SEFA Model Development and Evaluation of Instream Habitat Metrics for Gainer Spring Group, Williford Spring Group, and Sylvan Spring Group Minimum Flows and Levels

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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 Gainer Springs Group, Williford Springs Group, and Sylvan Springs Group (Econfina Creek MFL). 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 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 water management districts – Southwest, St. Johns River, Suwannee River, and more 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.

SEFA has been applied in several MFL 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/lie 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 loss of habitat associated with decreases in flows (Herrick, 2021). As a result, the patterns of flow 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 Econfina Creek.

2.0 ECONFINA CREEK – GENERAL DESCRIPTION

The District produced a Water Resources Special Report (2002) that provides a summary of the Econfina Creek system. Econfina Creek originates in Jackson County and flows through Bay County, Washington County and back into Bay County where it enters Deer Point Lake. Econfina Creek itself has a surface water basin covering 275 square miles (~176,000 acres).

This 41,363-acre watershed in Washington and Bay counties runs 14 miles along the course of Econfina Creek and also encompasses xeric sandhill uplands with dozens of shallow, clear sand-bottomed lakes. These uplands recharge the springs that feed the creek. Along the creek hardwood forests and hammocks grow above fern-covered limestone bluffs and outcrops. The Econfina Creek is a state-designated canoe trail.

The creek is relatively narrow and shallow with primarily sandy bottoms. The mean creek depths in the transects in the portion of creek examined in this project is 3.8 ft and ranges from 2.2 to 5.8 ft. The mean creek channel width is 194 ft and ranges from less than 40 ft to 2017 ft.

3.0 DATA SOURCES

3.1 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 documented to occur in Econfina Creek. Data sources include the Florida Wildlife Commission and University of Florida fish collection library.

Species	Common Name	Species	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

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

Species	Common Name	Species	Common Name
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

*Indicates a macroinvertebrate species. All other species are fish.

3.2 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.

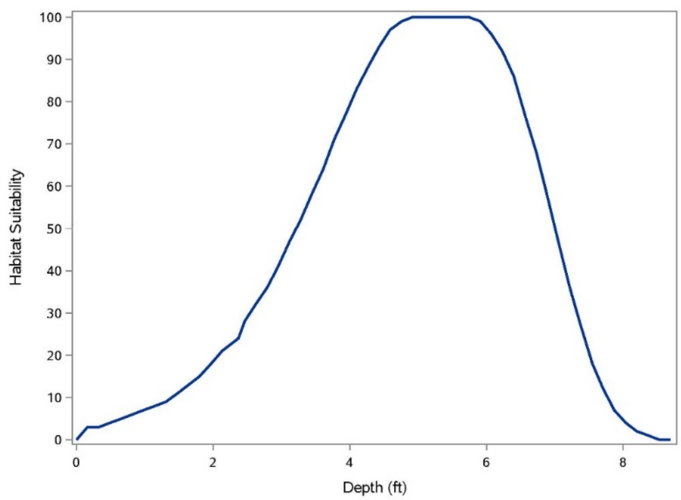


Figure 1. Example of a habitat suitability curve.

Habitat suitability curves have been identified 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.

Table 3. Fishes documented in Econfina Creek for which habitat suitability have been identified.

ECONFINA TAXA		GORE CURVES	NAGID CURVES
Aphredoderus sayanus	Pirate perch		X
Ictoalurus punctatus	Channel catfish	X	
Lepomis auratus	Redbreast sunfish	X	X
Lepomis macrochirus	Bluegill	X	X
Lepomis punctatus	Spotted sunfish	X	X
Micropterus salmoides floridanus x salmoides	Largemouth bass hybrid	X	X
Minytrema melanops	Spotted sucker		X
Notropis harperi	Redeye chub		X
Noturus leptacanthus	Speckled madtom		X
Habitat Guild – Deep Fast		X	
Habitat Guild – Deep Slow		X	
Habitat Guild – Shallow Fast		X	
Habitat Guild – Shallow Slow		X	

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.

In addition to the habitat suitability curves, the SEFA application is based on flow data for the gages found in the subject waterbody and output from the HEC-RAS model used to simulate water depths and velocities as a function of creek flow. The creek flows are expressed as total flow. Table 4 presents the creek flow scenarios that were simulated by the HEC-RAS model. Figure 2 presents the HEC-RAS transects for which the SEFA modeling was completed

Table 4. Baseline Creek Flows – 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

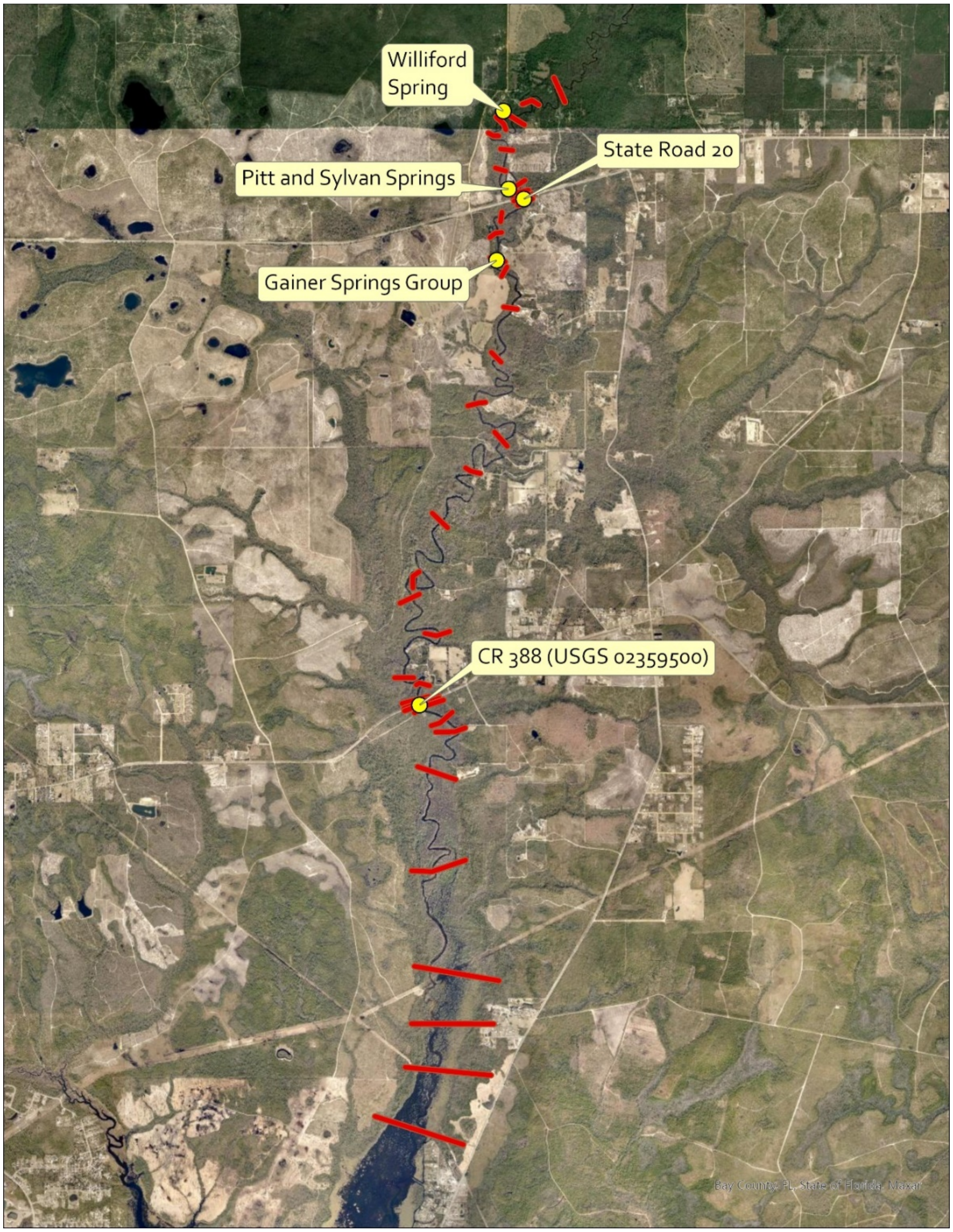


Figure 2. Econfina Creek HEC-RAS transects.

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

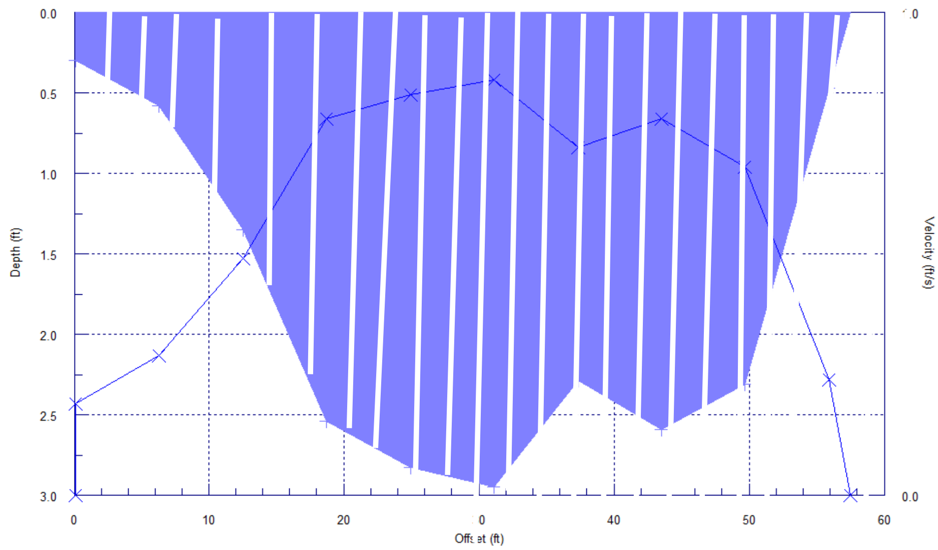


Figure 3. Example cross section and verticals from which depth and velocities are estimated by the HEC-RAS model.

4.0 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 area and weighting by the area of that 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.)

5.0 APPLICATION OF SEFA RESULTS TO DEVELOPMENT OF THE MFL 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. MFL 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.

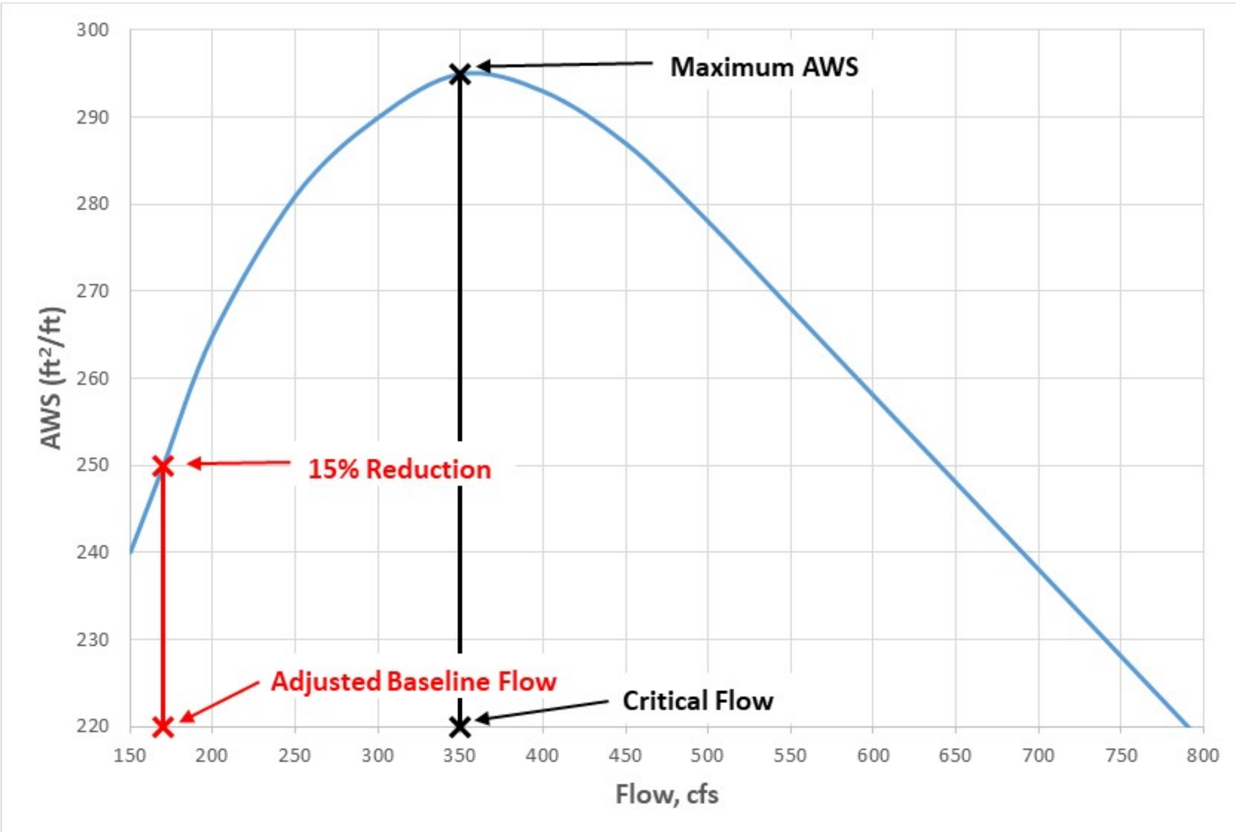
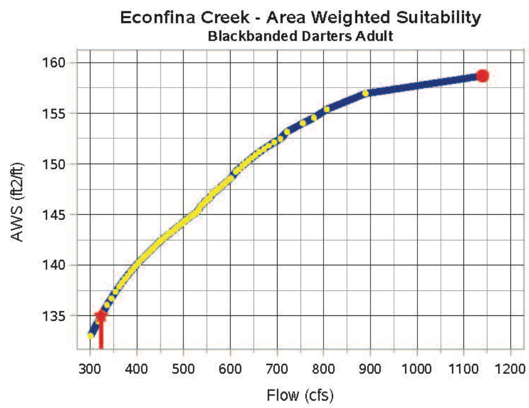
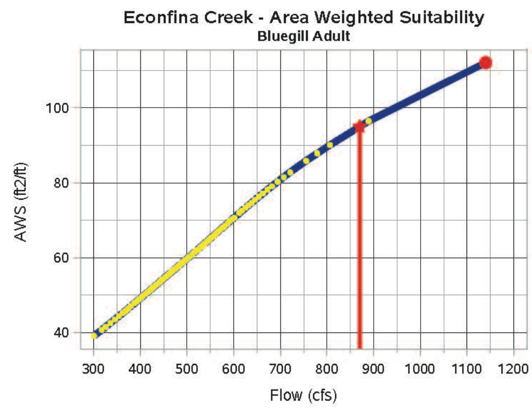


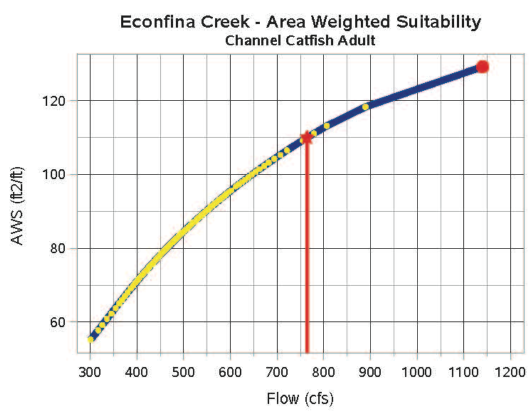
Figure 4. Conceptual depiction of the estimation of the critical flow that results in a 15% reduction in AWS.

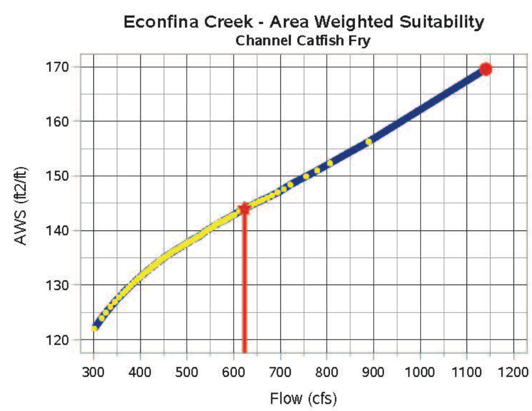
The first step in this process entailed the identification of those taxa/life stages that displayed a reduction in AWS with reductions in flow. This resulted in the exclusion of those taxa/life stages that displayed a reduction in AWS at higher flows, i.e. those taxa/life stages that are not candidates for establishing an MFL for Econfina Creek as the definition of an MFL is a flow below which significant harm occurs.

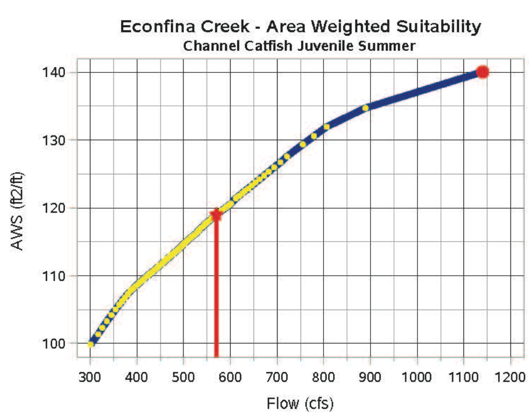
The following figures present the results that estimate the critical flows for those taxa/life stages whose AWS declines with reductions in flows. Positive results are found when increasing flow led to increased AWS. Negative results are found when AWS decreases with decreasing flows.

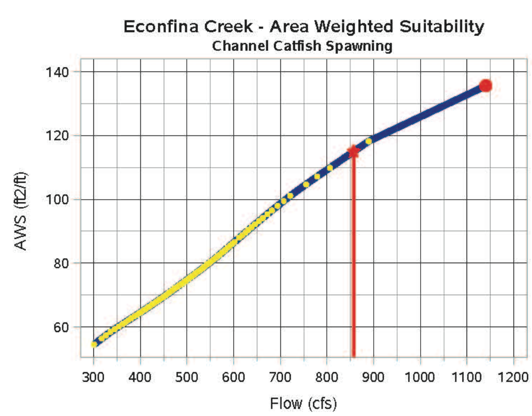

Econfina Creek - Area Weighted Suitability
Blackbanded Darters Adult
AWS (ft2/ft)
Flow (cfs)

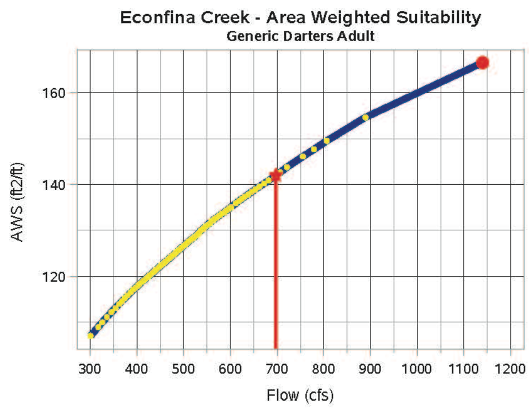

Econfina Creek - Area Weighted Suitability
Bluegill Adult
AWS (ft2/ft)
Flow (cfs)

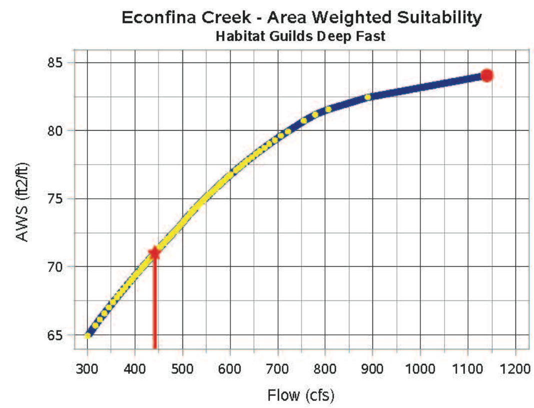

Econfina Creek - Area Weighted Suitability
Channel Catfish Adult
AWS (ft2/ft)
Flow (cfs)

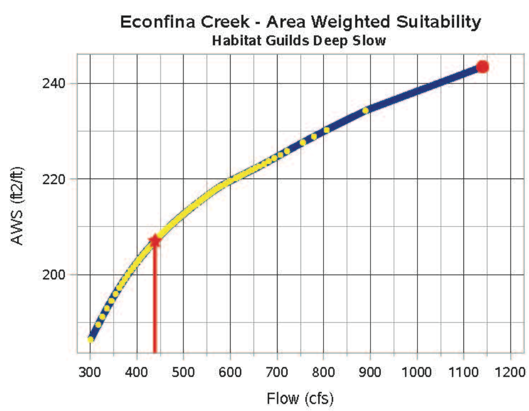

Econfina Creek - Area Weighted Suitability
Channel Catfish Fry
AWS (ft2/ft)
Flow (cfs)

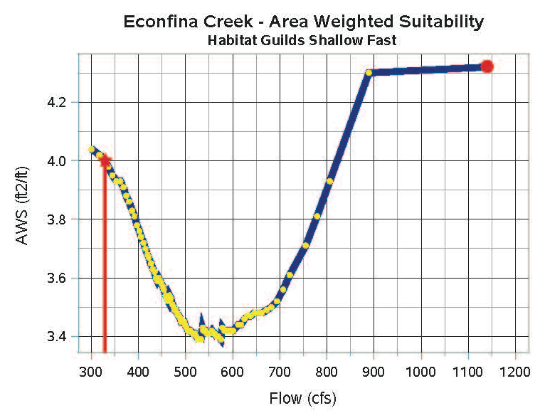

Econfina Creek - Area Weighted Suitability
Channel Catfish Juvenile Summer
AWS (ft2/ft)
Flow (cfs)

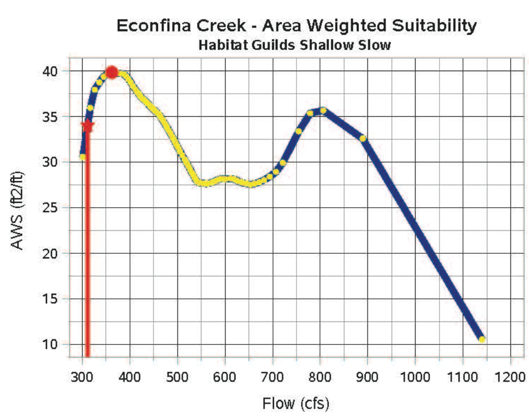

Econfina Creek - Area Weighted Suitability
Channel Catfish Spawning
AWS (ft2/ft)
Flow (cfs)

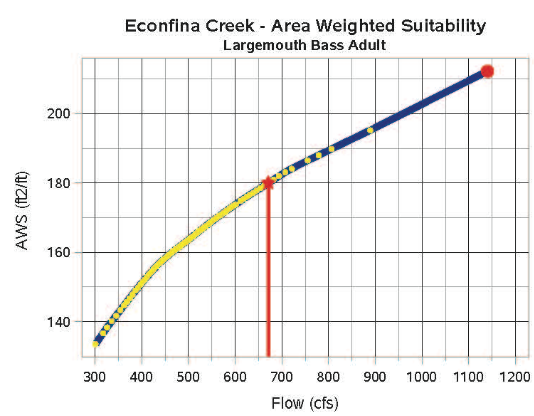

Econfina Creek - Area Weighted Suitability
Generic Darters Adult
AWS (ft2/ft)
Flow (cfs)

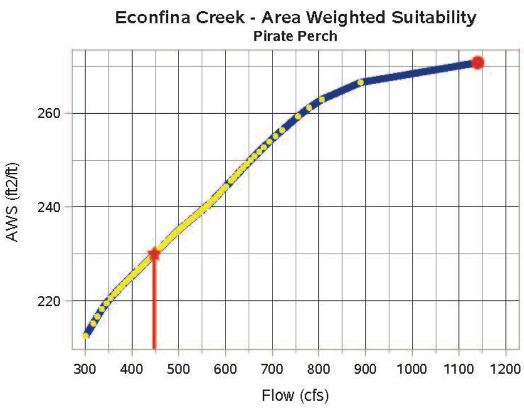

Econfina Creek - Area Weighted Suitability
Habitat Guilds Deep Fast
AWS (ft2/ft)
Flow (cfs)

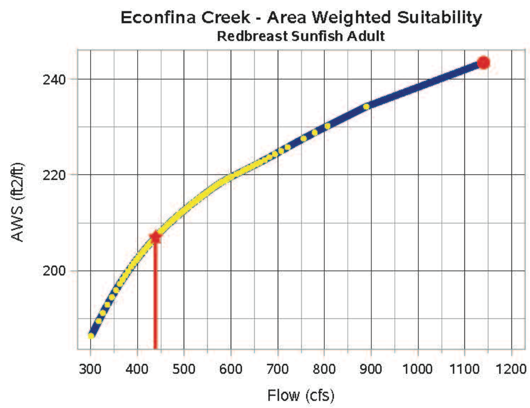

Econfina Creek - Area Weighted Suitability
Habitat Guilds Deep Slow
AWS (ft2/ft)
Flow (cfs)

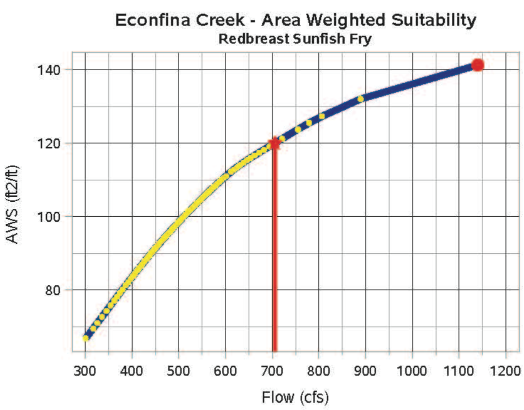

Econfina Creek - Area Weighted Suitability
Habitat Guilds Shallow Fast
AWS (ft2/ft)
Flow (cfs)

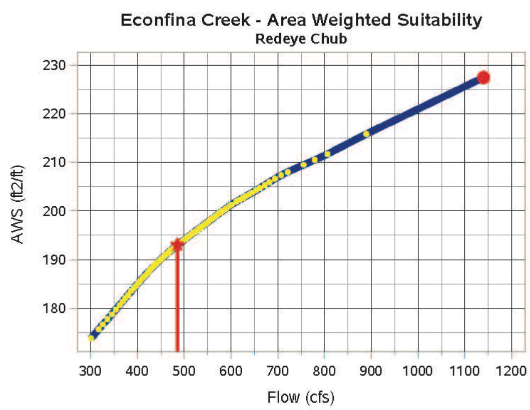

Econfina Creek - Area Weighted Suitability
Habitat Guilds Shallow Slow
AWS (ft2/ft)
Flow (cfs)

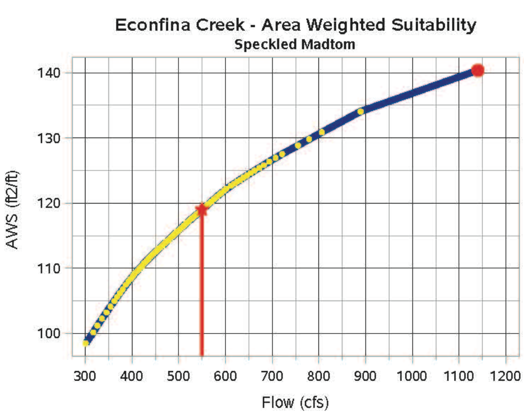

Econfina Creek - Area Weighted Suitability
Largemouth Bass Adult
AWS (ft2/ft)
Flow (cfs)

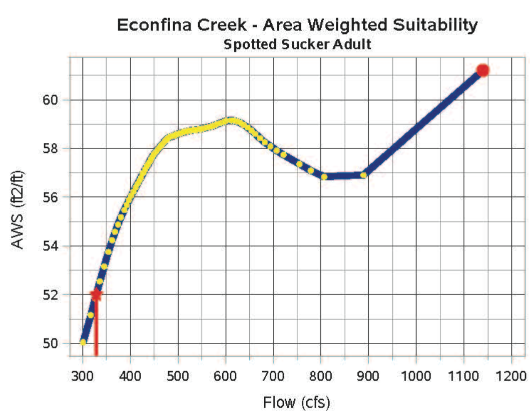

Econfina Creek - Area Weighted Suitability
Pirate Perch
AWS (ft2/ft)
220
240
260
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)


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)
80
100
120
140
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)


Econfina Creek - Area Weighted Suitability
Redeye Chub
AWS (ft2/ft)
180
190
200
210
220
230
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)


Econfina Creek - Area Weighted Suitability
Speckled Madtom
AWS (ft2/ft)
100
110
120
130
140
300 400 500 600 700 800 900 1000 1100 1200
Flow (cfs)


Econfina Creek - Area Weighted Suitability
Spotted Sucker Adult
AWS (ft2/ft)
50
52
54
56
58
60
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 max 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
- % Change in Flow to Achieve 15% Reduction in 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	% Change in Flow to Achieve 15% Reduction in AWS
Habitat Guilds Shallow Slow	39.8	362	34	311	-14.1
Bluegill Adult	112.1	1140	95	870	-23.8
Channel Catfish Spawning	135.6	1140	115	857	-24.9
Channel Catfish Adult	129.3	1140	110	764	-33.1
Redbreast Sunfish Fry	141.3	1140	120	706	-38.2
Generic Darters Adult	166.6	1140	142	698	-38.9
Largemouth Bass Adult	212.3	1140	180	671	-41.2
Channel Catfish Fry	169.6	1140	144	623	-45.4
Channel Catfish Juvenile Summer	140.0	1140	119	570	-50.0
Speckled Madtom	140.4	1140	119	550	-51.8
Redeye Chub	227.4	1140	193	486	-57.5
Pirate Perch	270.8	1140	230	448	-60.8
Habitat Guilds Deep Fast	84.1	1140	71	442	-61.3
Habitat Guilds Deep Slow	243.4	1140	207	439	-61.6

Table 5. SEFA model results.					
Taxon	**Maximum AWS**	**Flow @ Maximum AWS**	**15% Reduction in Maximum AWS**	**Flow @ Reduced Maximum AWS**	**% Change in Flow to Achieve 15% Reduction in AWS**
Redbreast Sunfish Adult	243.4	1140	207	439	-61.6
Habitat Guilds Shallow Fast	4.3	1140	4	329	-71.1
Spotted Sucker Adult	61.2	1140	52	328	-71.2
Blackbanded Darters Adult	158.7	1140	135	323	-71.7

These results reflect the general lack of sensitivity in most of the taxa/life stages as relatively large flow reductions are required to achieve a 15% allowable reduction in AWS. The Slow Shallow Guild taxa display the greatest sensitivity to flow change as a 14.1% flow reduction results in a 15% reduction in AWS. The fish taxa that comprise the Shallow Slow Guild 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:

- Redbreast Sunfish (*Lepomis auritus*)
- Bluegill (*Lepomis macrochirus*)
- Largemouth Bass (*Micropterus salmoides*) (juveniles)
- Spotted Sunfish (*Lepomis punctatus*)
- Warmouth (*Lepomis gulosus*)
- Eastern Mosquitofish (*Gambusia Holbrook*

6.0 LITERATURE CITED

Damiani, M., Montserrat Núñez, Philippe Roux, Eléonore Loiseau & Ralph K. Rosenbaum (2018). Addressing water needs of freshwater ecosystems in life cycle impact assessment of water consumption: state of the art and applicability of ecohydrological approaches to ecosystem quality characterization. Int J Life Cycle Assess 23, 2071–2088.

Evans, J., & England, R.H. (1995). A Recommended Method to Protect lnstream Flows in Georgia. Georgia: Georgia Department of Natural Resources Wildlife Resources Division.

Filipek, S.P., Keith, W.E., & Giese, J. (1987). Status of the Instream Flow Issue in Arkansas. Journal of the Arkansas Academy of Science.

Freeman, M., Bowen, Z., & Crance, J. (1997). Transferability of habitat suitability criteria for fishes in warmwater streams. North American Journal of Fisheries Management, 17, 20-31.

Gore, J., Dahm, C., & Klimas, C. (2002). A Review of "Upper Peace River: An Analysis of Minimum Flows and Levels. Brooksville, FL: Southwest Florida Water Management District.

Hardy, T. (1997). Methodologies for quantification of multiple-use sustained-yield act claims: US Forest Service. County of Twin Falls: Boise Adjudication Team.

Herrick, G, (2021) Instream Habitat Modeling in the Little Manatee River. Update using System for Environmental Flow Analysis (SEFA). Southwest Florida Water Management District.

Hood, J. (2006). Standardized Methods Utilized by the Ecologic Evaluation Section for Collection and Management of Physical Habitat Simulation Model and lnstream Habitat Data. Brooksville, Florida: Southwest Florida Water Management District.

Mathews, RC., & Bao, Y.X. (1991). The Texas method of preliminary instream flow assessment. Rivers, 2(4), 295-310.

Munson, A.N. and J. Delfino. 2007, Minimum Wet-Season Flows and Levels in Southwest Florida River. Journal of the American Water Resources Association.

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.

Normandeau Associates, Inc. 2017. Illinois River Instream Flow Assessment, Physical Habitat. Simulation (IFIM Phases 1-3). Tulsa District: Oklahoma.

Northwest Florida Water Management District. 2004. Econfina Creek Spring Inventory Washington and Bay Counties, Florida Water Resources Special Report 04-02.

Northwest Florida Water Management District. 2019. Recommended Minimum Flows for the St. Marks River Rise. Leon County, Florida. March 2019.

Northwest Florida Water Management District. 2021. Recommended Minimum Flows for Wakulla Spring and Sally Ward Spring. Wakulla County, Florida. March 2021.

Northwest Florida Water Management District. 2024. Update and Calibration of the Hydrologic Engineering Center River Analysis System (HEC-RAS) Model Econfina Creek System.

Richards, C.J., "Potentiometric Surface of the Floridan Aquifer, August 1996", Northwest Florida Water Management District, Map Series 99-2, 1999.

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.

Richter, B.D. M.M. David, C. Apse, C. and C. Konrad . 2011.
Short Communication: A Presumptive Standard For Environmental Flow Protection. River Research And Applications. DOI: 10.1002/rra.

Southwest Florida Water Management District. 2008. Weeki Wachee River System Recommended Minimum Flows and Levels. Technical Report of the Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District. 2010. Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek. Technical Report of the Southwest Florida Water Management District, Brooksville, Florida

Southwest Florida Water Management District. 2011. The Determination of Minimum Flows for the Lower Myakka River. Technical Report of the Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District. 2012a. Recommended Minimum Flows for the Homosassa River System. Technical Report of the Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District. 2012b. Recommended Minimum Flows for the Chassahowitzka River System. Technical Report of the Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District. 2017a. Recommended Minimum flow for the Crystal River/Kings Bay System, Revised Final Report. Technical Report of the Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District. 2017b. Recommended Minimum flow for the Rainbow River System, Revised Final Draft Report. Technical Report of the Southwest Florida Water Management District, Brooksville, 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.

St. Johns River Water Management District. 2017. Minimum Flows Determination for Silver Springs. Marion County, Florida. Final Report. Technical Publication SJ2017-2, Palatka, Florida.

Suwannee River Water Management District. 2005. Lower Suwannee River MFLs Technical Report. Suwannee River Water Management District, Live Oak, Florida.

Suwannee River Water Management District. 2007. MFL Establishment for the Upper Santa Fe River. Suwannee River Water Management District, Live Oak, Florida.

Suwannee River Water Management District. 2013. Minimum Flows and Levels for the Lower Santa Fe and Ichetucknee Rivers and Priority Springs.

Suwannee River Water Management District. 2015. Minimum Flows and Levels, Econfina River, Florida. https://www.srwmd.org/DocumentCenter/View/11357.

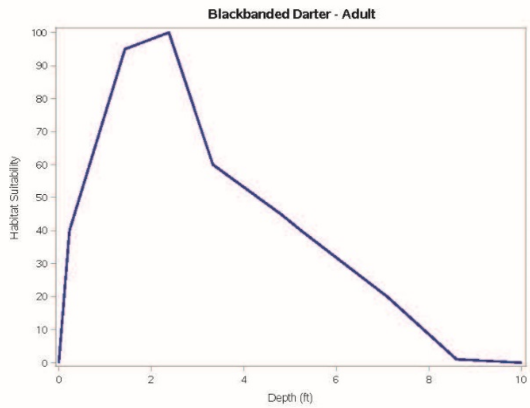
Suwannee River Water Management District. 2016a. Minimum Flows and Levels for the Aucilla River, Wacissa River and Priority Springs. Technical Report prepared for the Southwest Florida Water Management District.

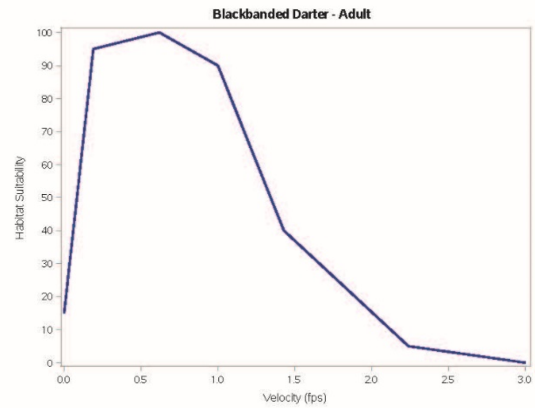
Suwannee River Water Management District. 2016b. Minimum Flows and Levels Assessment for the Upper Suwannee River and Priority Springs. Suwannee River Water Management District, Live Oak, Florida.

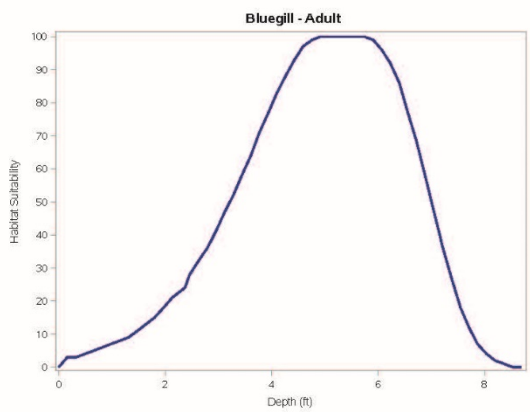
Suwannee River Water Management District. 2021. Minimum Flows and Minimum Water Levels Re-Evaluation for the Lower Santa Fe and Ichetucknee Rivers and Priority Springs, Final Report. Suwannee River Water Management District, Live Oak, Florida.

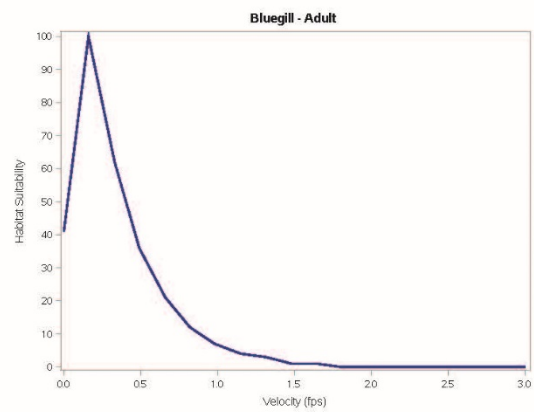
APPENDIX A.

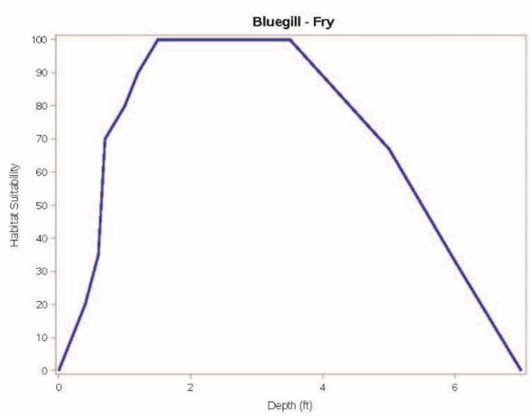
Habitat Suitability Curves.

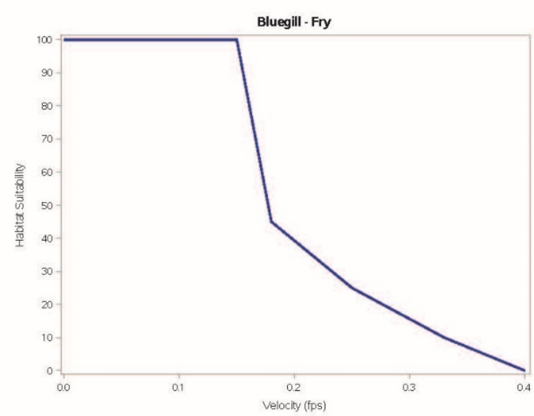

Blackbanded Darter - Adult
Habitat Suitability
Depth (ft)

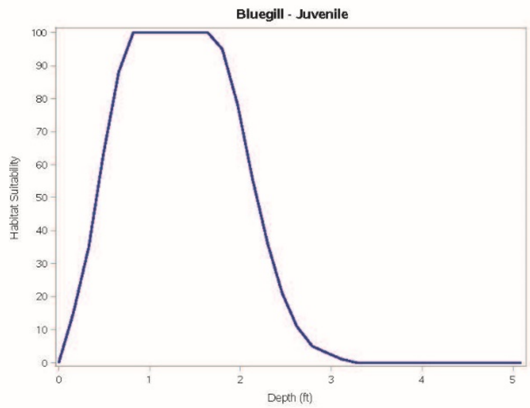

Blackbanded Darter - Adult
Habitat Suitability
Velocity (fps)


Bluegill - Adult
Habitat Suitability
Depth (ft)


Bluegill - Adult
Habitat Suitability
Velocity (fps)


Bluegill - Fry
Habitat Suitability
Depth (ft)


Bluegill - Fry
Habitat Suitability
Velocity (fps)


Bluegill - Juvenile
Habitat Suitability
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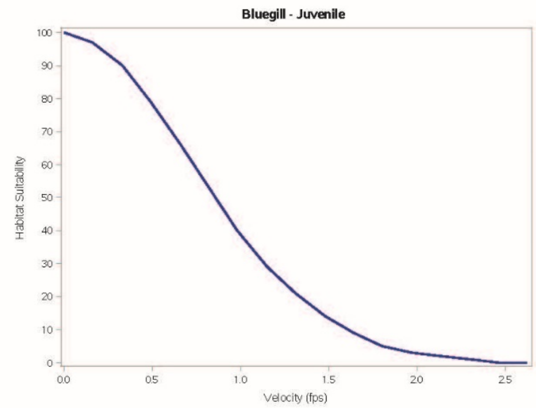
0 1 2 3 4 5
Depth (ft)


Bluegill - Juvenile
Habitat Suitability
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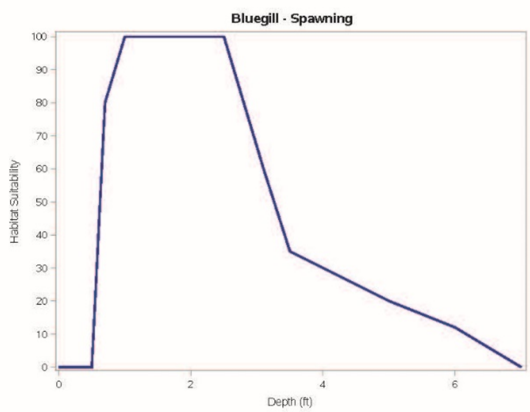
Velocity (fps)


Bluegill - Spawning
Habitat Suitability
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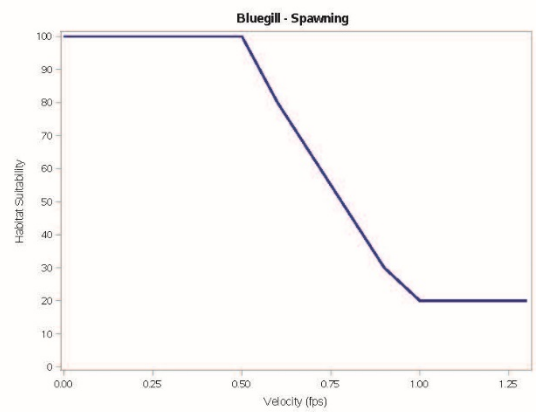
Depth (ft)


Bluegill - Spawning
Habitat Suitability
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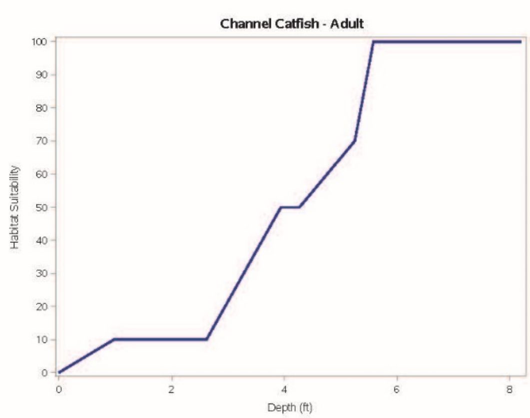
Velocity (fps)


Channel Catfish - Adult
Habitat Suitability
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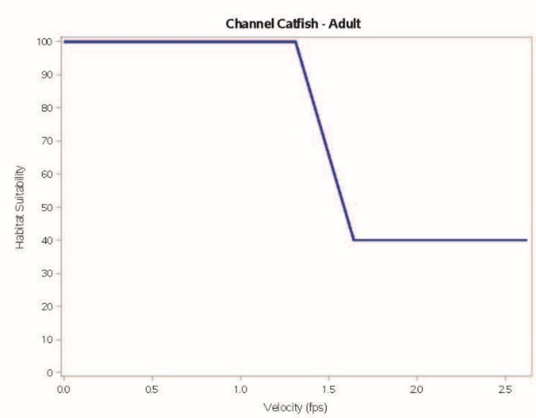
0 2 4 6 8
Depth (ft)


Channel Catfish - Adult
Habitat Suitability
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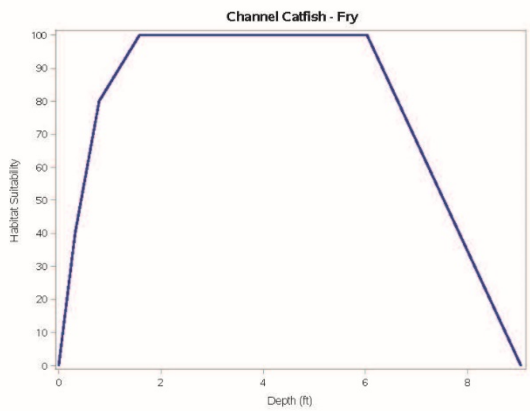
0.0 0.5 1.0 1.5 2.0 2.5
Velocity (fps)


Channel Catfish - Fry
Habitat Suitability
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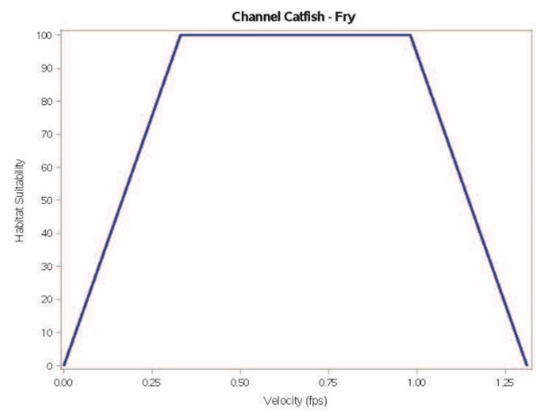
0 2 4 6 8
Depth (ft)


Channel Catfish - Fry
Habitat Suitability
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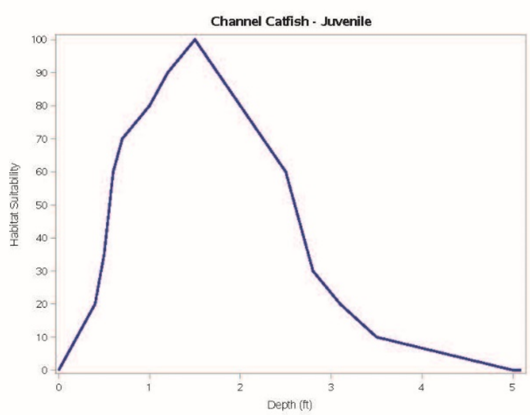
0.00 0.25 0.50 0.75 1.00 1.25
Velocity (fps)


Channel Catfish - Juvenile
Habitat Suitability
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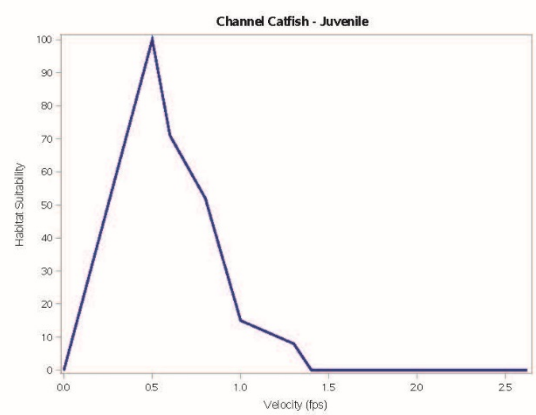
0 1 2 3 4 5
Depth (ft)


Channel Catfish - Juvenile
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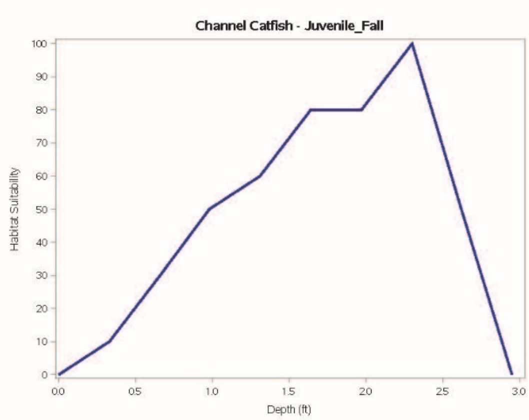
0.0 0.5 1.0 1.5 2.0 2.5
Velocity (fps)


Channel Catfish - Juvenile_Fall
Habitat Suitability
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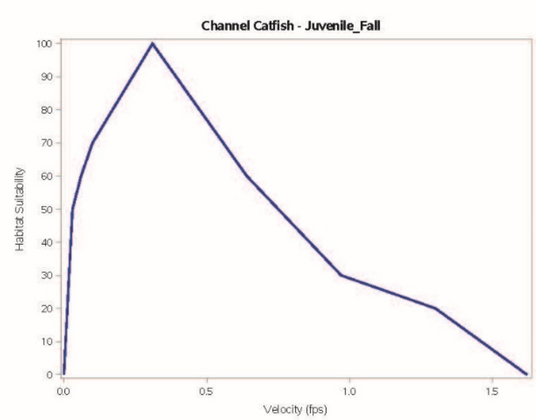
Depth (ft)


Channel Catfish - Juvenile_Fall
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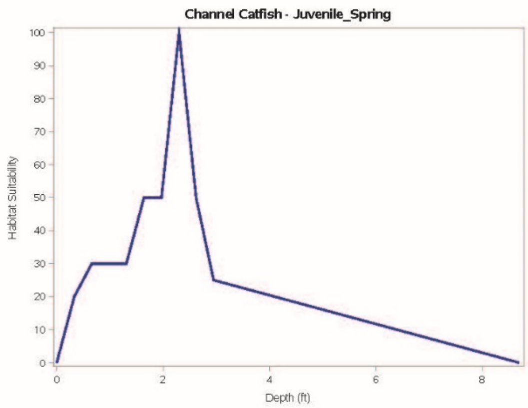
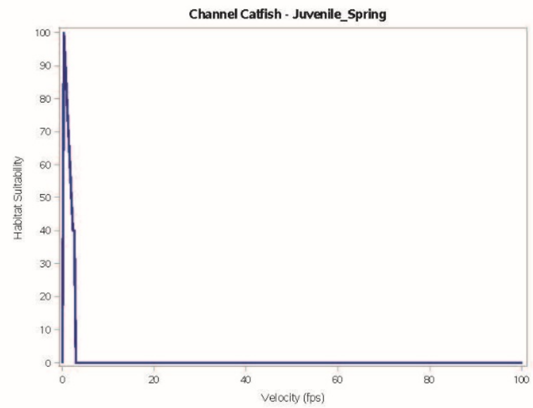
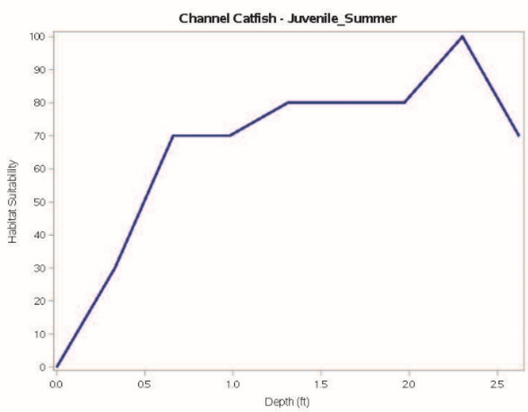
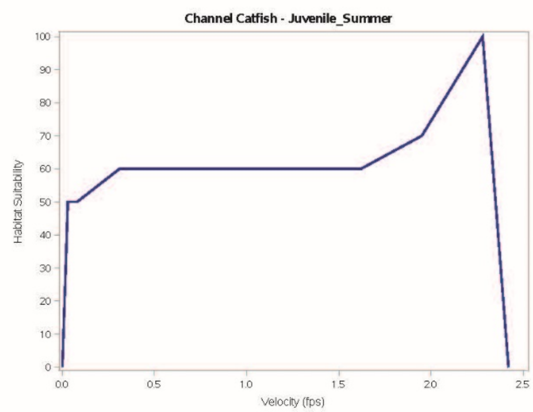
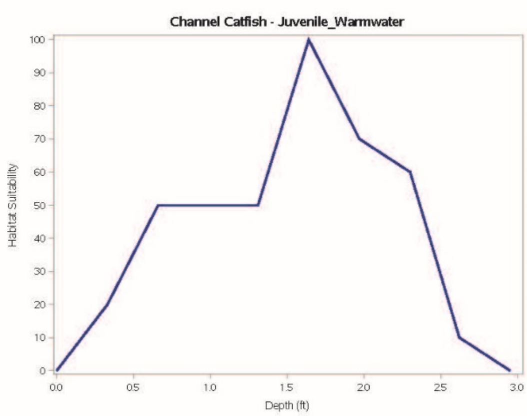
Velocity (fps)

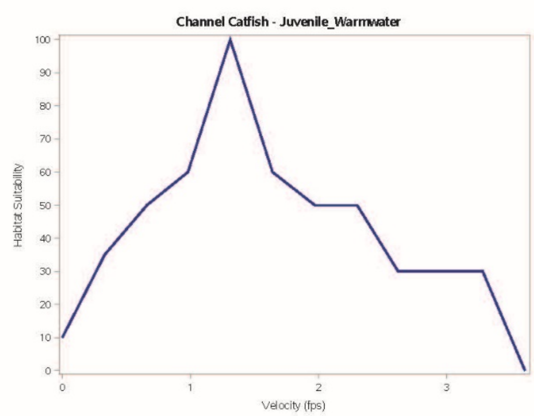

Channel Catfish - Juvenile_Spring
Habitat Suitability
Depth (ft)

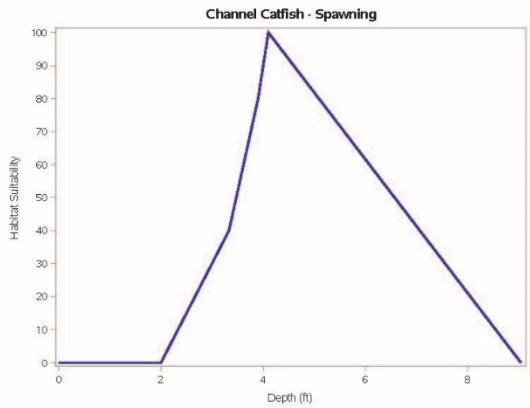

Channel Catfish - Juvenile_Spring
Habitat Suitability
Velocity (fps)


Channel Catfish - Juvenile_Summer
Habitat Suitability
Depth (ft)


Channel Catfish - Juvenile_Summer
Habitat Suitability
Velocity (fps)


Channel Catfish - Juvenile_Warmwater
Habitat Suitability
Depth (ft)


Channel Catfish - Juvenile_Warmwater
Habitat Suitability
Velocity (fps)


Channel Catfish - Spawning
Habitat Suitability
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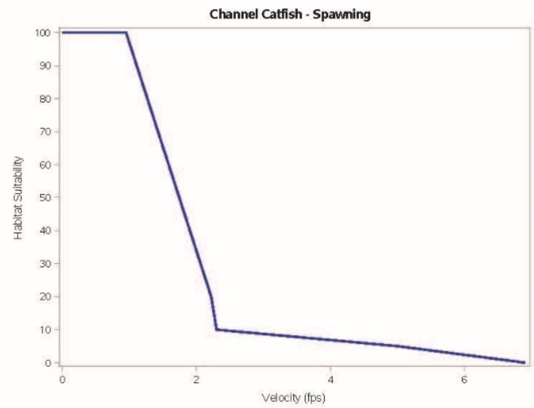
0 2 4 6 8
Depth (ft)


Channel Catfish - Spawning
Habitat Suitability
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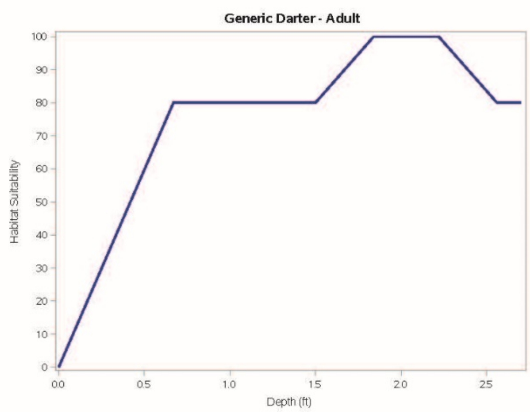
0 2 4 6
Velocity (fps)


Generic Darter - Adult
Habitat Suitability
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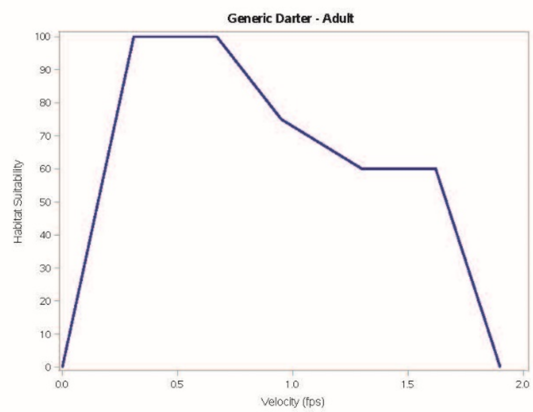
Depth (ft)


Generic Darter - Adult
Habitat Suitability
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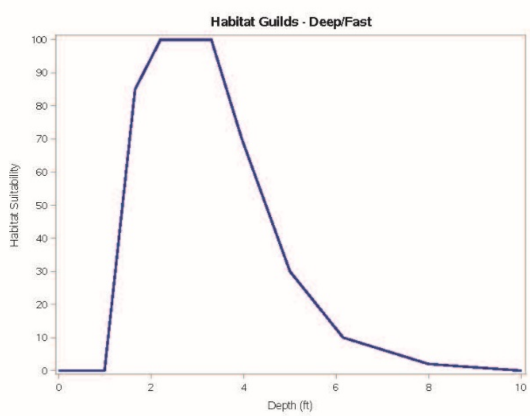
Velocity (fps)


Habitat Guilds - Deep/Fast
Habitat Suitability
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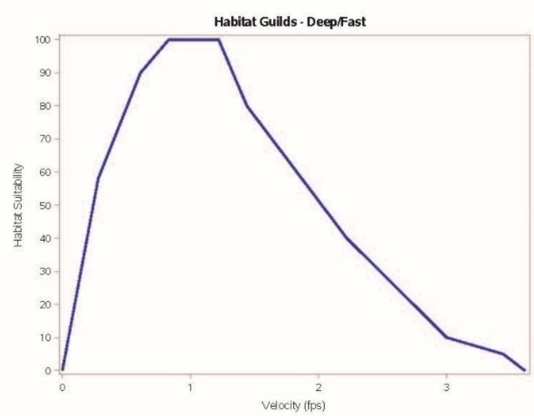
0 2 4 6 8 10
Depth (ft)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Habitat Suitability
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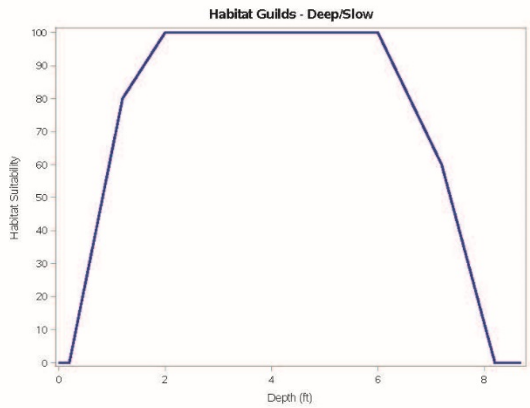
0 1 2 3
Velocity (fps)


Habitat Guilds - Deep/Slow
Habitat Suitability
Depth (ft)
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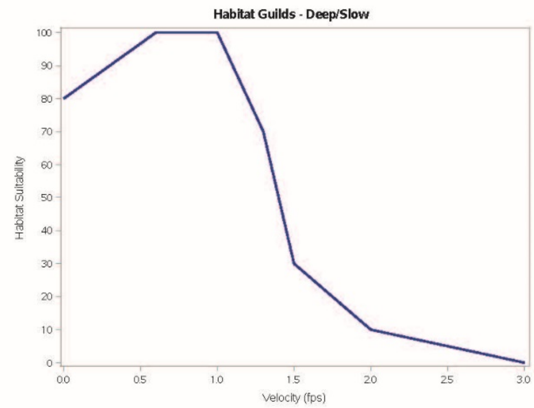
0 2 4 6 8


Habitat Guilds - Deep/Slow
Habitat Suitability
Velocity (fps)
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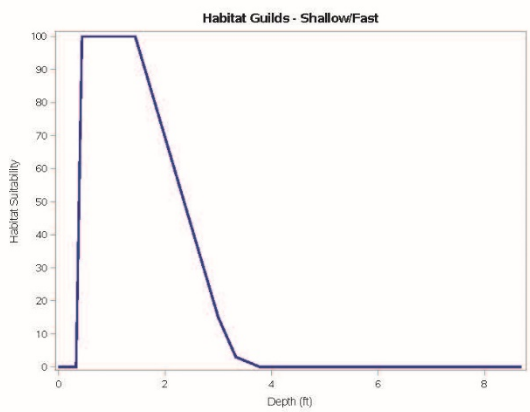
0.0 0.5 1.0 1.5 2.0 2.5 3.0


Habitat Guilds - Shallow/Fast
Habitat Suitability
Depth (ft)
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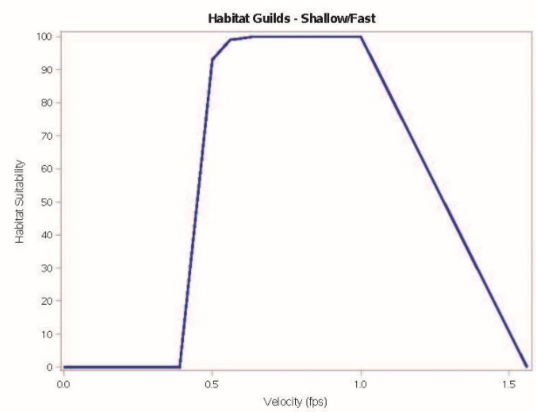
0 2 4 6 8


Habitat Guilds - Shallow/Fast
Habitat Suitability
Velocity (fps)
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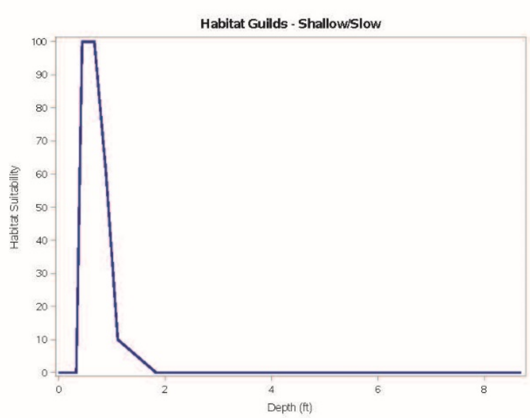
0.0 0.5 1.0 1.5


Habitat Guilds - Shallow/Slow
Habitat Suitability
Depth (ft)
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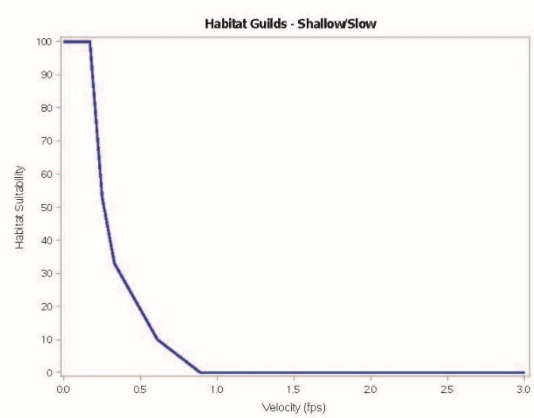
0 2 4 6 8


Habitat Guilds - Shallow/Slow
Habitat Suitability
Velocity (fps)
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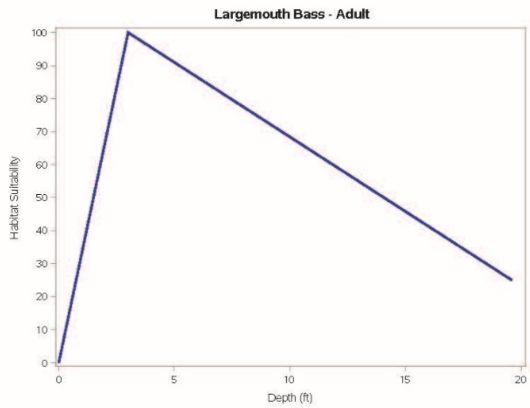
0.0 0.5 1.0 1.5 2.0 2.5 3.0


Largemouth Bass - Adult
Habitat Suitability
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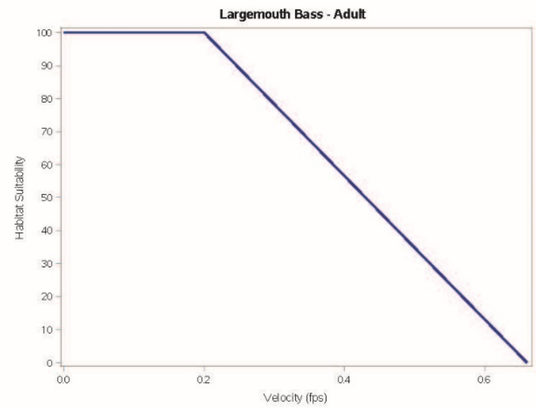
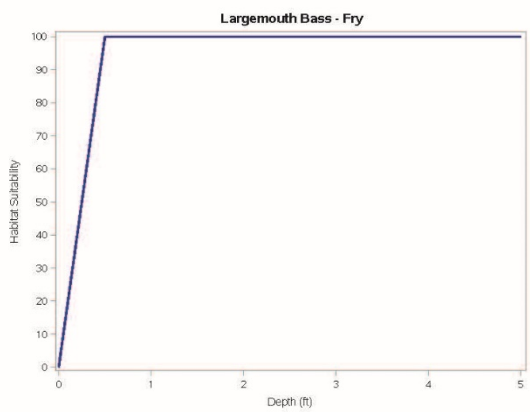
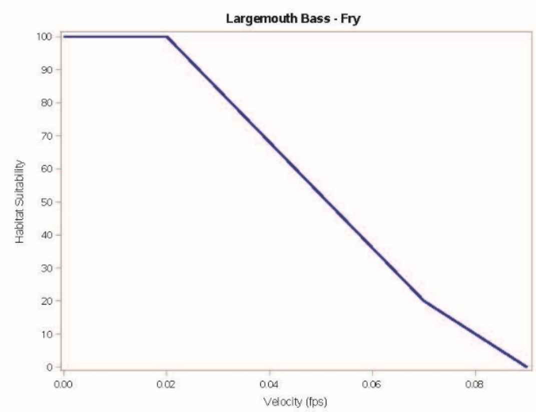
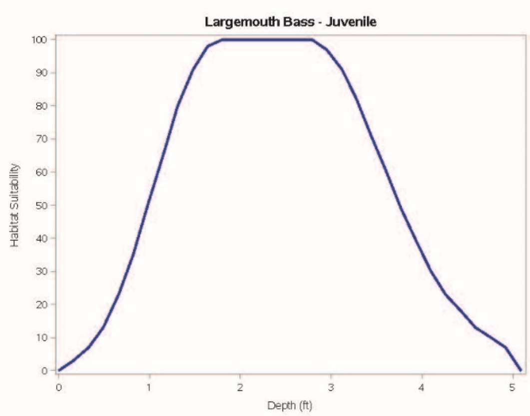
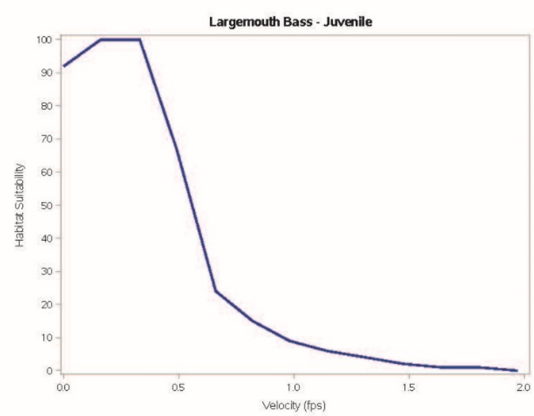
0 5 10 15 20
Depth (ft)

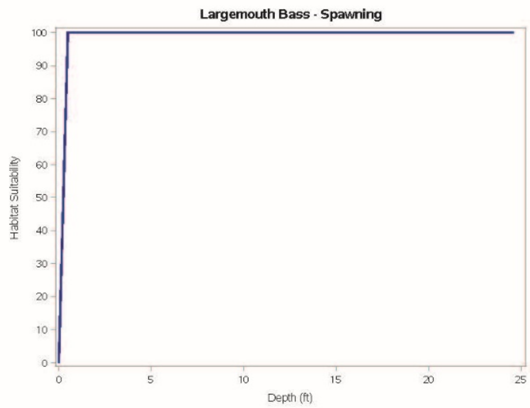

Largemouth Bass - Adult
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0.0 0.2 0.4 0.6
Velocity (fps)

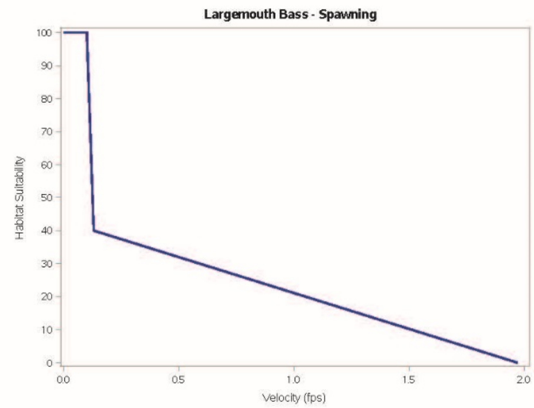

Largemouth Bass - Fry
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5
Depth (ft)

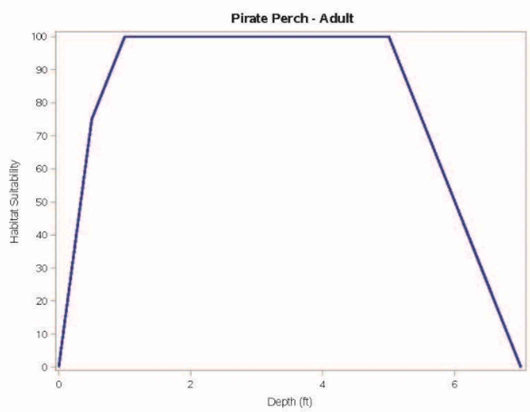

Largemouth Bass - Fry
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0.00 0.02 0.04 0.06 0.08
Velocity (fps)

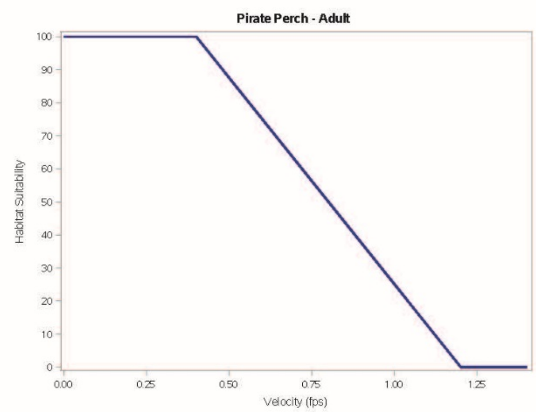

Largemouth Bass - Juvenile
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5
Depth (ft)

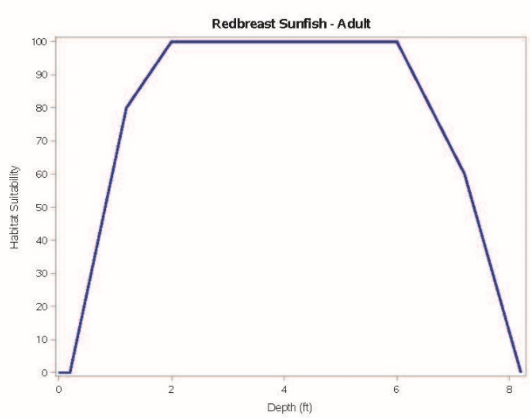

Largemouth Bass - Juvenile
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0.0 0.5 1.0 1.5 2.0
Velocity (fps)

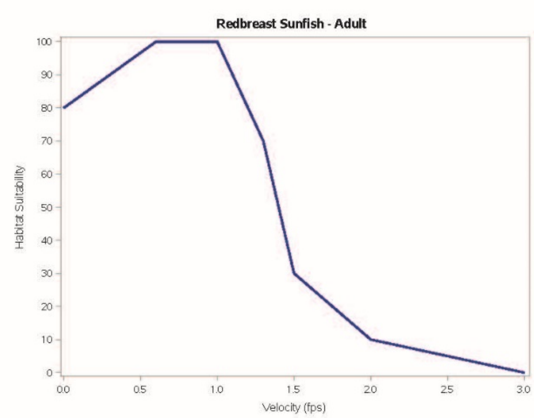

Largemouth Bass - Spawning
Habitat Suitability
Depth (ft)

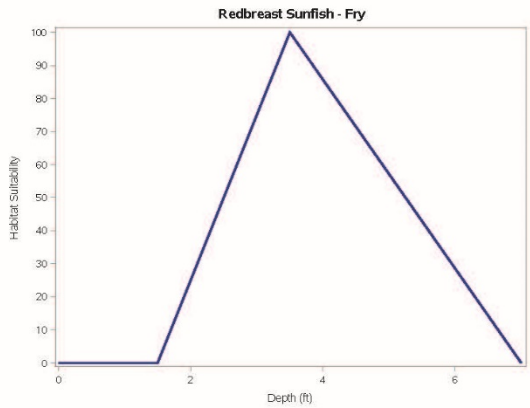

Largemouth Bass - Spawning
Habitat Suitability
Velocity (fps)

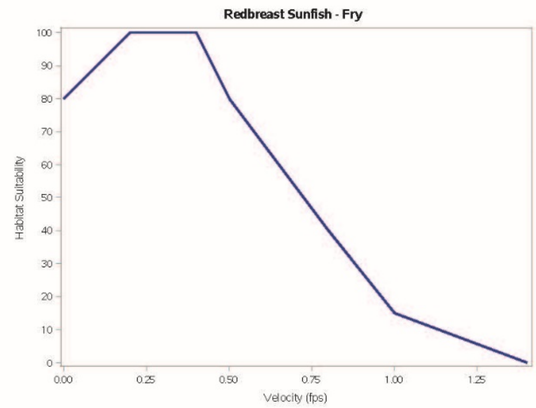

Pirate Perch - Adult
Habitat Suitability
Depth (ft)

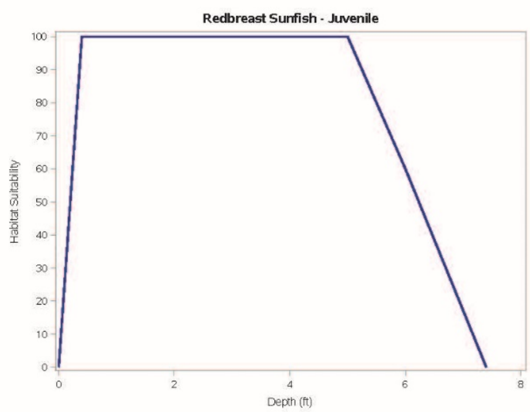

Pirate Perch - Adult
Habitat Suitability
Velocity (fps)

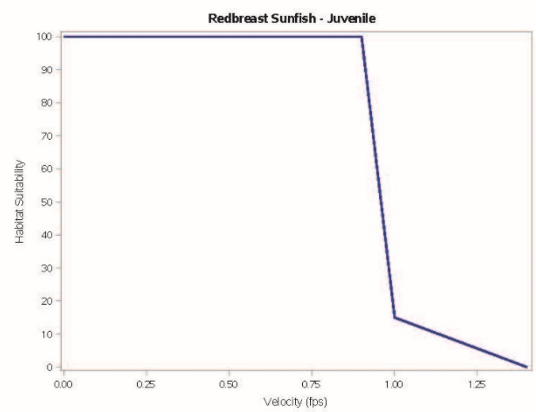

Redbreast Sunfish - Adult
Habitat Suitability
Depth (ft)

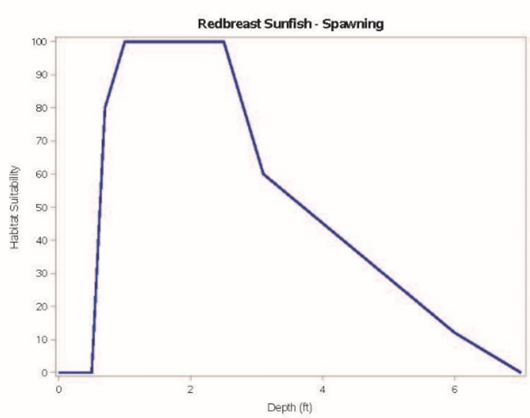

Redbreast Sunfish - Adult
Habitat Suitability
Velocity (fps)

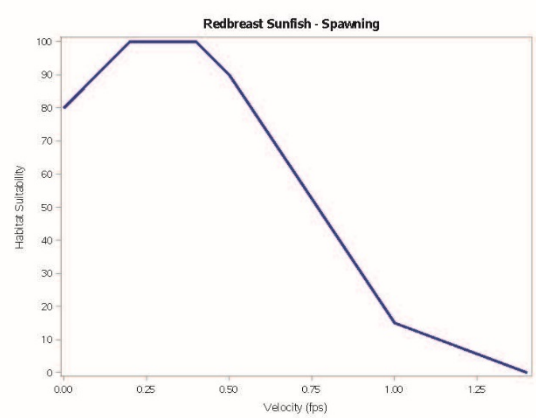

Redbreast Sunfish - Fry
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0 2 4 6
Depth (ft)

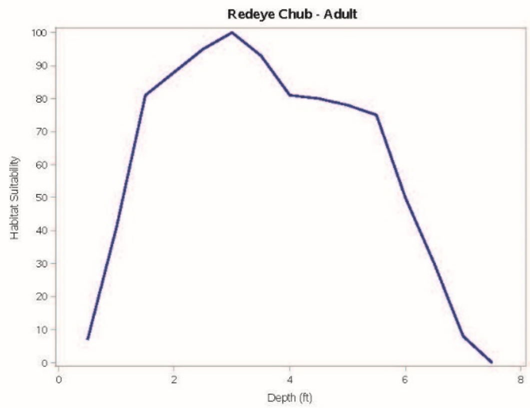

Redbreast Sunfish - Fry
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0.00 0.25 0.50 0.75 1.00 1.25
Velocity (fps)

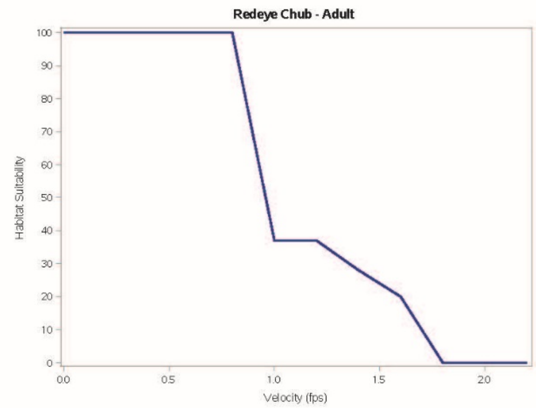

Redbreast Sunfish - Juvenile
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0 2 4 6 8
Depth (ft)

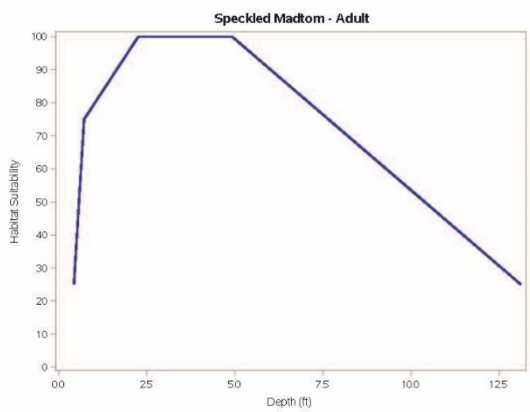

Redbreast Sunfish - Juvenile
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0.00 0.25 0.50 0.75 1.00 1.25
Velocity (fps)

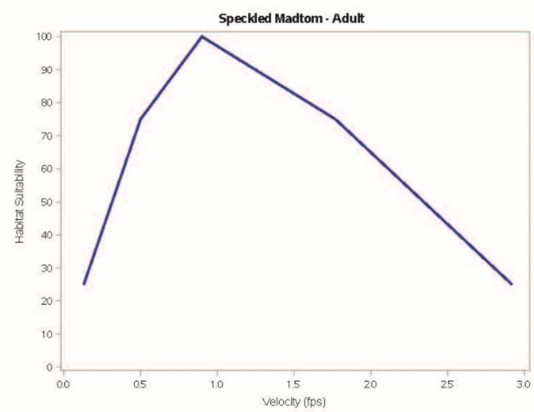

Redbreast Sunfish - Spawning
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0 2 4 6
Depth (ft)

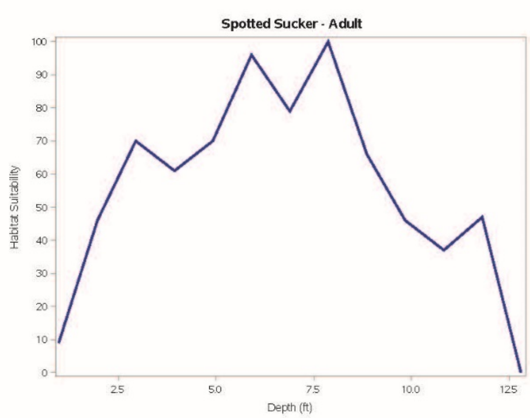

Redbreast Sunfish - Spawning
Habitat Suitability
0 10 20 30 40 50 60 70 80 90 100
0.00 0.25 0.50 0.75 1.00 1.25
Velocity (fps)

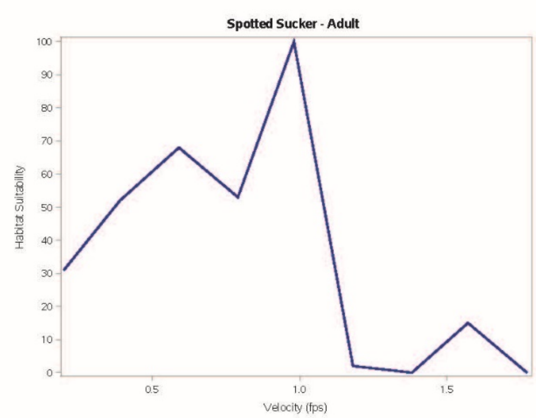

Redeye Chub - Adult
Habitat Suitability
Depth (ft)
0 2 4 6 8
0 10 20 30 40 50 60 70 80 90 100

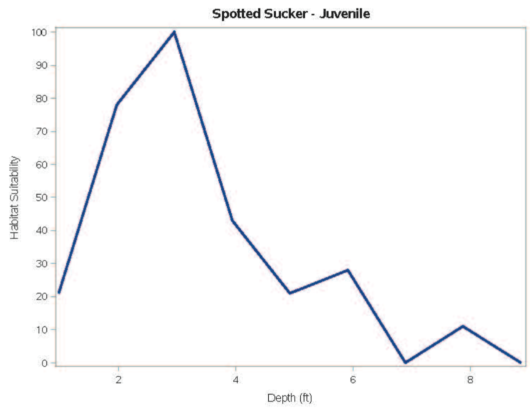

Redeye Chub - Adult
Habitat Suitability
Velocity (fps)
0.0 0.5 1.0 1.5 2.0
0 10 20 30 40 50 60 70 80 90 100

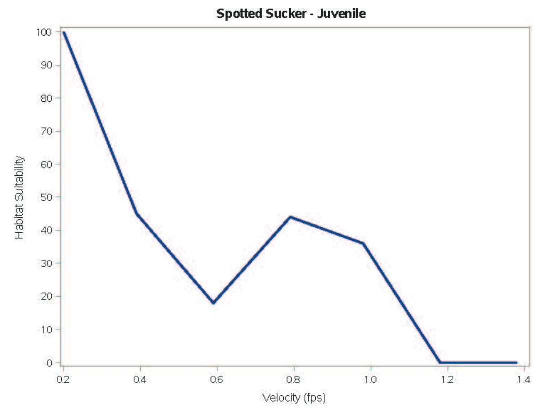

Speckled Madtom - Adult
Habitat Suitability
Depth (ft)
0.0 2.5 5.0 7.5 10.0 12.5
0 10 20 30 40 50 60 70 80 90 100

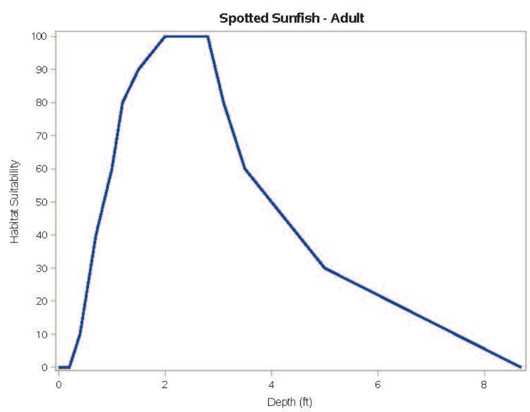

Speckled Madtom - Adult
Habitat Suitability
Velocity (fps)
0.0 0.5 1.0 1.5 2.0 2.5 3.0
0 10 20 30 40 50 60 70 80 90 100

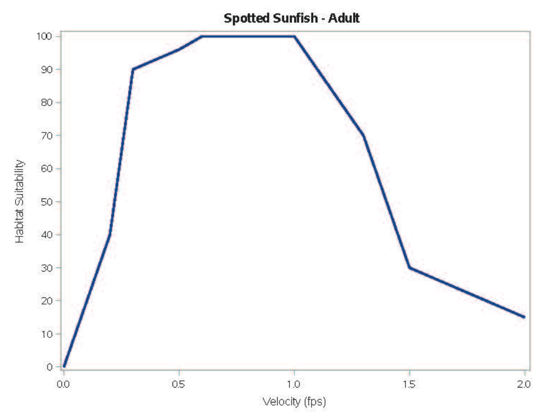

Spotted Sucker - Adult
Habitat Suitability
Depth (ft)
2.5 5.0 7.5 10.0 12.5
0 10 20 30 40 50 60 70 80 90 100

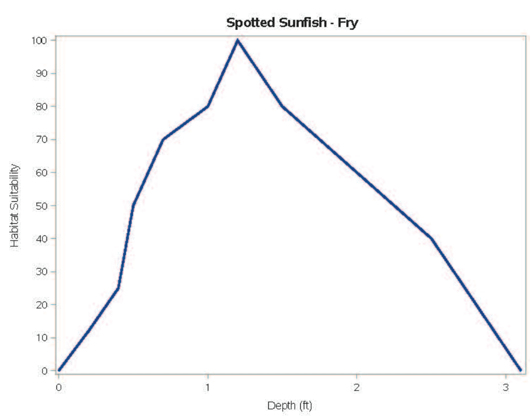

Spotted Sucker - Adult
Habitat Suitability
Velocity (fps)
0.5 1.0 1.5
0 10 20 30 40 50 60 70 80 90 100

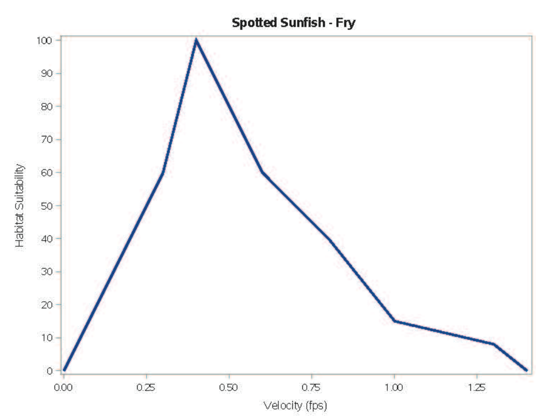

Spotted Sucker - Juvenile
Habitat Suitability
Depth (ft)

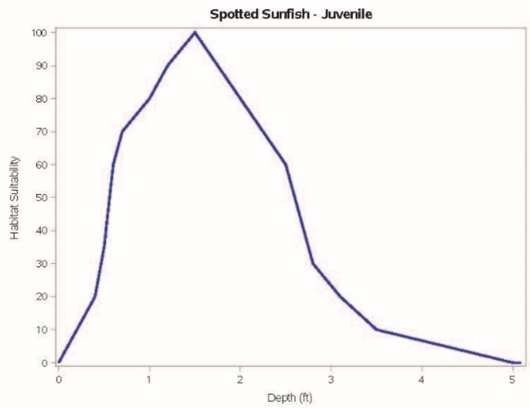

Spotted Sucker - Juvenile
Habitat Suitability
Velocity (fps)

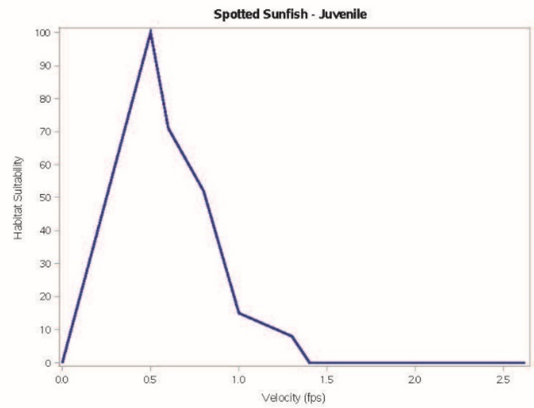

Spotted Sunfish - Adult
Habitat Suitability
Depth (ft)

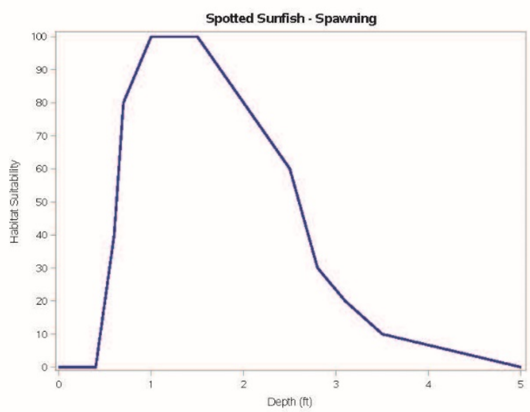

Spotted Sunfish - Adult
Habitat Suitability
Velocity (fps)

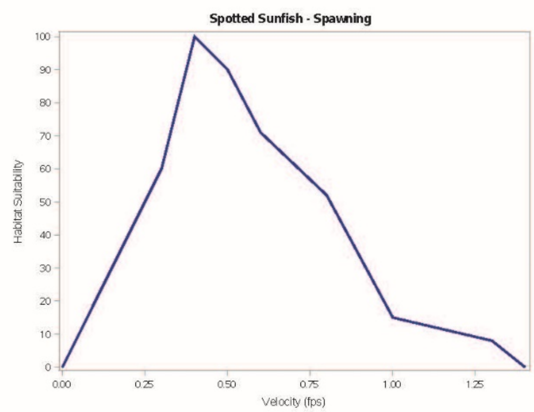

Spotted Sunfish - Fry
Habitat Suitability
Depth (ft)


Spotted Sunfish - Fry
Habitat Suitability
Velocity (fps)


Spotted Sunfish - Juvenile
Habitat Suitability
Depth (ft)


Spotted Sunfish - Juvenile
Habitat Suitability
Velocity (fps)


Spotted Sunfish - Spawning
Habitat Suitability
Depth (ft)


Spotted Sunfish - Spawning
Habitat Suitability
Velocity (fps)

APPENDIX B.

Baseline, 10 Percent Flow Reduction, and 20 Percent Flow Reduction AWS Results.

Mean, median and maximum AWS and associated flows for the Baseline Scenario.						
Taxon	Mean		Median		Maximum	
	AWS	Flow @ Mean AWS	AWS	Flow @ Median AWS	AWS	Flow @ Maximum AWS
Blackbanded Darters Adult	145	516	144	500	159	1140
Bluegill Adult	62	519	60	500	112	1140
Bluegill Fry	156	435	158	478	161	612
Bluegill Juvenile	102		102		106	301
Bluegill Spawning	170	381	171	381	173	422
Channel Catfish Adult	85	506	85	500	129	1140
Channel Catfish Fry	138	507	138	500	170	1140
Channel Catfish Juvenile	34		34		35	387
Channel Catfish Juvenile Fall	65		65		75	301
Channel Catfish Juvenile Spring	47	507	47	500	53	1140
Channel Catfish Juvenile Summer	116	511	115	500	140	1140
Channel Catfish Juvenile Warmwater	16		16		18	301
Channel Catfish Spawning	77	524	75	500	136	1140
Generic Darters Adult	128	511	127	500	167	1140
Habitat Guilds Deep Fast	74	507	73	500	84	1140
Habitat Guilds Deep Slow	212	495	213	500	243	1140
Habitat Guilds Shallow Fast	4	449	3	663	4	1140
Habitat Guilds Shallow Slow	32	302	32	302	40	362
Largemouth Bass Adult	164	507	164	500	212	1140
Largemouth Bass Fry	21		21		23	345
Largemouth Bass Juvenile	179	465	180	495	183	631
Largemouth Bass Spawning	151	576	150	549	159	779
Pirate Perch	236	516	235	500	271	1140
Redbreast Sunfish Adult	212	495	213	500	243	1140
Redbreast Sunfish Fry	99	503	99	500	141	1140
Redbreast Sunfish juvenile	257	528	254	500	280	889
Redbreast Sunfish spawning	166	473	167	500	176	889
Redeye Chub	194	503	194	500	227	1140

Mean, median and maximum AWS and associated flows for the Baseline Scenario.						
Taxon	Mean		Median		Maximum	
	AWS	Flow @ Mean AWS	AWS	Flow @ Median AWS	AWS	Flow @ Maximum AWS
Speckled Madtom	116	506	116	500	140	1140
Spotted Sucker Adult	58	444	58	673	61	1140
Spotted Sucker Juvenile	141	441	141	490	144	601
Spotted Sunfish Adult	162	446	164	487	164	570
Spotted Sunfish Fry	25		25		26	301
Spotted Sunfish Spawning	35	354	35	337	36	406
Spotted Sunfish juvenile	74	363	74	369	75	415

Mean, median and maximum AWS and associated flows for the 10 Percent Flow Reduction Scenario.						
Taxon	Mean		Median		Maximum	
	AWS	Flow @ Mean AWS	AWS	Flow @ Median AWS	AWS	Flow @ Maximum AWS
Blackbanded Darters Adult	139	472	138	456	152	1026
Bluegill Adult	62	478	60	456	117	1026
Bluegill Fry	167	435	168	450	175	649
Bluegill Juvenile	102		102		107	271
Bluegill Spawning	171	343	172	343	174	388
Channel Catfish Adult	84	463	84	456	130	1026
Channel Catfish Fry	132	465	131	456	158	1026
Channel Catfish Juvenile	31		31		32	271
Channel Catfish Juvenile Fall	63		63		73	271
Channel Catfish Juvenile Spring	44	478	44	456	49	1026
Channel Catfish Juvenile Summer	115	475	114	456	138	1026
Channel Catfish Juvenile Warmwater	15		15		17	271
Channel Catfish Spawning	80	481	77	456	137	1026
Generic Darters Adult	121	472	119	456	157	1026
Habitat Guilds Deep Fast	70	465	70	456	78	1026
Habitat Guilds Deep Slow	214	453	214	456	244	1026
Habitat Guilds Shallow Fast	4	430	4	450	5	1026
Habitat Guilds Shallow Slow	32	272	32	272	40	326
Largemouth Bass Adult	166	460	166	456	213	1026
Largemouth Bass Fry	26		27	272	28	319

Mean, median and maximum AWS and associated flows for the 10 Percent Flow Reduction Scenario.						
Taxon	**Mean**		**Median**		**Maximum**	
	AWS	**Flow @ Mean AWS**	**AWS**	**Flow @ Median AWS**	**AWS**	**Flow @ Maximum AWS**
Largemouth Bass Juvenile	179	420	181	448	183	568
Largemouth Bass Spawning	164		163		172	311
Pirate Perch	239	472	237	456	272	1026
Redbreast Sunfish Adult	214	453	214	456	244	1026
Redbreast Sunfish Fry	100	460	100	456	141	1026
Redbreast Sunfish juvenile	259	489	257	456	281	800
Redbreast Sunfish spawning	165	429	166	456	176	870
Redeye Chub	197	460	197	456	228	1026
Speckled Madtom	114	463	114	456	136	1026
Spotted Sucker Adult	57	432	58	456	60	1026
Spotted Sucker Juvenile	143	410	143	443	147	546
Spotted Sunfish Adult	159	405	161	435	162	518
Spotted Sunfish Fry	23		23		24	271
Spotted Sunfish Spawning	33		33		33	357
Spotted Sunfish juvenile	70	312	71	327	71	374

Mean, median and maximum AWS and associated flows for the 20 Percent Flow Reduction Scenario.						
Taxon	**Mean**		**Median**		**Maximum**	
	AWS	**Flow @ Mean AWS**	**AWS**	**Flow @ Median AWS**	**AWS**	**Flow @ Maximum AWS**
Blackbanded Darters Adult	133	419	132	405	146	912
Bluegill Adult	61	425	59	405	121	912
Bluegill Fry	175	396	175	405	190	711
Bluegill Juvenile	103		103		107	241
Bluegill Spawning	172	300	173	305	175	341
Channel Catfish Adult	81	413	80	405	131	912
Channel Catfish Fry	125	409	125	405	148	912
Channel Catfish Juvenile	29		29		30	241
Channel Catfish Juvenile Fall	62		61		71	241
Channel Catfish Juvenile Spring	42	427	41	405	46	912
Channel Catfish Juvenile Summer	113	419	112	405	137	912

Mean, median and maximum AWS and associated flows for the 20 Percent Flow Reduction Scenario.						
Taxon	Mean		Median		Maximum	
	AWS	Flow @ Mean AWS	AWS	Flow @ Median AWS	AWS	Flow @ Maximum AWS
Channel Catfish Juvenile Warmwater	15		15		17	241
Channel Catfish Spawning	81	425	78	405	139	912
Generic Darters Adult	113	419	112	405	148	912
Habitat Guilds Deep Fast	67	413	67	405	73	912
Habitat Guilds Deep Slow	214	405	214	405	245	912
Habitat Guilds Shallow Fast	4		4		5	241
Habitat Guilds Shallow Slow	32	242	32	242	40	290
Largemouth Bass Adult	168	409	167	405	215	912
Largemouth Bass Fry	31		32		34	269
Largemouth Bass Juvenile	180	374	181	399	184	505
Largemouth Bass Spawning	180	255	180	255	184	329
Pirate Perch	240	419	239	405	273	912
Redbreast Sunfish Adult	214	405	214	405	245	912
Redbreast Sunfish Fry	100	409	99	405	140	912
Redbreast Sunfish juvenile	262	435	260	405	283	711
Redbreast Sunfish spawning	165	376	165	405	175	773
Redeye Chub	199	406	198	405	229	912
Speckled Madtom	111	409	111	405	132	912
Spotted Sucker Adult	57	394	57	405	60	912
Spotted Sucker Juvenile	145	376	145	396	149	485
Spotted Sunfish Adult	157	367	158	392	159	462
Spotted Sunfish Fry	21		21		23	241
Spotted Sunfish Spawning	30		30		31	322
Spotted Sunfish juvenile	67		68		69	322