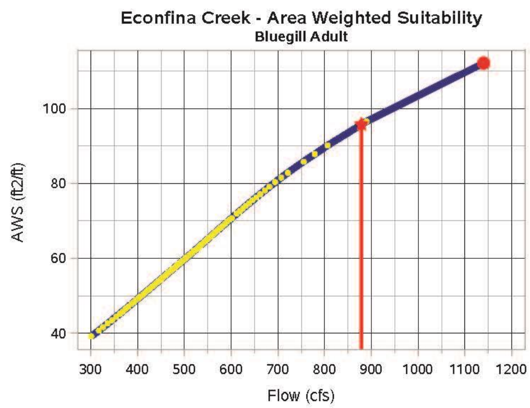


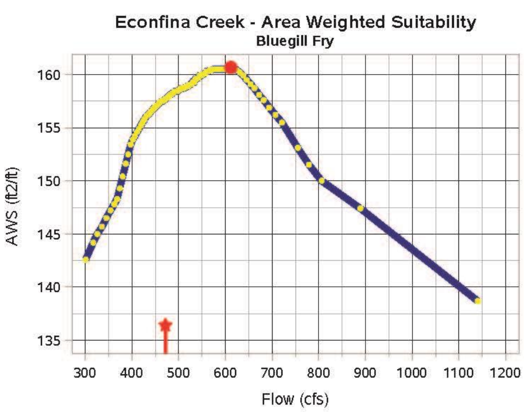
Figure 4. Conceptual depiction of the estimation of the critical flow that results in a 15% reduction in AWS.

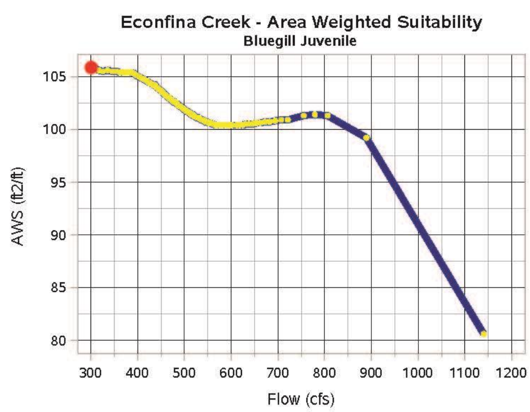
The first step in this process entailed the identification of those taxa/life stages that displayed a reduction in AWS with reductions in flow. Taxa/life stages that are not candidates for establishing an MFL for Econfina Creek include those that display reduced AWS with increasing flows.

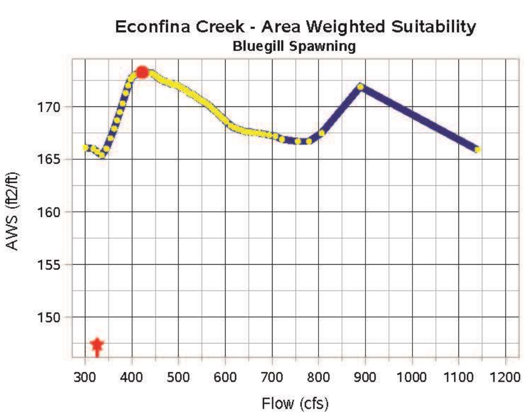
The following figures present the results that estimate the critical flows for those taxa/life stages whose AWS declines with reductions in flows. Positive results are found when increasing flow led to increased AWS. Negative results are found when AWS decreases with decreasing flows.

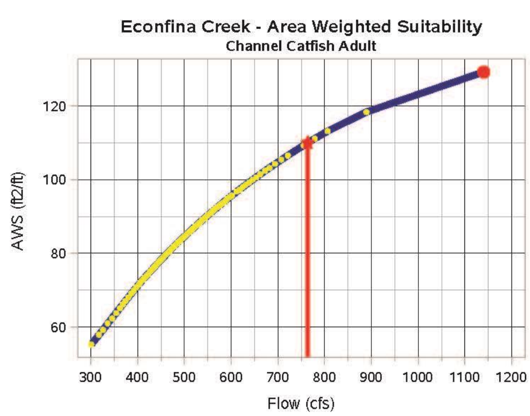

Econfina Creek - Area Weighted Suitability
Blackbanded Darters Adult
AWS (ft2/ft)
160
155
150
145
140
135
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)

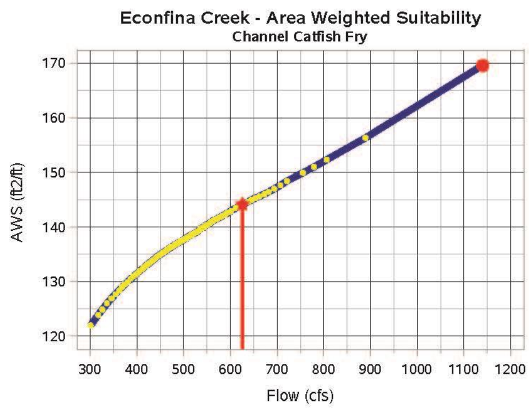

Econfina Creek - Area Weighted Suitability
Bluegill Adult
AWS (ft2/ft)
100
80
60
40
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)

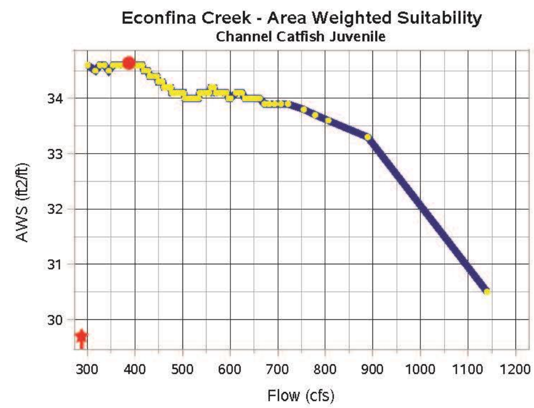

Econfina Creek - Area Weighted Suitability
Bluegill Fry
AWS (ft2/ft)
160
155
150
145
140
135
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)

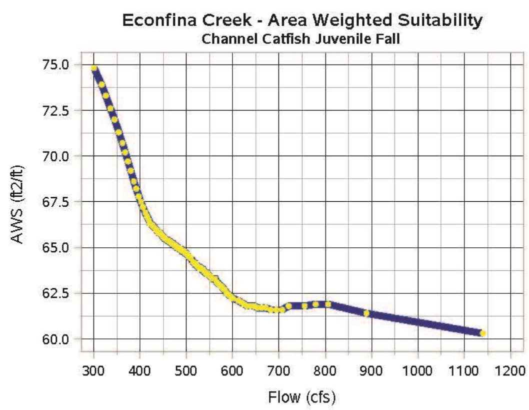

Econfina Creek - Area Weighted Suitability
Bluegill Juvenile
AWS (ft2/ft)
105
100
95
90
85
80
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)

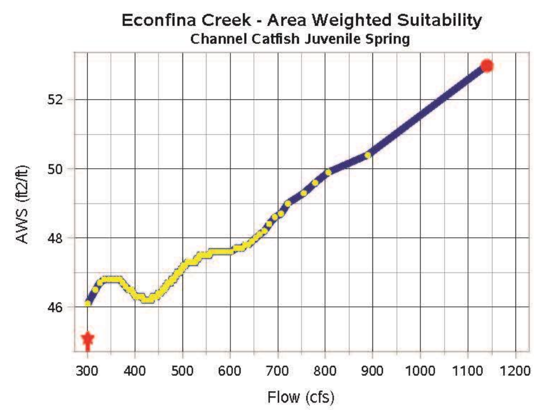

Econfina Creek - Area Weighted Suitability
Bluegill Spawning
AWS (ft2/ft)
170
165
160
155
150
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)

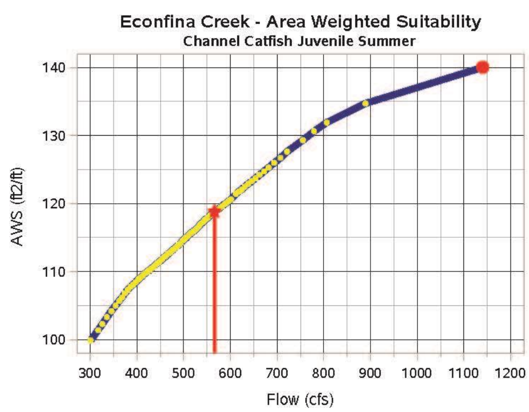

Econfina Creek - Area Weighted Suitability
Channel Catfish Adult
AWS (ft2/ft)
120
100
80
60
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)

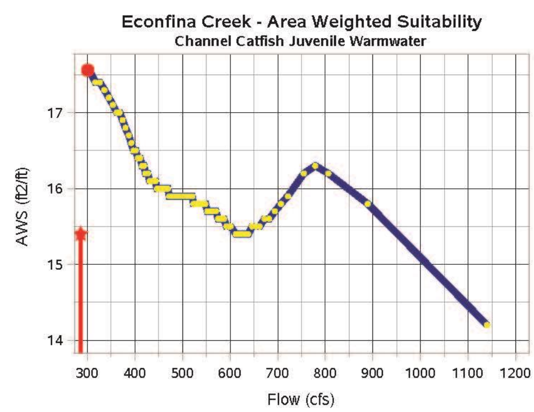

Econfina Creek - Area Weighted Suitability
Channel Catfish Fry
AWS (ft2/ft)
Flow (cfs)

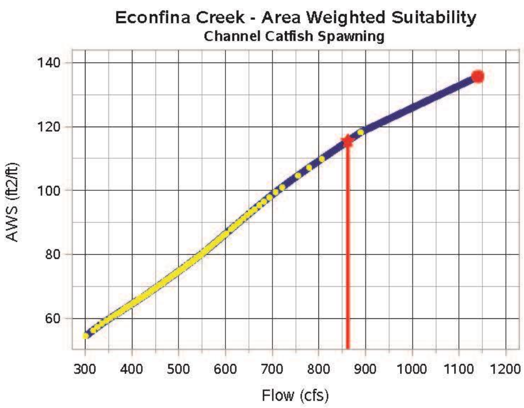

Econfina Creek - Area Weighted Suitability
Channel Catfish Juvenile
AWS (ft2/ft)
Flow (cfs)

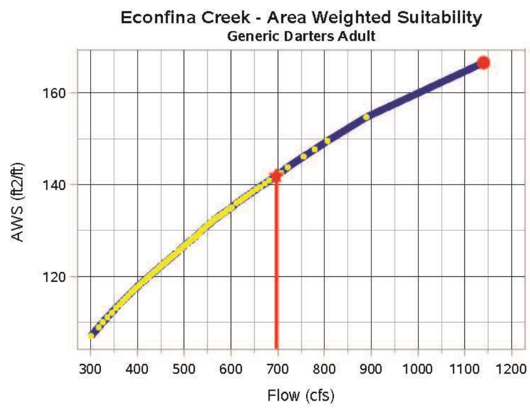

Econfina Creek - Area Weighted Suitability
Channel Catfish Juvenile Fall
AWS (ft2/ft)
Flow (cfs)

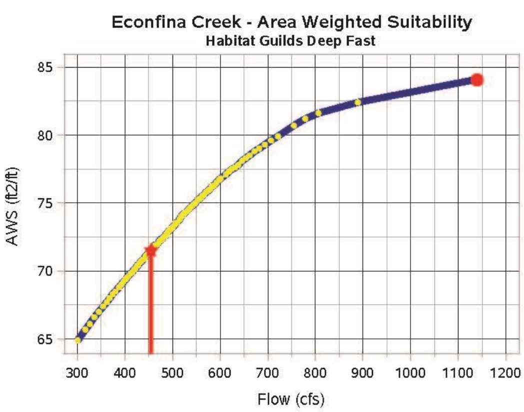

Econfina Creek - Area Weighted Suitability
Channel Catfish Juvenile Spring
AWS (ft2/ft)
Flow (cfs)

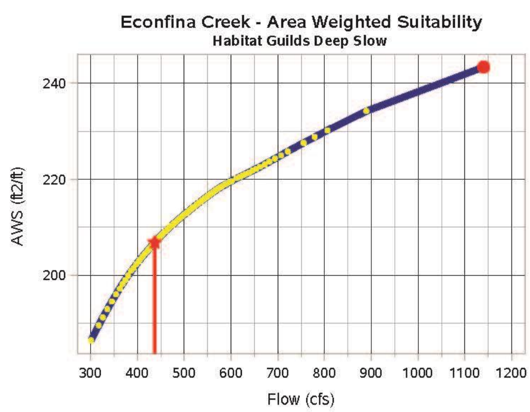

Econfina Creek - Area Weighted Suitability
Channel Catfish Juvenile Summer
AWS (ft2/ft)
Flow (cfs)

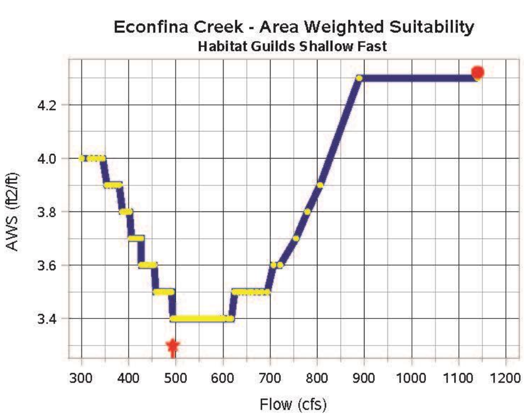

Econfina Creek - Area Weighted Suitability
Channel Catfish Juvenile Warmwater
AWS (ft2/ft)
Flow (cfs)

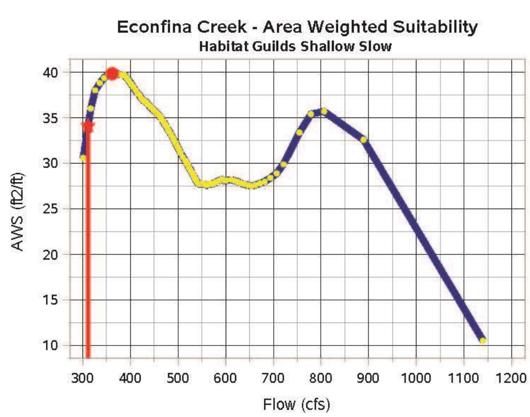

Econfina Creek - Area Weighted Suitability
Channel Catfish Spawning
AWS (ft2/ft)
Flow (cfs)

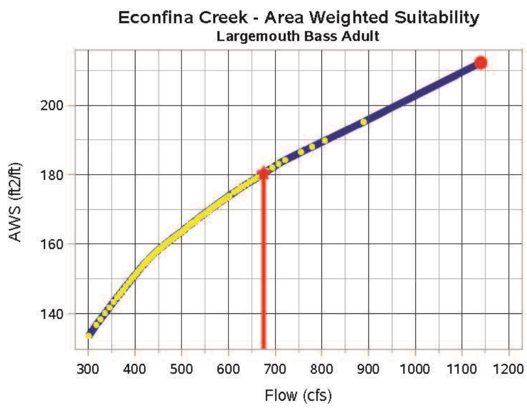

Econfina Creek - Area Weighted Suitability
Generic Darters Adult
AWS (ft2/ft)
Flow (cfs)

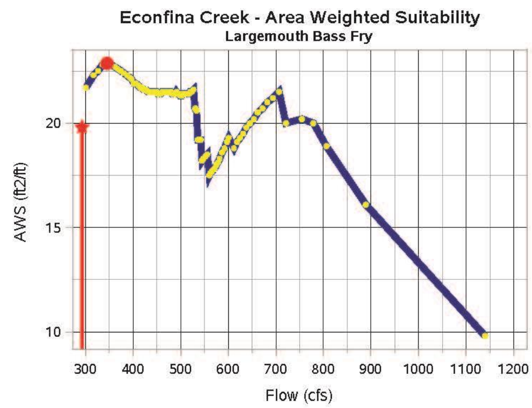

Econfina Creek - Area Weighted Suitability
Habitat Guilds Deep Fast
AWS (ft2/ft)
Flow (cfs)

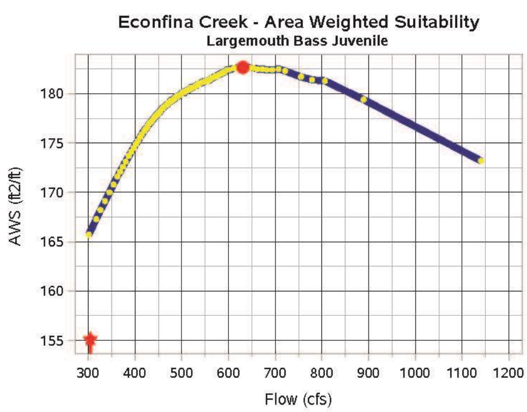

Econfina Creek - Area Weighted Suitability
Habitat Guilds Deep Slow
AWS (ft2/ft)
Flow (cfs)

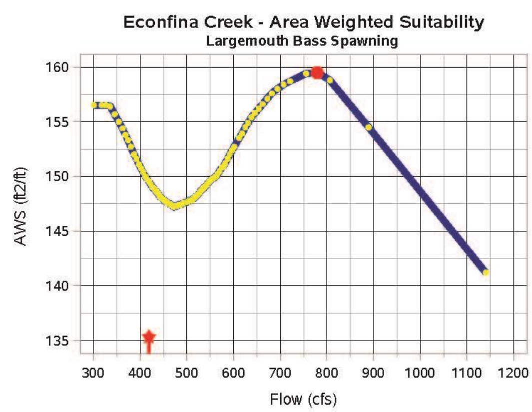

Econfina Creek - Area Weighted Suitability
Habitat Guilds Shallow Fast
AWS (ft2/ft)
Flow (cfs)

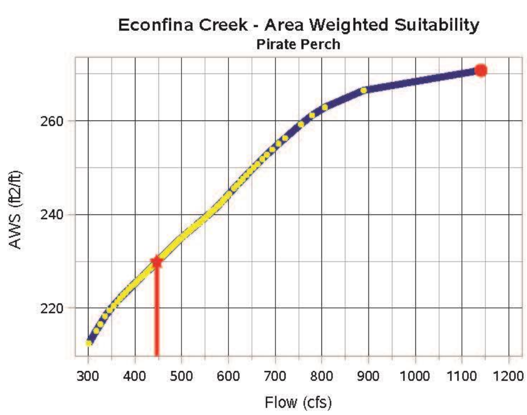

Econfina Creek - Area Weighted Suitability
Habitat Guilds Shallow Slow
AWS (ft2/ft)
Flow (cfs)

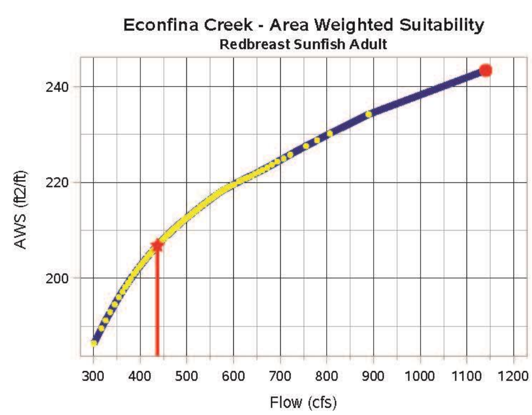

Econfina Creek - Area Weighted Suitability
Largemouth Bass Adult
AWS (ft2/ft)
140
160
180
200
300
400
500
600
700
800
900
1000
1100
1200
Flow (cfs)

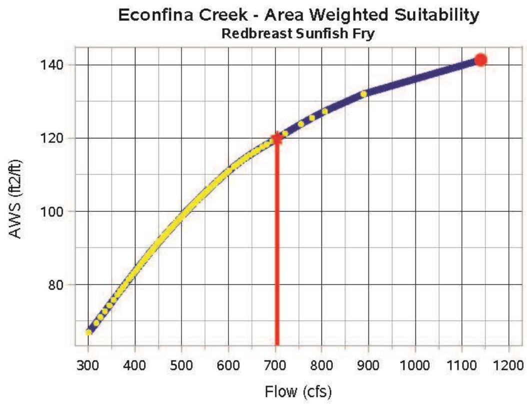

Econfina Creek - Area Weighted Suitability
Largemouth Bass Fry
AWS (ft2/ft)
10
15
20
300
400
500
600
700
800
900
1000
1100
1200
Flow (cfs)

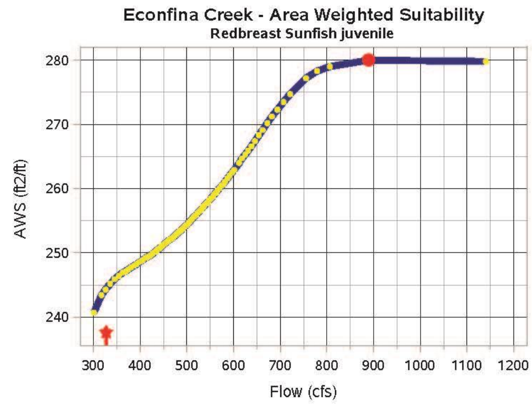

Econfina Creek - Area Weighted Suitability
Largemouth Bass Juvenile
AWS (ft2/ft)
155
160
165
170
175
180
300
400
500
600
700
800
900
1000
1100
1200
Flow (cfs)

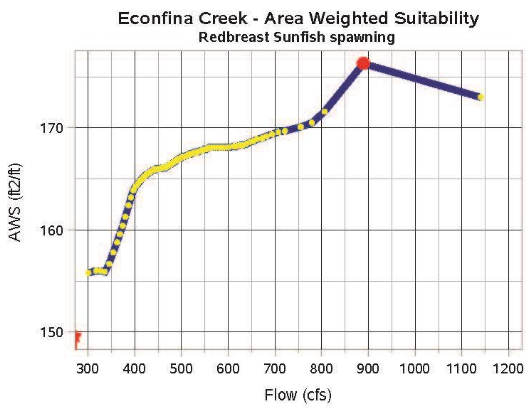

Econfina Creek - Area Weighted Suitability
Largemouth Bass Spawning
AWS (ft2/ft)
135
140
145
150
155
160
300
400
500
600
700
800
900
1000
1100
1200
Flow (cfs)

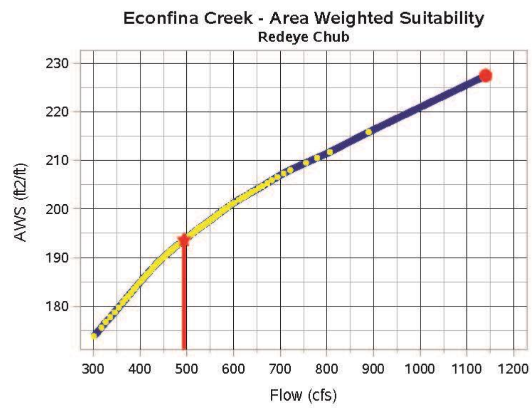

Econfina Creek - Area Weighted Suitability
Pirate Perch
AWS (ft2/ft)
220
240
260
300
400
500
600
700
800
900
1000
1100
1200
Flow (cfs)

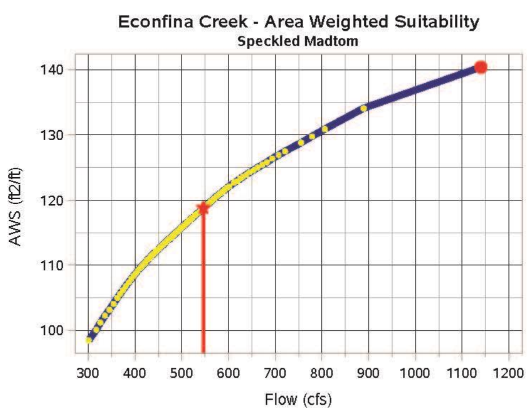

Econfina Creek - Area Weighted Suitability
Redbreast Sunfish Adult
AWS (ft2/ft)
200
220
240
300
400
500
600
700
800
900
1000
1100
1200
Flow (cfs)

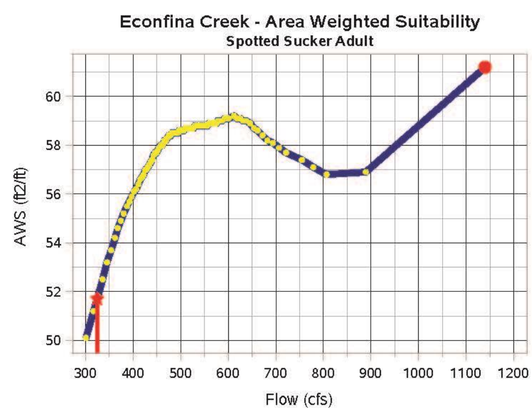

Econfina Creek - Area Weighted Suitability
Redbreast Sunfish Fry
AWS (ft2/ft)
Flow (cfs)

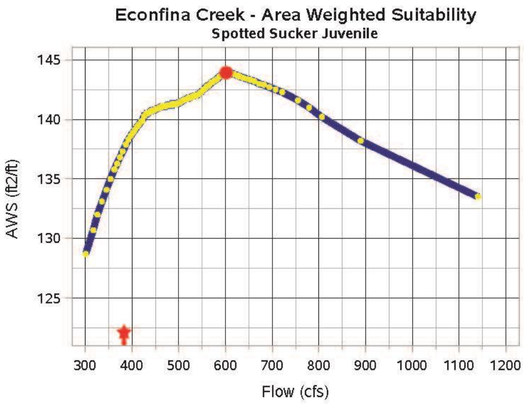

Econfina Creek - Area Weighted Suitability
Redbreast Sunfish juvenile
AWS (ft2/ft)
Flow (cfs)

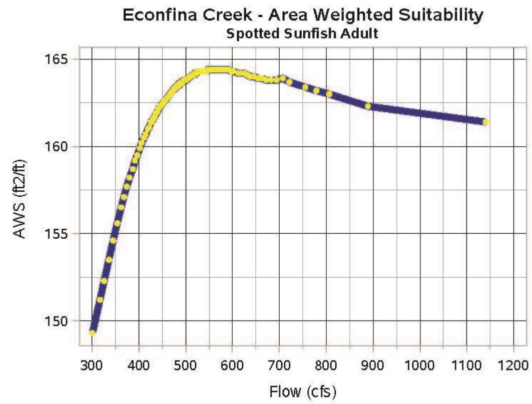

Econfina Creek - Area Weighted Suitability
Redbreast Sunfish spawning
AWS (ft2/ft)
Flow (cfs)

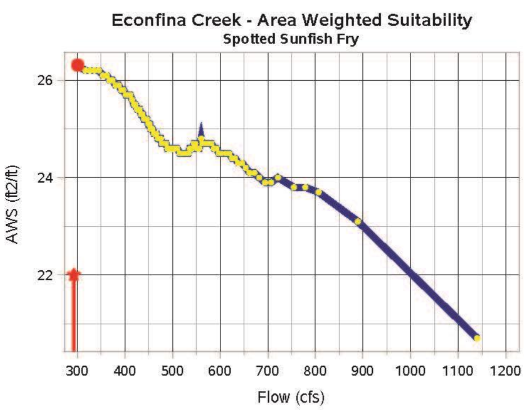

Econfina Creek - Area Weighted Suitability
Redeye Chub
AWS (ft2/ft)
Flow (cfs)

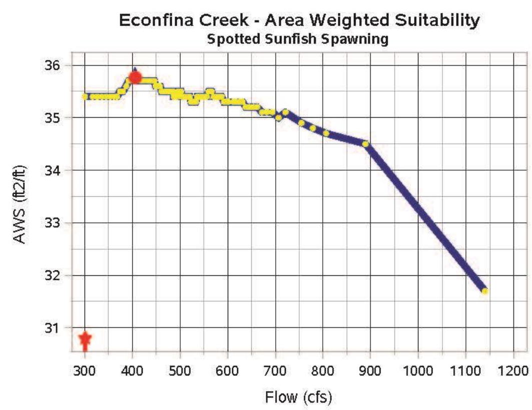

Econfina Creek - Area Weighted Suitability
Speckled Madtom
AWS (ft2/ft)
Flow (cfs)

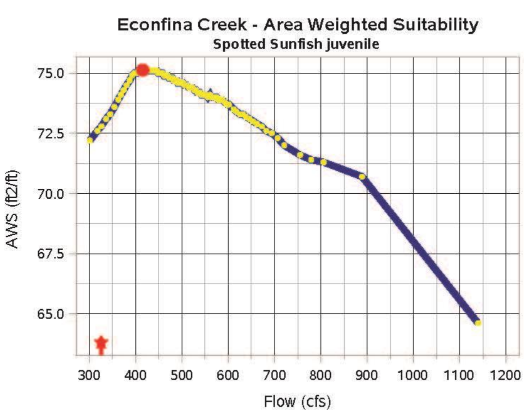

Econfina Creek - Area Weighted Suitability
Spotted Sucker Adult
AWS (ft2/ft)
Flow (cfs)

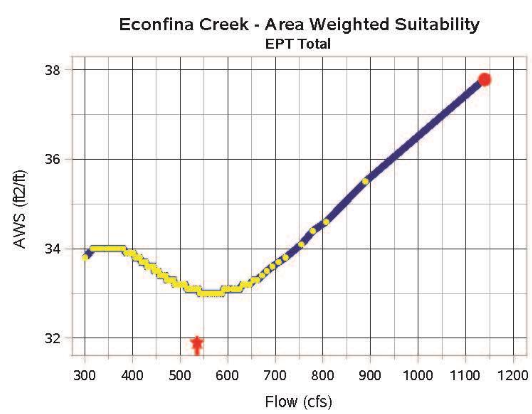

Econfina Creek - Area Weighted Suitability
Spotted Sucker Juvenile
AWS (ft2/ft)
Flow (cfs)

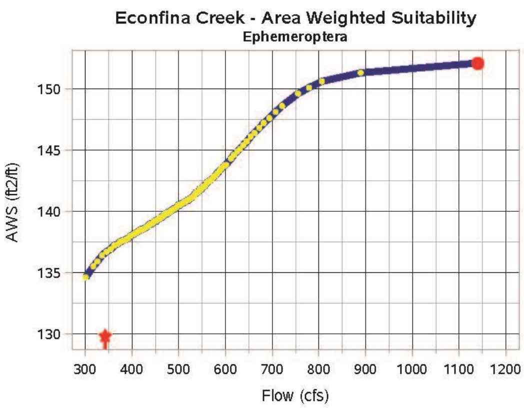

Econfina Creek - Area Weighted Suitability
Spotted Sunfish Adult
AWS (ft2/ft)
Flow (cfs)

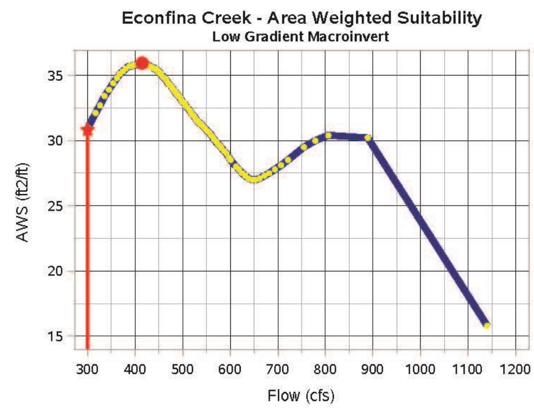

Econfina Creek - Area Weighted Suitability
Spotted Sunfish Fry
AWS (ft2/ft)
Flow (cfs)

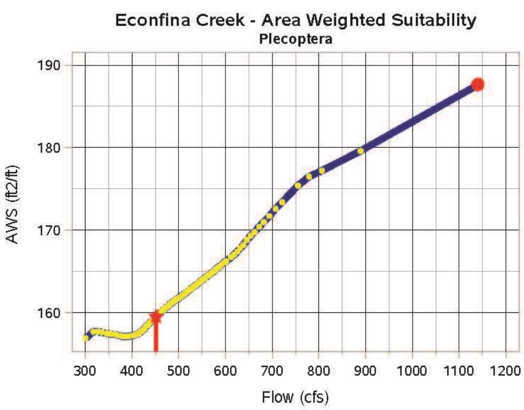

Econfina Creek - Area Weighted Suitability
Spotted Sunfish Spawning
AWS (ft2/ft)
Flow (cfs)

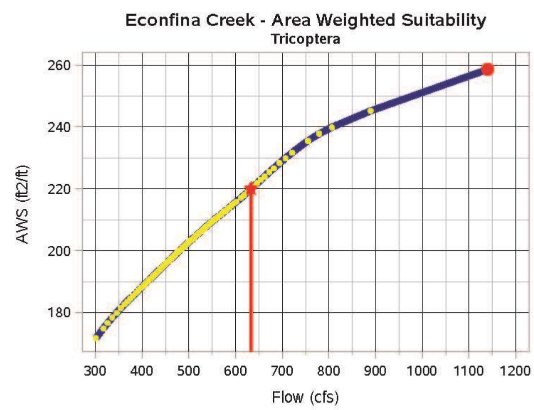

Econfina Creek - Area Weighted Suitability
Spotted Sunfish juvenile
AWS (ft2/ft)
Flow (cfs)


Econfina Creek - Area Weighted Suitability
EPT Total
AWS (ft2/ft)
Flow (cfs)


Econfina Creek - Area Weighted Suitability
Ephemeroptera
AWS (ft2/ft)
130
135
140
145
150
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)


Econfina Creek - Area Weighted Suitability
Low Gradient Macroinvert
AWS (ft2/ft)
15
20
25
30
35
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)


Econfina Creek - Area Weighted Suitability
Plecoptera
AWS (ft2/ft)
160
170
180
190
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)


Econfina Creek - Area Weighted Suitability
Tricoptera
AWS (ft2/ft)
180
200
220
240
260
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)

The flow range that defines the X-axis is the range from the 1% to 99% flows presented in Table 4. The maximum AWS for many of the taxa/life stages occur at the 99% flow (1141.8 cfs). To examine whether the maximum AWS for these taxa was reasonable, the flow record was extrapolated beyond the 99% showed that the AWS declined at flows greater than the 99%.

Therefore, the AWS maxima used to estimate the critical flow are reasonable representation of the relationship between AWS and the observed range in creek flows.

Table 5 presents a summary of the results for each taxa/life stage shown in the figures above and includes:

- Maximum AWS
- Flow @ Maximum AWS
- 15% Reduction in AWS
- Flow @ Reduced Maximum AWS

The maximum AWS was chosen as it best defines the significant harm criterion.

Table 5. SEFA model results.

Taxon	Maximum AWS	Flow @ Maximum AWS	15% Reduction in Maximum AWS	Flow @ Reduced Maximum AWS
Blackbanded Darters Adult	159	1141.8	135	327
Bluegill Adult	112	1141.8	95	879
Bluegill Fry	161	613.8	137	472
Bluegill Juvenile	106	302.8	90	212
Bluegill Spawning	173	423.8	147	325
Channel Catfish Adult	129	1141.8	110	764
Channel Catfish Fry	170	1141.8	144	626
Channel Catfish Juvenile	35	388.8	30	288
Channel Catfish Juvenile Fall	75	302.8	64	325
Channel Catfish Juvenile Spring	53	1141.8	45	301
Channel Catfish Juvenile Summer	140	1141.8	119	566

Table 5. SEFA model results.				
Taxon	**Maximum AWS**	**Flow @ Maximum AWS**	**15% Reduction in Maximum AWS**	**Flow @ Reduced Maximum AWS**
Channel Catfish Juvenile Warmwater	18	302.8	15	286
Channel Catfish Spawning	136	1141.8	116	862
Generic Darters Adult	167	1141.8	142	697
Habitat Guilds Deep Fast	84	1141.8	71	455
Habitat Guilds Deep Slow	243	1141.8	207	438.8
Habitat Guilds Shallow Fast	4	1141.8	3.4	495.8
Habitat Guilds Shallow Slow	40	363.8	34	312.8
Largemouth Bass Adult	212	1141.8	180	676.8
Largemouth Bass Fry	23	346.8	20	294.8
Largemouth Bass Juvenile	183	632.8	155	305.8
Largemouth Bass Spawning	159	780.8	135	420.8
Pirate Perch	271	1141.8	230	448.8
Redbreast Sunfish Adult	243	1141.8	207	438.8
Redbreast Sunfish Fry	141	1141.8	120	705.8
Redbreast Sunfish Juvenile	280	890.8	238	328.8
Redbreast Sunfish spawning	176	890.8	150	273.8
Redeye Chub	227	1141.8	193	495.8
Speckled Madtom	140	1141.8	119	548.8
Spotted Sucker Adult	61	1141.8	52	326.8
Spotted Sucker Juvenile	144	602.8	122	384.8
Spotted Sunfish Adult	164	571.8	139	835.8
Spotted Sunfish Fry	26	302.8	22	294.8
Spotted Sunfish Spawning	36	407.8	31	302.8
Spotted Sunfish Juvenile	75	416.8	64	326.8
EPT Total	38	1141.8	32	537.8
Ephemeroptera	152	1141.8	129	344.8
Low Gradient Macroinvertebrates	36	416.8	31	301.8
Plecoptera	188	1141.8	160	453.8
Tricoptera	259	1141.8	220	634.8

These results reflect the general lack of sensitivity in most of the taxa/life stages, as indicated by large differences between the "Flow at Maximum AWS" and "Flow at Reduced Maximum AWS." The fish taxa that comprise the Shallow Slow Guild, which is the most sensitive to changes in flow, were previously defined (Herrick, 2021). These taxa have similar taxonomic, functional, and life history characteristics and as a result have similar habitat suitability curves for velocity, depth, and substrate/cover. These taxa include:

- *Lepomis cyanellus* (green sunfish
- *Fundulus olivaceus* (minnows)
- *Micropterus coosae* (redeye bass)
- *Lepomis humilis* (orange spotted sunfish
- *Poecilia reticulata* (guppies)
- *Etheosoma edwini* (brown darter)
- *Gambusia holbrooki* (eastern mosquitofish)
- *Lepomis microlophus* (redear sunfish)
- *Lepomis megalotis* (longear sunfish)

Lepomis cyanellus, Lepomis megalotis, Lepomis microlophus and *Lepomis humilis* are congeners of *Lepomis macrochirus* and may have very similar habitat curves.

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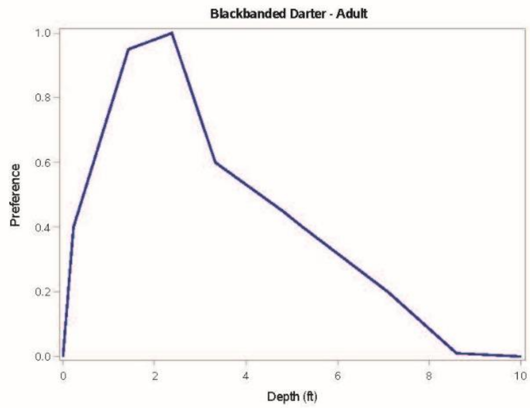
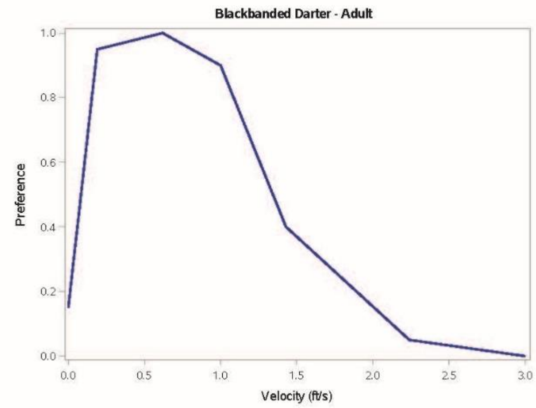
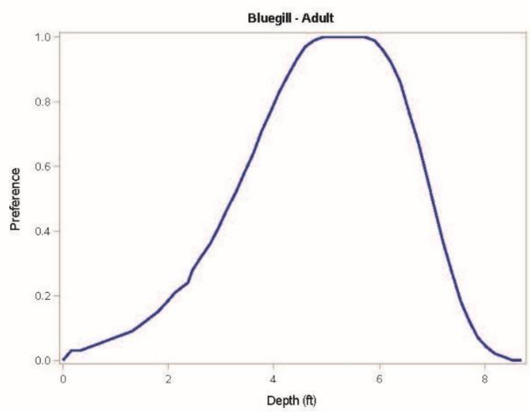
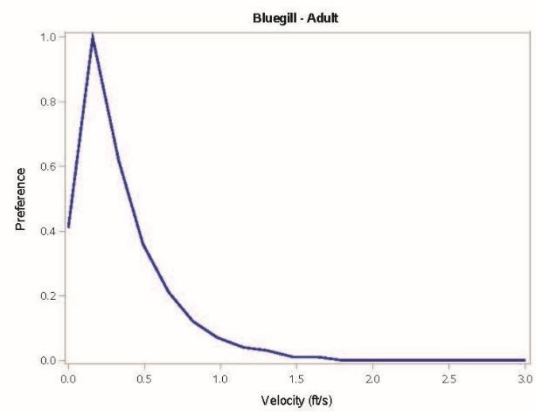
APPENDIX A.

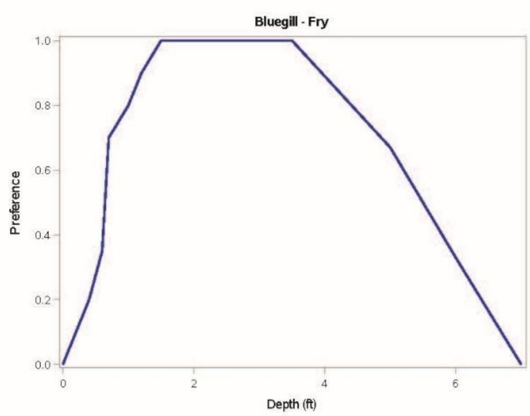
Habitat Suitability Curves

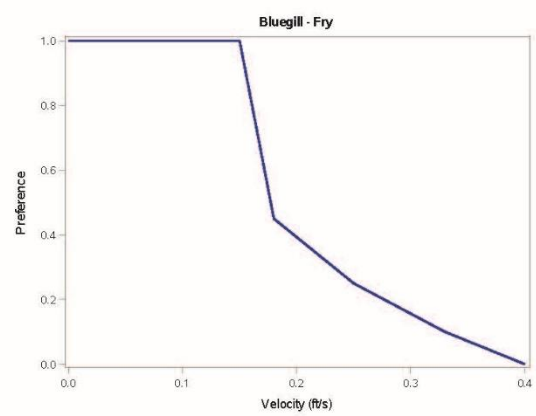

Blackbanded Darter - Adult
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
Depth (ft)

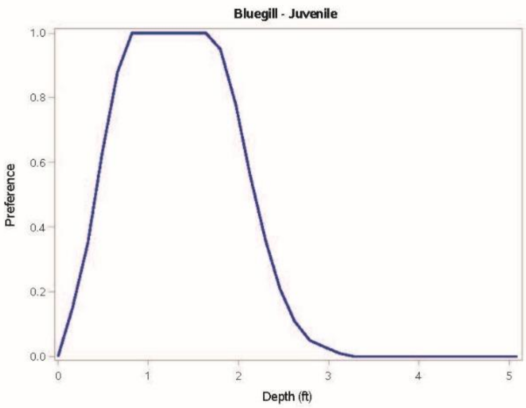

Blackbanded Darter - Adult
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Velocity (ft/s)

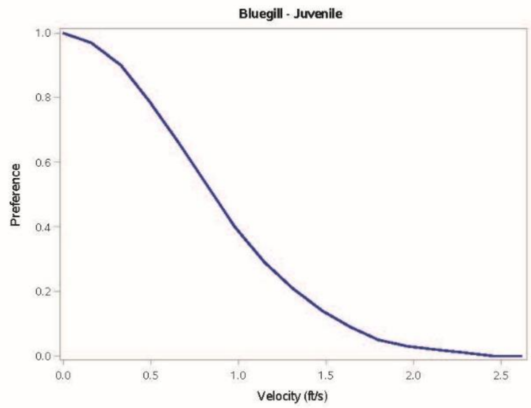

Bluegill - Adult
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
Depth (ft)

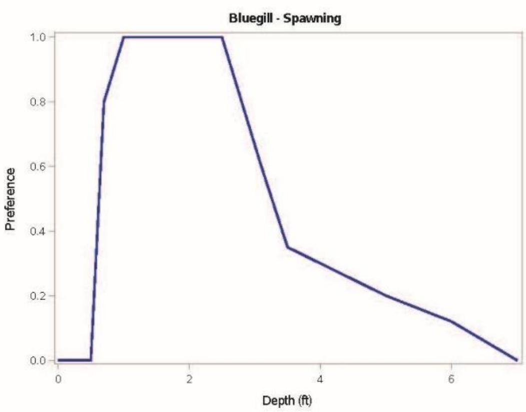

Bluegill - Adult
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Velocity (ft/s)

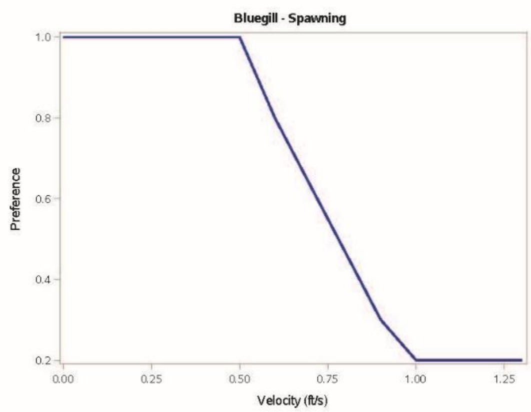

Bluegill - Fry
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
Depth (ft)

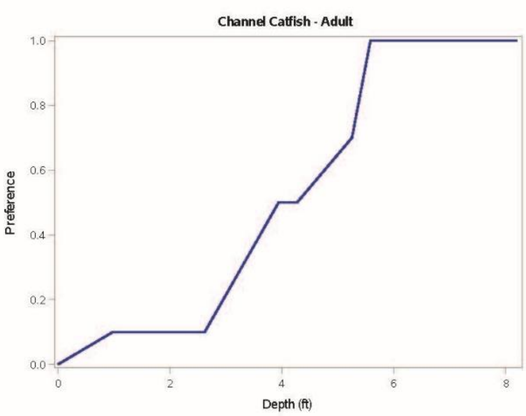

Bluegill - Fry
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.1
0.2
0.3
0.4
Velocity (ft/s)

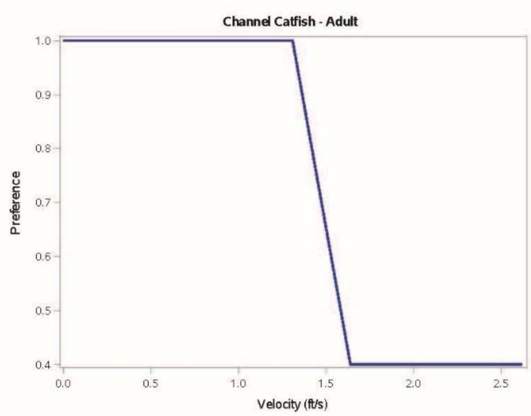

Bluegill - Juvenile
Preference
Depth (ft)
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5

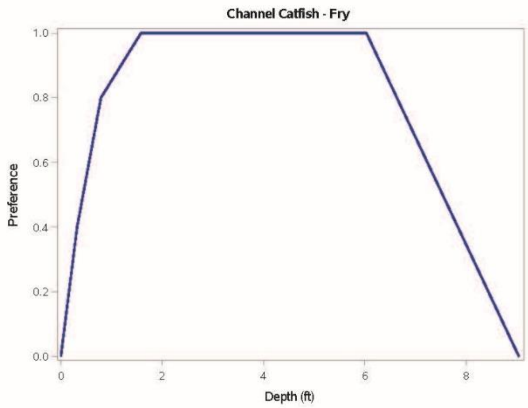

Bluegill - Juvenile
Preference
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5

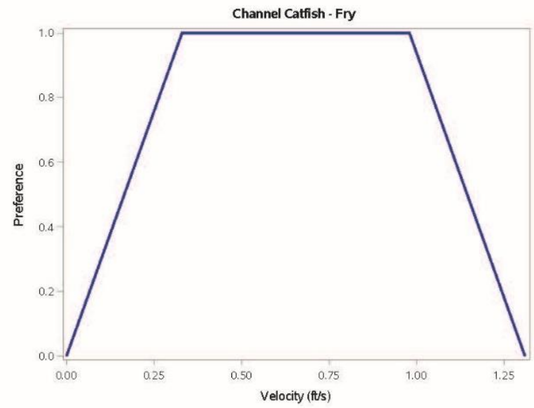

Bluegill - Spawning
Preference
Depth (ft)
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6

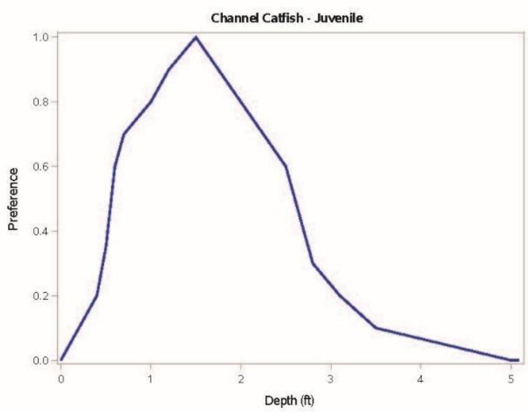

Bluegill - Spawning
Preference
Velocity (ft/s)
1.0
0.8
0.6
0.4
0.2
0.00
0.25
0.50
0.75
1.00
1.25

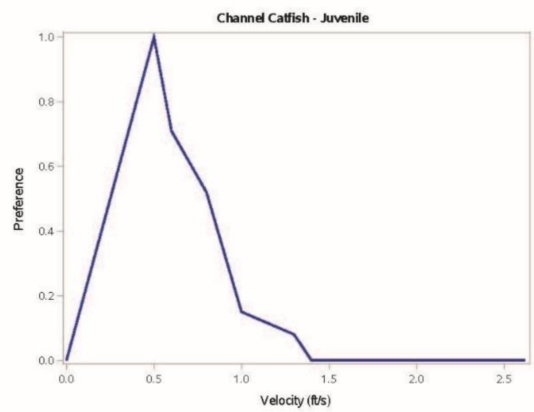

Channel Catfish - Adult
Preference
Depth (ft)
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8

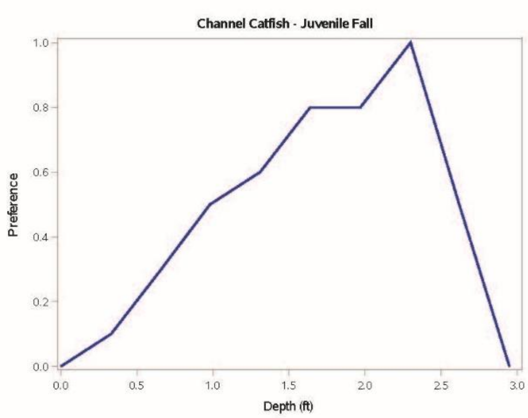

Channel Catfish - Adult
Preference
Velocity (ft/s)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.0
0.5
1.0
1.5
2.0
2.5

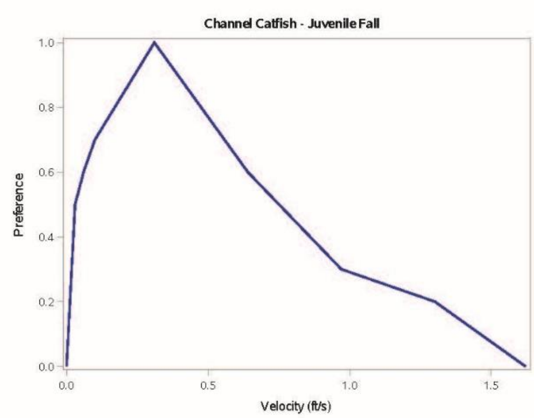

Channel Catfish - Fry
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
Depth (ft)

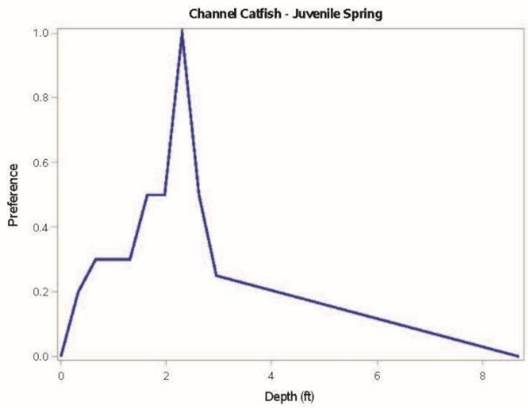
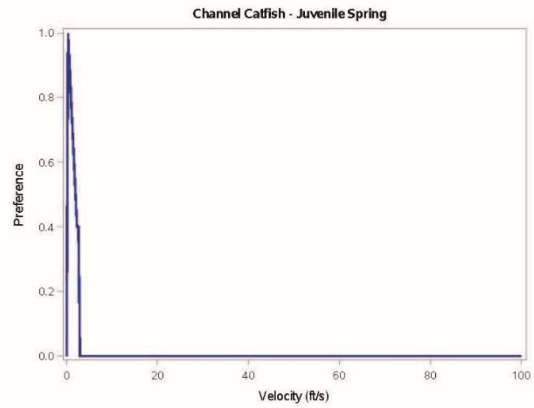
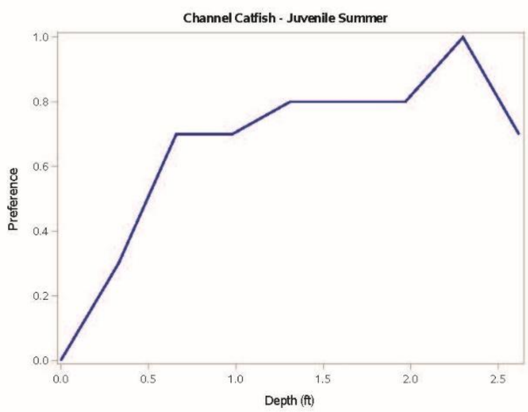
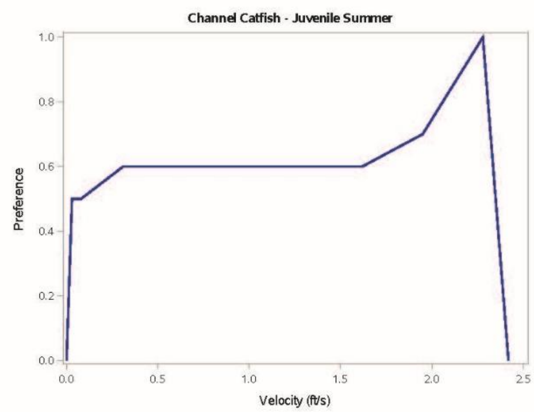
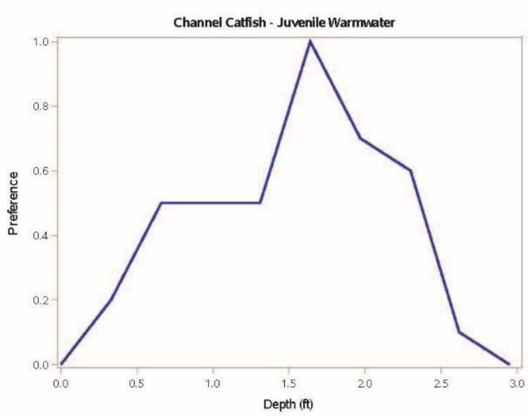
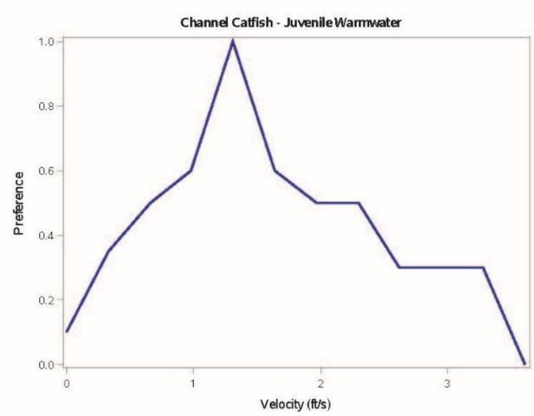

Channel Catfish - Fry
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.25
0.50
0.75
1.00
1.25
Velocity (ft/s)

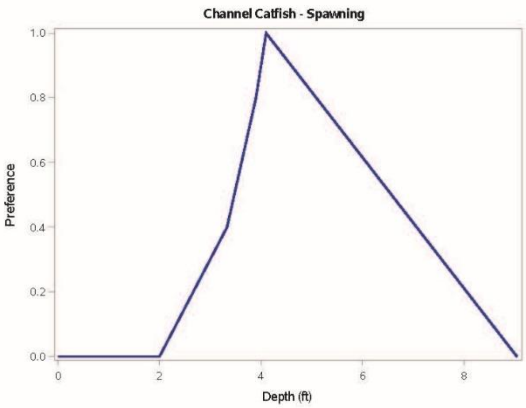

Channel Catfish - Juvenile
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
Depth (ft)

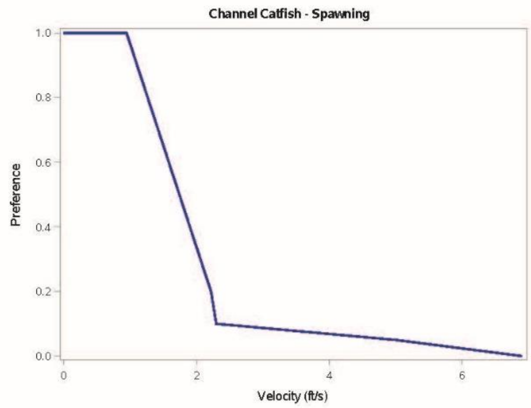

Channel Catfish - Juvenile
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
Velocity (ft/s)

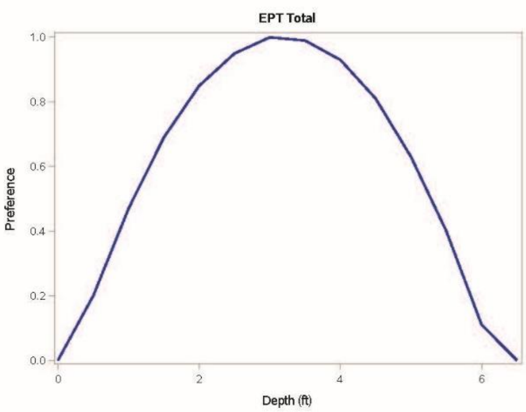

Channel Catfish - Juvenile Fall
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth (ft)

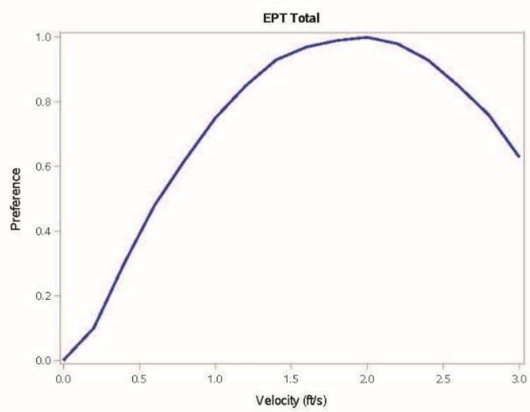

Channel Catfish - Juvenile Fall
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
Velocity (ft/s)

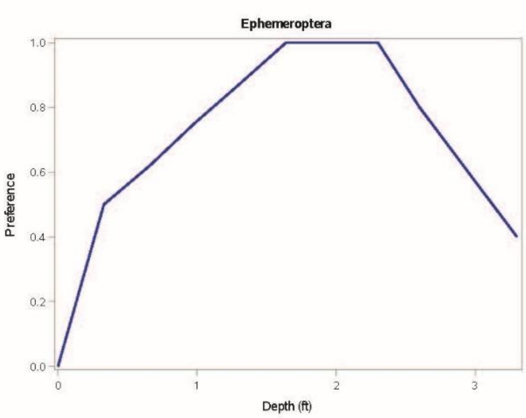

Channel Catfish - Juvenile Spring
Preference
Depth (ft)
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8

Channel Catfish - Juvenile Spring
Preference
Velocity (ft/s)
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100

Channel Catfish - Juvenile Summer
Preference
Depth (ft)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0
2.5

Channel Catfish - Juvenile Summer
Preference
Velocity (ft/s)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0
2.5

Channel Catfish - Juvenile Warmwater
Preference
Depth (ft)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0

Channel Catfish - Juvenile Warmwater
Preference
Velocity (ft/s)
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3

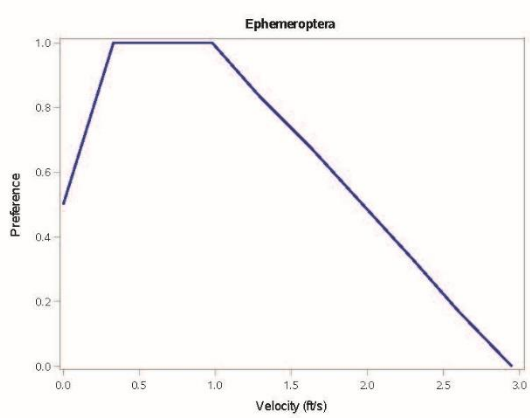

Channel Catfish - Spawning
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
Depth (ft)

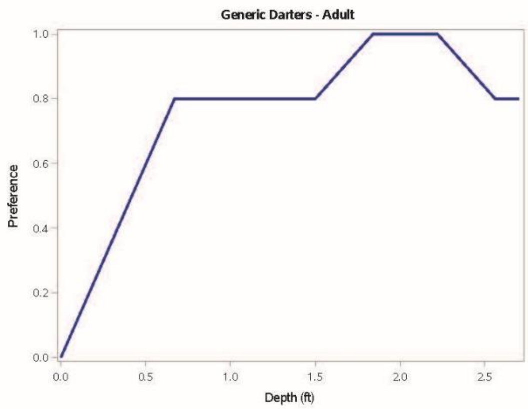

Channel Catfish - Spawning
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
Velocity (ft/s)

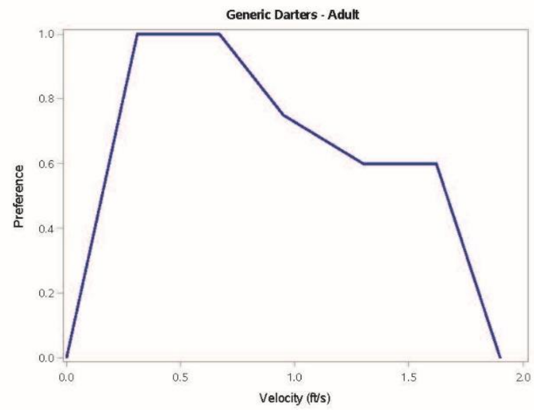

EPT Total
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
Depth (ft)

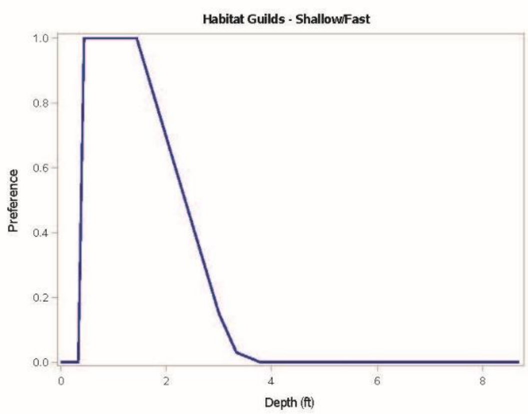

EPT Total
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Velocity (ft/s)

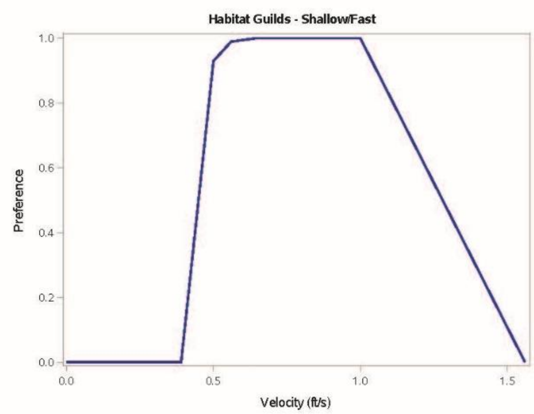

Ephemeroptera
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
Depth (ft)

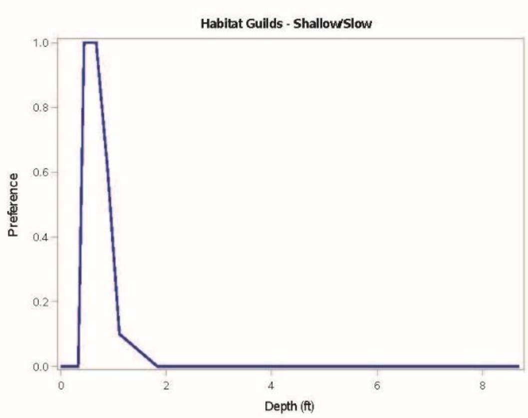

Ephemeroptera
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Velocity (ft/s)

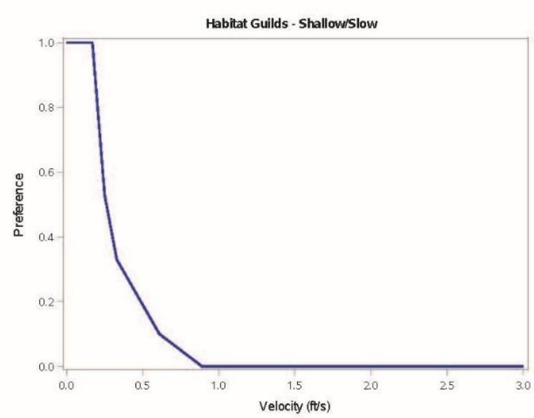

Generic Darters - Adult
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
Depth (ft)

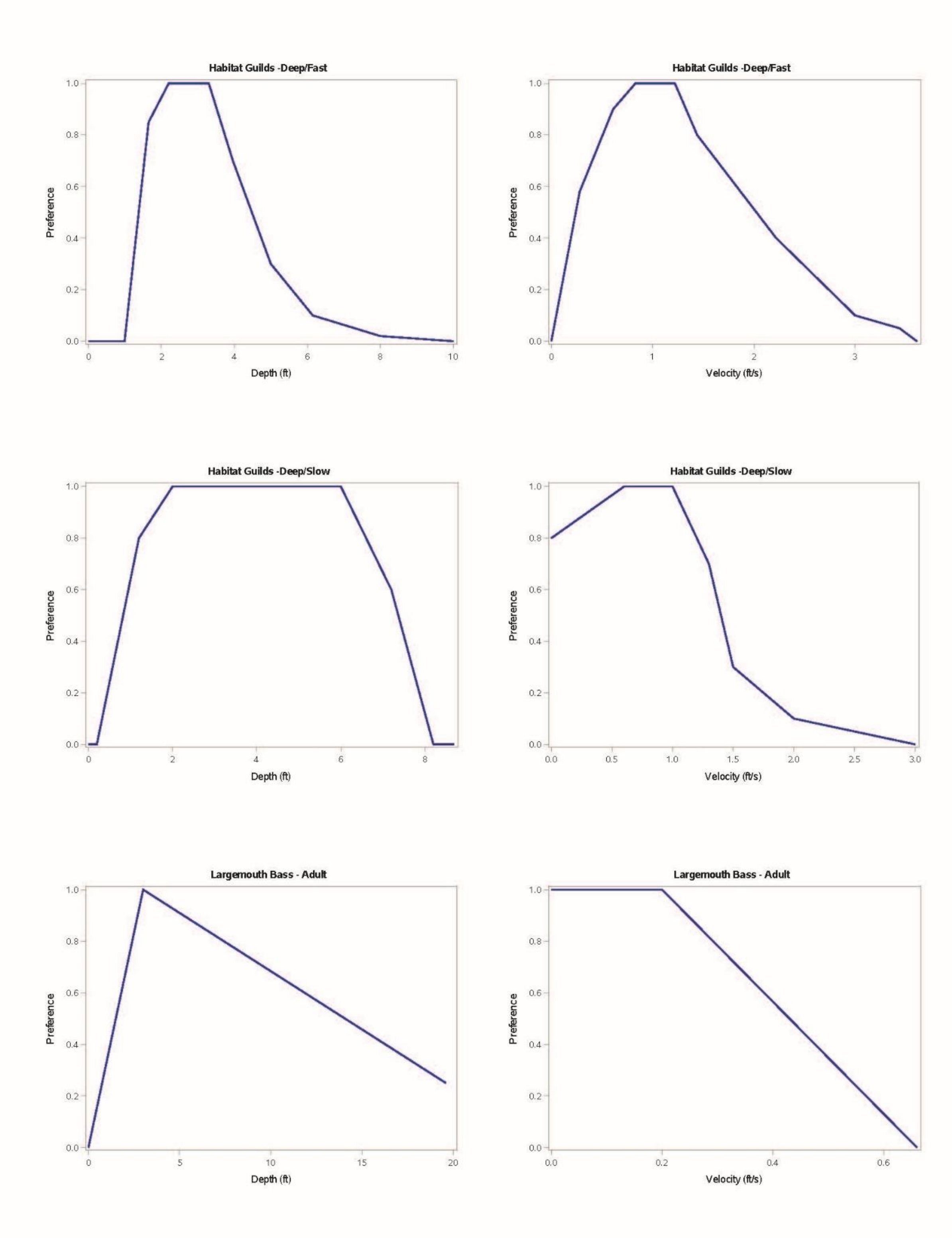

Generic Darters - Adult
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
Velocity (ft/s)

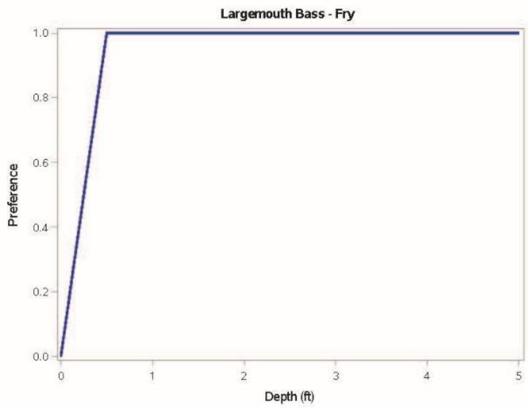

Habitat Guilds - Shallow/Fast
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
Depth (ft)

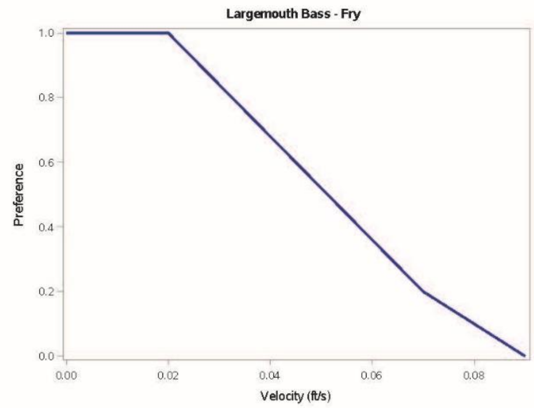

Habitat Guilds - Shallow/Fast
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
Velocity (ft/s)

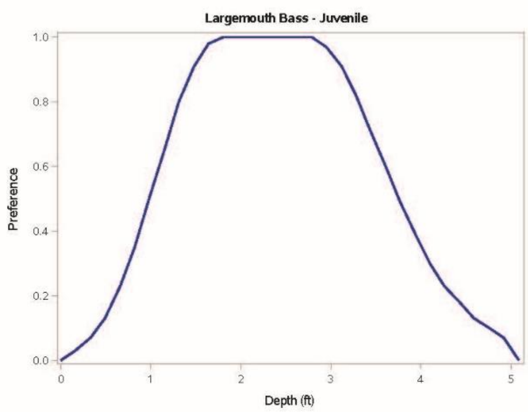

Habitat Guilds - Shallow/Slow
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
Depth (ft)

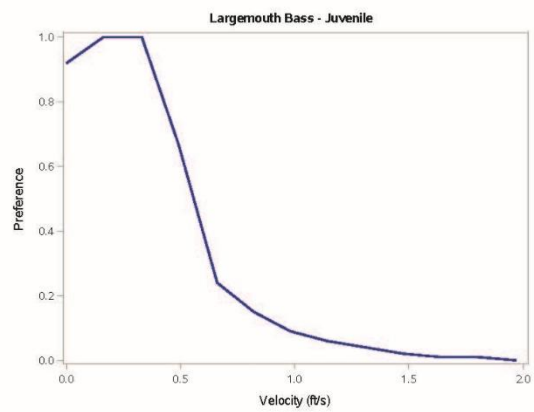

Habitat Guilds - Shallow/Slow
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Velocity (ft/s)

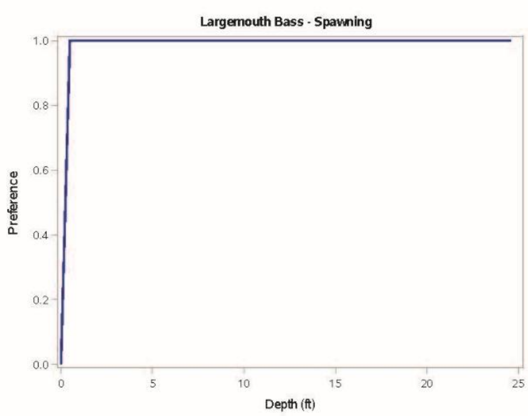

Habitat Guilds -Deep/Fast
Preference
Depth (ft)
Habitat Guilds -Deep/Fast
Preference
Velocity (ft/s)
Habitat Guilds -Deep/Slow
Preference
Depth (ft)
Habitat Guilds -Deep/Slow
Preference
Velocity (ft/s)
Largemouth Bass - Adult
Preference
Depth (ft)
Largemouth Bass - Adult
Preference
Velocity (ft/s)

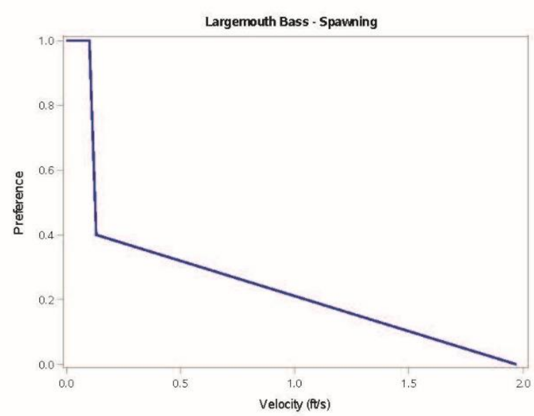

Largemouth Bass - Fry
Preference
Depth (ft)

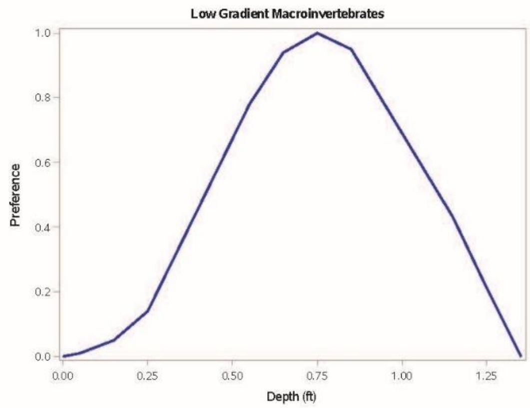

Largemouth Bass - Fry
Preference
Velocity (ft/s)

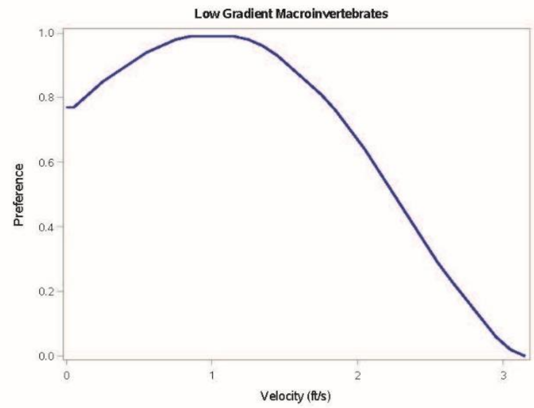

Largemouth Bass - Juvenile
Preference
Depth (ft)

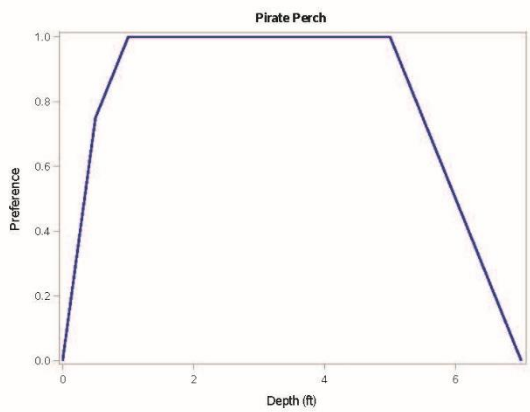

Largemouth Bass - Juvenile
Preference
Velocity (ft/s)

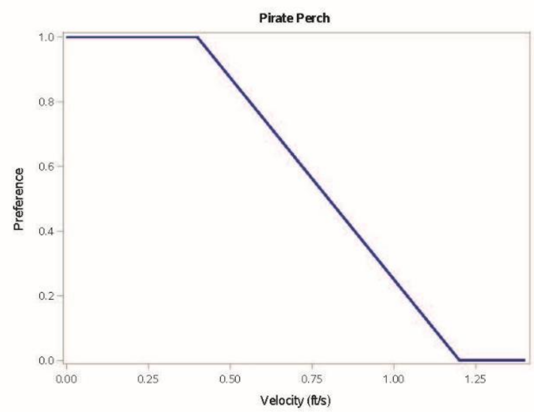

Largemouth Bass - Spawning
Preference
Depth (ft)

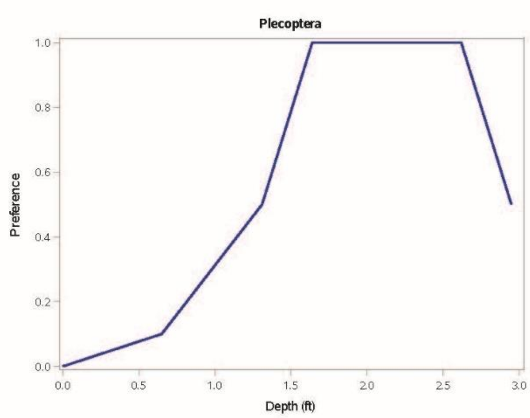

Largemouth Bass - Spawning
Preference
Velocity (ft/s)

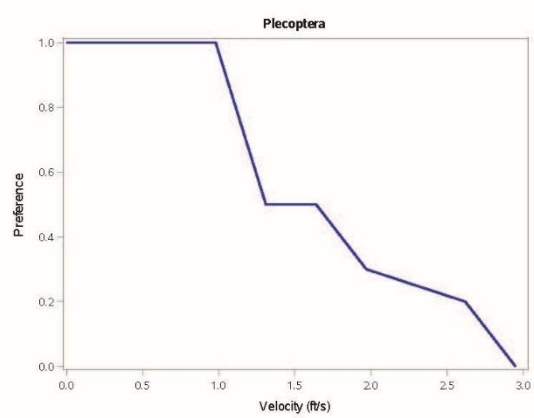

Low Gradient Macroinvertebrates
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.25
0.50
0.75
1.00
1.25
Depth (ft)

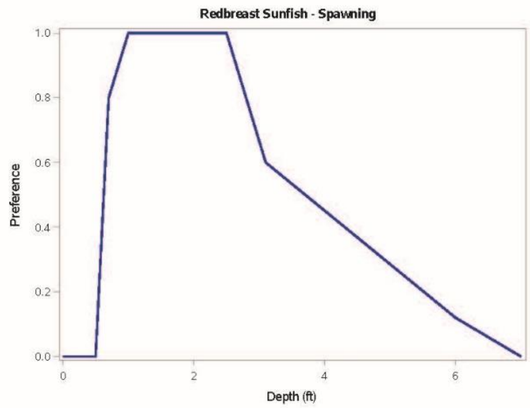

Low Gradient Macroinvertebrates
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
Velocity (ft/s)

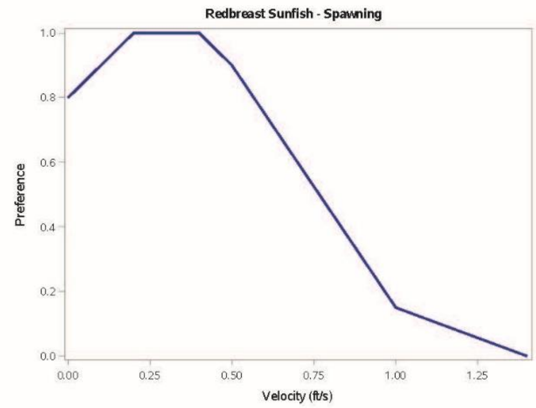

Pirate Perch
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
Depth (ft)

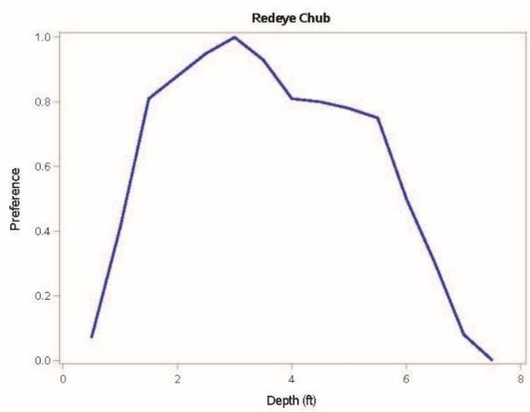

Pirate Perch
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.25
0.50
0.75
1.00
1.25
Velocity (ft/s)

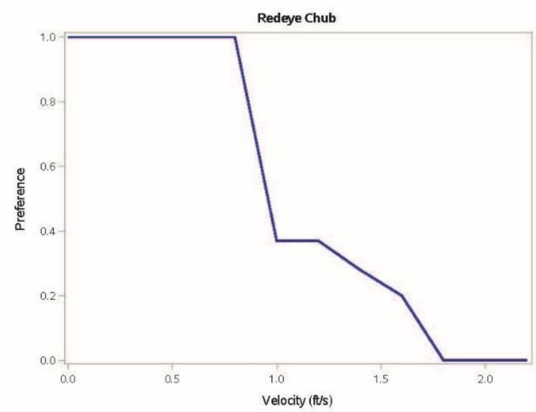

Plecoptera
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth (ft)

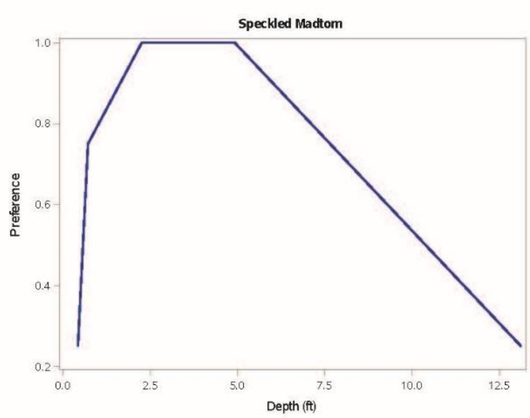

Plecoptera
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Velocity (ft/s)

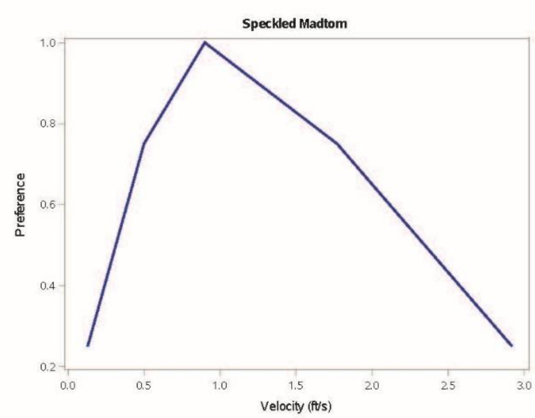

Redbreast Sunfish - Spawning
Preference
Depth (ft)
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6

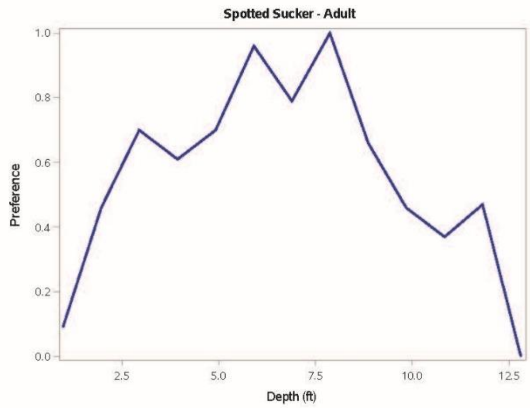

Redbreast Sunfish - Spawning
Preference
Velocity (ft/s)
0.0
0.2
0.4
0.6
0.8
1.0
0.00
0.25
0.50
0.75
1.00
1.25

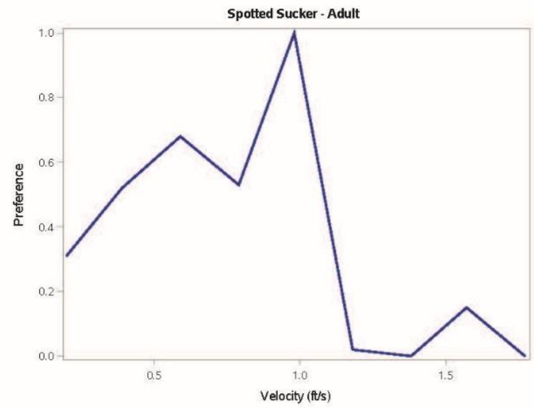

Redeye Chub
Preference
Depth (ft)
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8

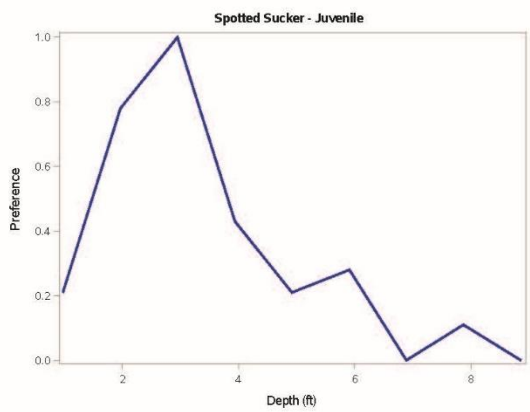

Redeye Chub
Preference
Velocity (ft/s)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0

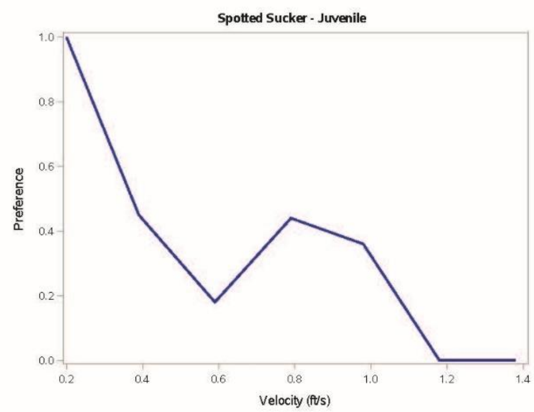

Speckled Madtom
Preference
Depth (ft)
0.2
0.4
0.6
0.8
1.0
0.0
2.5
5.0
7.5
10.0
12.5

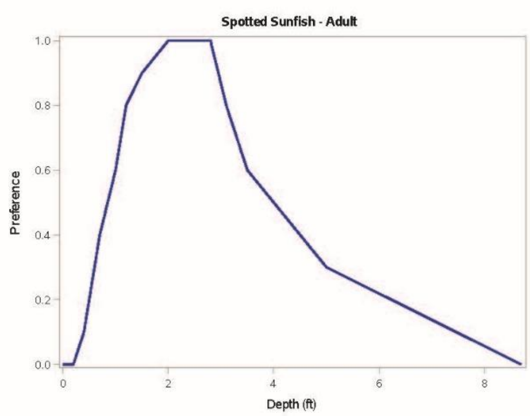

Speckled Madtom
Preference
Velocity (ft/s)
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0

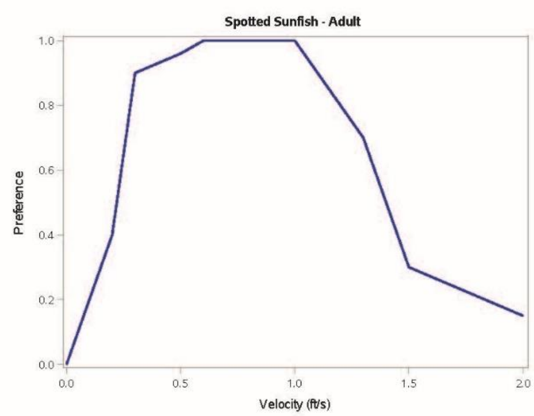

Spotted Sucker - Adult
Preference
Depth (ft)

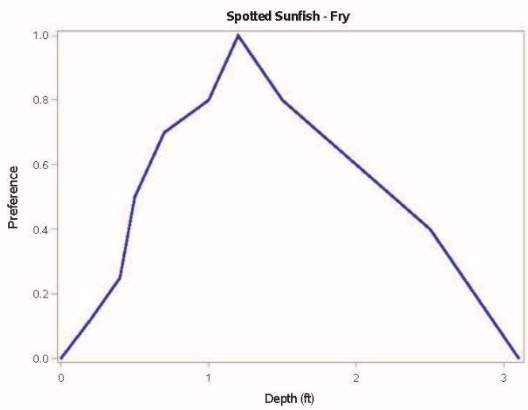

Spotted Sucker - Adult
Preference
Velocity (ft/s)

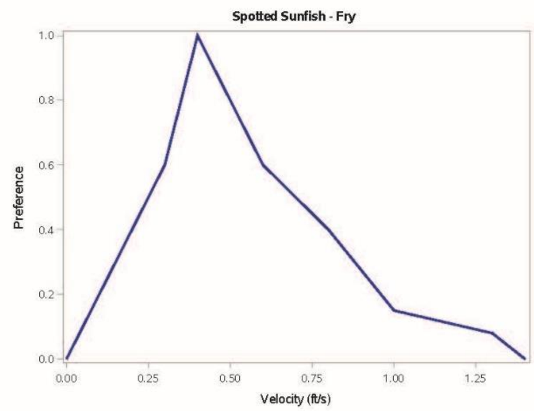

Spotted Sucker - Juvenile
Preference
Depth (ft)

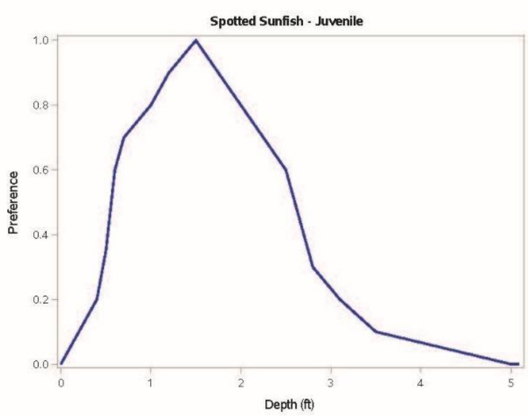

Spotted Sucker - Juvenile
Preference
Velocity (ft/s)

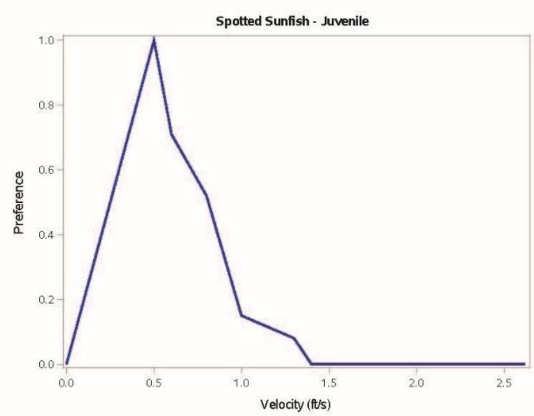

Spotted Sunfish - Adult
Preference
Depth (ft)

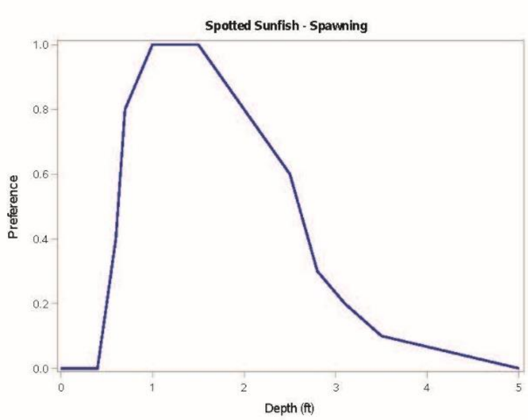

Spotted Sunfish - Adult
Preference
Velocity (ft/s)

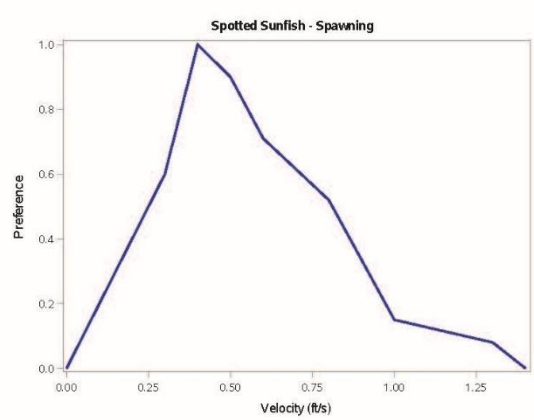

Spotted Sunfish - Fry
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
Depth (ft)

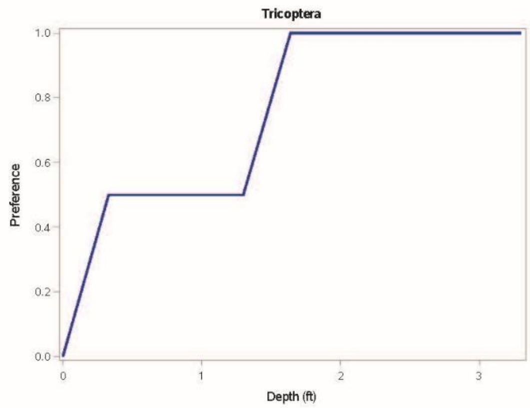

Spotted Sunfish - Fry
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.25
0.50
0.75
1.00
1.25
Velocity (ft/s)

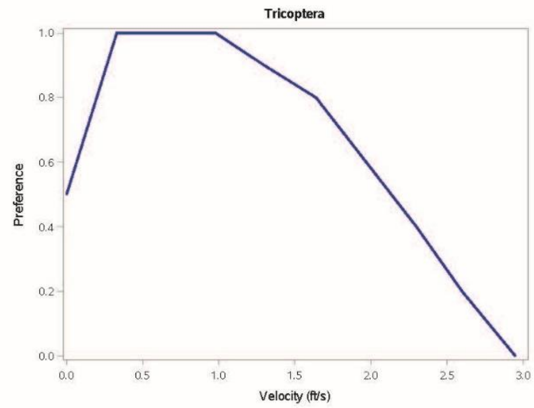

Spotted Sunfish - Juvenile
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
Depth (ft)


Spotted Sunfish - Juvenile
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
Velocity (ft/s)


Spotted Sunfish - Spawning
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
Depth (ft)


Spotted Sunfish - Spawning
Preference
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.25
0.50
0.75
1.00
1.25
Velocity (ft/s)


Tricoptera
Preference
Depth (ft)
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3


Tricoptera
Preference
Velocity (ft/s)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0

APPENDIX B

Baseline AWS Results.

Mean, median and maximum AWS and associated flows at CR 388 for the Baseline Scenario.						
Taxon	Mean		Median		Maximum	
	AWS	Flow @ Mean AWS	AWS	Flow @ Median AWS	AWS	Flow @ Maximum AWS
Blackbanded Darters Adult	145	517.8	144	501.8	159	1141.8
Bluegill Adult	62	520.8	60	501.8	112	1141.8
Bluegill Fry	156	436.8	158	479.8	161	613.8
Bluegill Juvenile	102		102		106	302.8
Bluegill Spawning	170	382.8	171	382.8	173	423.8
Channel Catfish Adult	85	507.8	85	501.8	129	1141.8
Channel Catfish Fry	138	508.8	138	501.8	170	1141.8
Channel Catfish Juvenile	34		34		35	388.8
Channel Catfish Juvenile Fall	65		65		75	302.8
Channel Catfish Juvenile Spring	47	508.8	47	501.8	53	1141.8
Channel Catfish Juvenile Summer	116	512.8	115	501.8	140	1141.8
Channel Catfish Juvenile Warmwater	16		16		18	302.8
Channel Catfish Spawning	77	525.8	75	501.8	136	1141.8
EPT Total	33	453.8	33	477.8	38	1141.8
Ephemeroptera	141	535.8	141	501.8	152	1141.8
Generic Darters Adult	128	512.8	127	501.8	167	1141.8
Habitat Guilds Deep Fast	74	508.8	73	501.8	84	1141.8
Habitat Guilds Deep Slow	212	496.8	213	501.8	243	1141.8
Habitat Guilds Shallow Fast	4	450.8	3	664.8	4	1141.8
Habitat Guilds Shallow Slow	32	303.8	32	303.8	40	363.8
Largemouth Bass Adult	164	508.8	164	501.8	212	1141.8
Largemouth Bass Fry	21		21		23	346.8
Largemouth Bass Juvenile	179	466.8	180	496.8	183	632.8
Largemouth Bass Spawning	151	577.8	150	550.8	159	780.8
Low Gradient Macroinvertebrates	32	319.8	33	319.8	36	416.8
Pirate Perch	236	517.8	235	501.8	271	1141.8
Redbreast Sunfish Adult	212	496.8	213	501.8	243	1141.8
Plecoptera	163	530.8	162	501.8	188	1141.8
Redbreast Sunfish Fry	99	504.8	99	501.8	141	1141.8

Mean, median and maximum AWS and associated flows at CR 388 for the Baseline Scenario.						
Taxon	Mean		Median		Maximum	
	AWS	Flow @ Mean AWS	AWS	Flow @ Median AWS	AWS	Flow @ Maximum AWS
Redbreast Sunfish juvenile	257	529.8	254	501.8	280	890.8
Redbreast Sunfish spawning	166	474.8	167	501.8	176	890.8
Redeye Chub	194	504.8	194	501.8	227	1141.8
Speckled Madtom	116	507.8	116	501.8	140	1141.8
Spotted Sucker Adult	58	445.8	58	674.8	61	1141.8
Spotted Sucker Juvenile	141	442.8	141	491.8	144	602.8