Horse Creek SEFA Memo

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Introduction

One of ten environmental values in the water resource implementation rule is “fish and wildlife habitats and the passage of fish”. Fish, including game fish, non-game fish, and the invertebrates that support the ecosystem have specific requirements for water depth, velocity, substrate, and cover. Instream habitat modeling combines field measurements of channel geometry, water depth and velocity with substrate and cover characteristics.

Aquatic biota, including fish and benthic macroinvertebrates, need sufficient habitat to obtain resources, avoid predation, and reproduce in a flowing water environment. This habitat can be quantified in terms of depth and velocity which vary with the quantity of discharge. In addition, qualitative habitat variables include substrate types, presence of organic detritus, nearby structural elements such as overhanging banks or logs, and other characteristics. As the total quantity of discharge varies in a stream, these habitat elements will vary as well, affecting the amount and quality of habitat available.

Predicting changes to depth and velocity with changing flow requires hydraulic modeling. The System for Environmental Flows Analysis (SEFA) software package offers a flexible modeling framework for quantifying changes to the habitat of aquatic biota in response to changing flow regimes (Jowett et al. 2020, Aquatic Habitat Analysts, Inc. 2021). The SEFA software is capable of analysis identical to PHABSIM, which was commonly used in past minimum flows analysis by the District, and offers options for analysis in addition to PHABSIM methods.

SEFA habitat modeling uses cross-sectional elevation profiles, water surface elevation, velocity, and qualitative habitat characteristics at specific locations across the channel to characterize habitat (Figure 1). In addition to these environmental cross sections, SEFA uses habitat suitability curves which relate water depth, water velocity, and an index of qualitative habitat characteristics including substrate and cover to habitat suitability for fish and aquatic macroinvertebrates (Figure 2). These habitat suitability curves can represent species, life history stages such as juveniles and adults, and habitat guilds, which include all organisms with similar habitat requirements such as deep, fast-moving water. Suitability is scaled on an index from zero (unsuitable) to one (maximally suitable), with intermediate values between zero and one. The history and development of the habitat suitability curves used by the District is described in Nagid (2022).

For a given flow, SEFA calculates the depth and velocity at each point along a cross section and uses the depth and velocity habitat suitability curves to get the suitability for each of these physical variables. In addition, field observations of qualitative habitat characteristics are converted to suitability using their habitat suitability curves. These three suitability values are averaged and weighted by the total quantity of the cross section represented to create a dimensionless index called the area weighted suitability

(AWS). AWS is a combined index of habitat quality and quantity. AWS can be modeled for an individual cross section, or in aggregate for any number of cross sections. The model output is a curve relating flow to AWS , with each value of flow having a single corresponding AWS value. Therefore, a time series of daily flow values can be converted into a daily time series of AWS values for each 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. As a result, the patterns of flow variation across time scales can be modeled under differing flow scenarios.

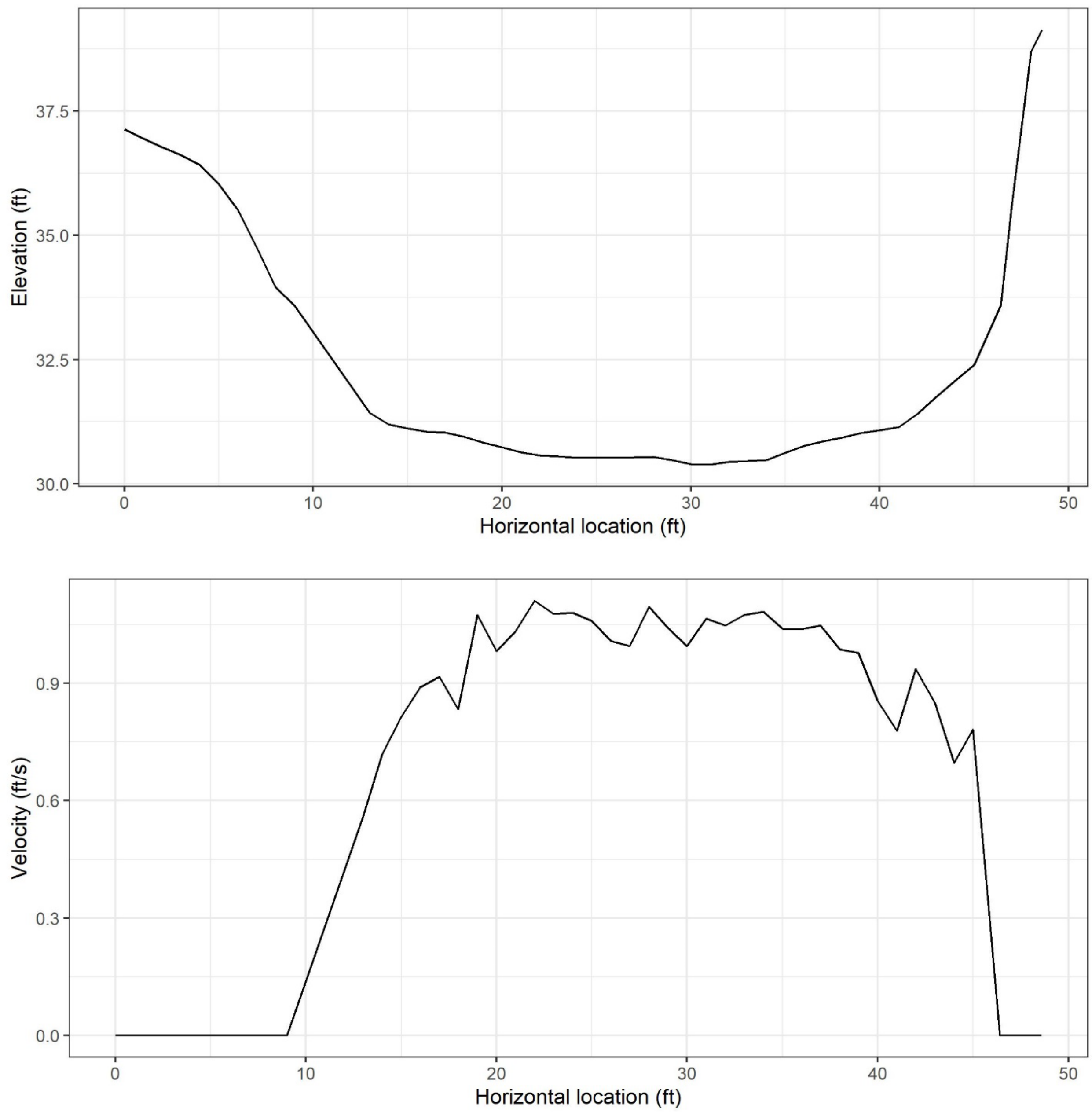

Figure 1. Example cross section profile of depth and velocity from field observations.

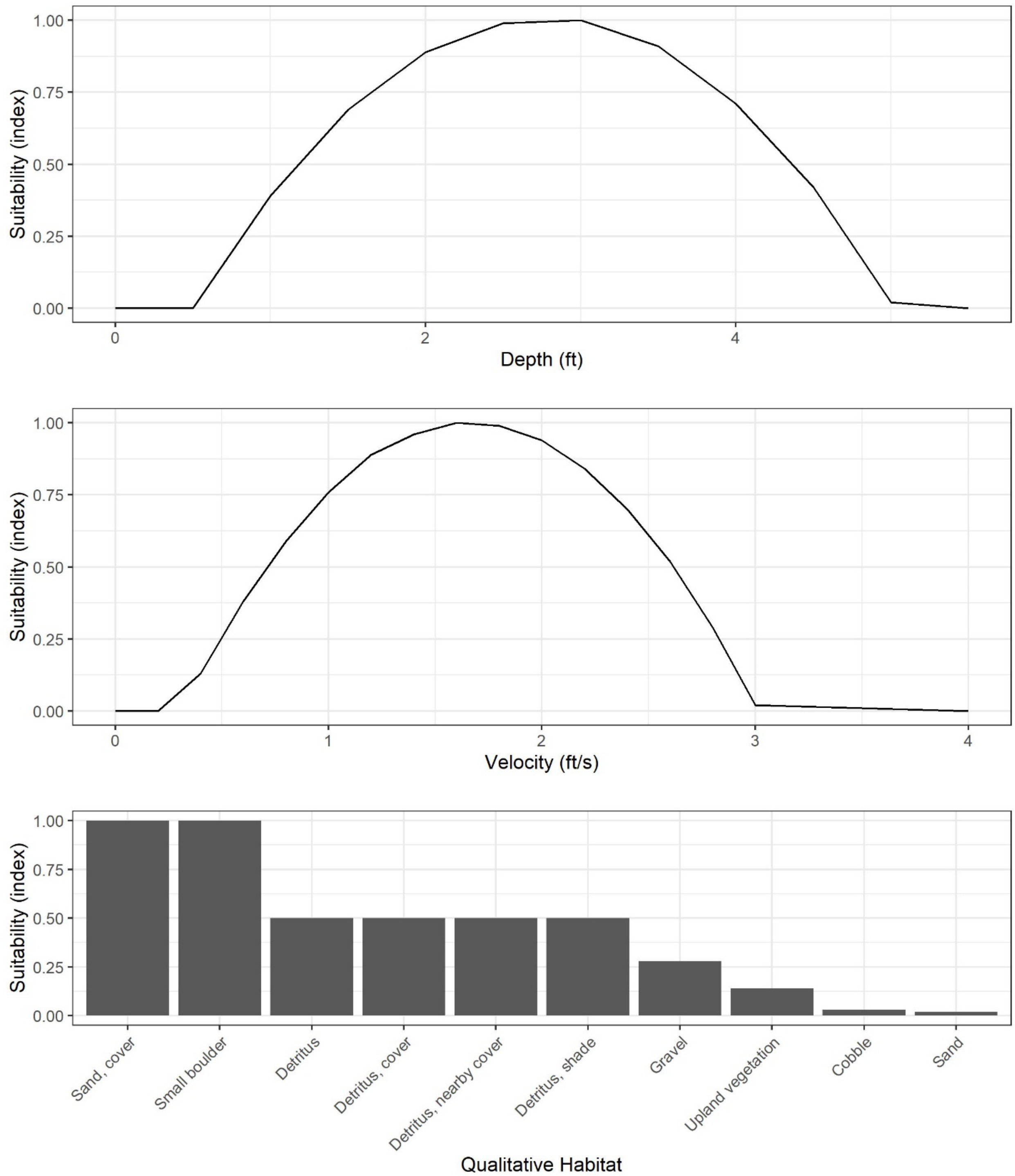

Figure 2. Example habitat suitability curves for net-spinning caddisflies (Hydropsychidae).

Methods and Results

Site Descriptions

Elevation profiles, depth, velocity, substrate and cover data was collected at five sites with three transects each (Figure 3, Table 1) (HSW 2021). From upstream to downstream, these sites are State Route 64 (SR64), State Route 70 (SR70), Pine Level Road (PLR), State Route 72 North (SR72N), and State Route 72 South (SR72S). These sites are bracketed between two USGS gaging stations, the upstream gage no. 02297155 Horse Creek near Myakka Head and downstream gage no. 02297310 Horse Creek near Arcadia. These gages may be referred to simply as “Myakka” and “Arcadia”. Detailed descriptions of site characteristics can be found in HSW (2021) and its appendix A.

Updates to Model

HSW (2021) collected SEFA data and performed a modeling analysis. Subsequently, District staff performed a separate modeling analysis of the data collected by HSW, which used different methods and produced different results the original HSW analysis. Consequently, different conclusions are reached, reflecting these differences in methods and results which are described below.

The HSW (2021) methods have the following characteristics:

- Use of medium flow as the survey flow
- SEFA default rating curves that force the curve through the survey flow (see section 12.2.1 of Jowett et al. 2020)
- Beta for velocity distribution value of -0.3, as specified in section 14.3 of Jowett et al. (2020)
- No adjustment to velocity distribution factors at elevations above the survey flow
- Habitat suitability curves as developed by Jim Gore
- The SR64 site was apportioned flows equal to the upstream Myakka gage, while the 4 downstream sites were apportioned flows equal to the downstream Arcadia gage.
- Flows are divided into blocks where Block 1 is less than 17cfs at the gage and Block 2 is between 17 cfs and 54 cfs at the gage

These methods were modified in the following manner:

- Adjustment to velocity distribution factors at points above survey flow water surface to near 1 as specified in section 14.5 of Jowett et al. (2020)
- Reach habitat curves (AWS-flow curves) were combined for all sections and flows apportioned as in Table 2.
- Flows were apportioned based on regression with USGS gaging sites. Details on flow apportionment below.
- Flows are analyzed in a single block from zero to 78 cfs at the gage, corresponding to the boundary between instream flows and floodplain inundation.

Rating Curves

Rating curves were developed for each section. Stage at zero flow was iteratively calculated by SEFA and modified in input files to get the best fit to observed data. This is appropriate when there is no known nearby hydraulic control point. Rating curves demonstrate a good fit to data based on correlation coefficients and mean error of Q (Table 3).

Flow Apportionment

Sites were combined to develop a single set of reach habitat curves that combines the area weighted suitability at all 15 transects. Modeling reach habitat curves requires specification of the range and increment of flows to be modeled. This is to ensure that upstream sites are modeled as receiving appropriately lower flows than downstream sites, simulating the natural accumulation of increasing flows with downstream distance. Flow apportionment was based on linear regression of flows at each site with the gaged flow on same date (Table 2). Linear modeling was done with a fixed intercept at zero to avoid negative flows that may be predicted if the intercept is allowed to vary at low gaged flows. The SR72N site was selected as the reference reach and other reaches were assigned the maxima and incremental values shown in Table 2.

The baseline flow record was developed elsewhere by the District, and is a daily record of flows from 1950-05-01 through 2021-12-31 at Arcadia adjusted for withdrawal impacts (Table 4). In the time series analysis, flows were modeled using all dates with flows less than or equal to 78 cfs, which is the maximum instream habitat value before floodplain inundation metrics apply and is the 62^{nd} percentile over the period of record. Because the high flow data was collected at nearly 300 cfs, flows could be modeled up to 600 cfs following the guideline for modeling flows up to twice the highest flow data collection event (Jowett et al. 2020). However, modeling above the survey flow introduces errors in the estimation of velocity distribution factors (Jowett et al. 2020).

Reach Habitat Curves

Habitat suitability curves relate physical features of the environment to suitability for occupation, feeding, reproduction, refuge, and other uses to meet habitat needs. A suite of habitat suitability curves were used representing a range of species, life history stages, and habitat guilds (Nagid 2022). These habitat suitability curves can be seen plotted in HSW (2021 Appendix B). In this report, names for each group are abbreviated into four letter codes (Table 5).

Reach habitat curves are the key modeling result of a SEFA analysis, and relate flow to area weighted suitability (AWS) as a measure of habitat availability (Figure 4). The x-axis shows flow at the Arcadia gage, while the y-axis shows the relative habitat suitability associated with each flow value. The reach habitat curves resulting from this analysis show a variety of responses. Some rise quickly and then start to level off, for example BBDA. These are often less sensitive to flow reduction scenarios because of the flat part of the curve at higher flows. Others rise to a peak then decrease with higher flows such as BLUJ. These peaked responses are often relatively insensitive to flow reduction scenarios because losses in habitat at low flows are offset by increases in habitat at high flows. Other reach habitat curves are J-shaped, such as SHFA and TVET, where habitat suitability is insensitive to increases in flow at the lowest flows. These J-shaped curves can be among the most sensitive responses to flow reduction scenarios because losses in flow near the median value tend to reduce habitat to zero. Others, such as HYDR, DPFA, TINV, and CCSP are nearly linear across the entire range of flows, although deviation from exact linearity can be seen in all cases (Figure 4). Linear responses can also be among the most sensitive to flow reductions because they consistently show a loss in habitat with loss in flows.

Filtering of Species based on AWS-Flow Relationships

The percent of flow method for determining minimum flows assumes a consistent relationship between habitat and flow. In order for a percent of flow loss to result in the same percent of habitat loss across a range of flows, the slope of the line relating flow on the x-axis to habitat on the y-axis must be invariant.

This means that the habitat-flow relationship must be linear in order to meet the implicit assumption in the percent of flow approach. J-shaped curves violate this assumption, and result in a situation where at flows corresponding to the initial insensitive part of the curve, further losses in flow do not result in losses of habitat. We do not think it is necessary that the linearity pass a formal statistical test, but it is possible to screen out relationships between AWS and flow that are not consistent across the flow range of interest. For Horse Creek, the flow range of interest is from 0 cfs to 78 cfs at the Arcadia gage. In order to eliminate species with curves that are overly concave or J-shaped, we can include only those with at least 5% of their maximum AWS by the time they reach the fish passage flow of 15 cfs. This will remove PSEU, SHFA, and TVET from further analysis.

Flow Reduction Scenarios

Using the reach habitat curves, the daily flow record of baseline flows is converted to daily records of habitat suitability. The average (mean) habitat suitability over this flow record is taken as a summary of the overall habitat provided by the flow record. Reduced flow scenarios are created by reducing each daily flow by a percentage, and recalculating habitat suitability based on each new reduced flow scenario. Reduced flow scenarios are then compared to the baseline flow scenario to calculate the percentage loss in habitat associated with percentage loss in flows (Figure 5). The most sensitive responses show a downward trend where habitat decreases with decreasing percent of flow. Note the x-axis is reversed such that 100 percent of flow is on the left.

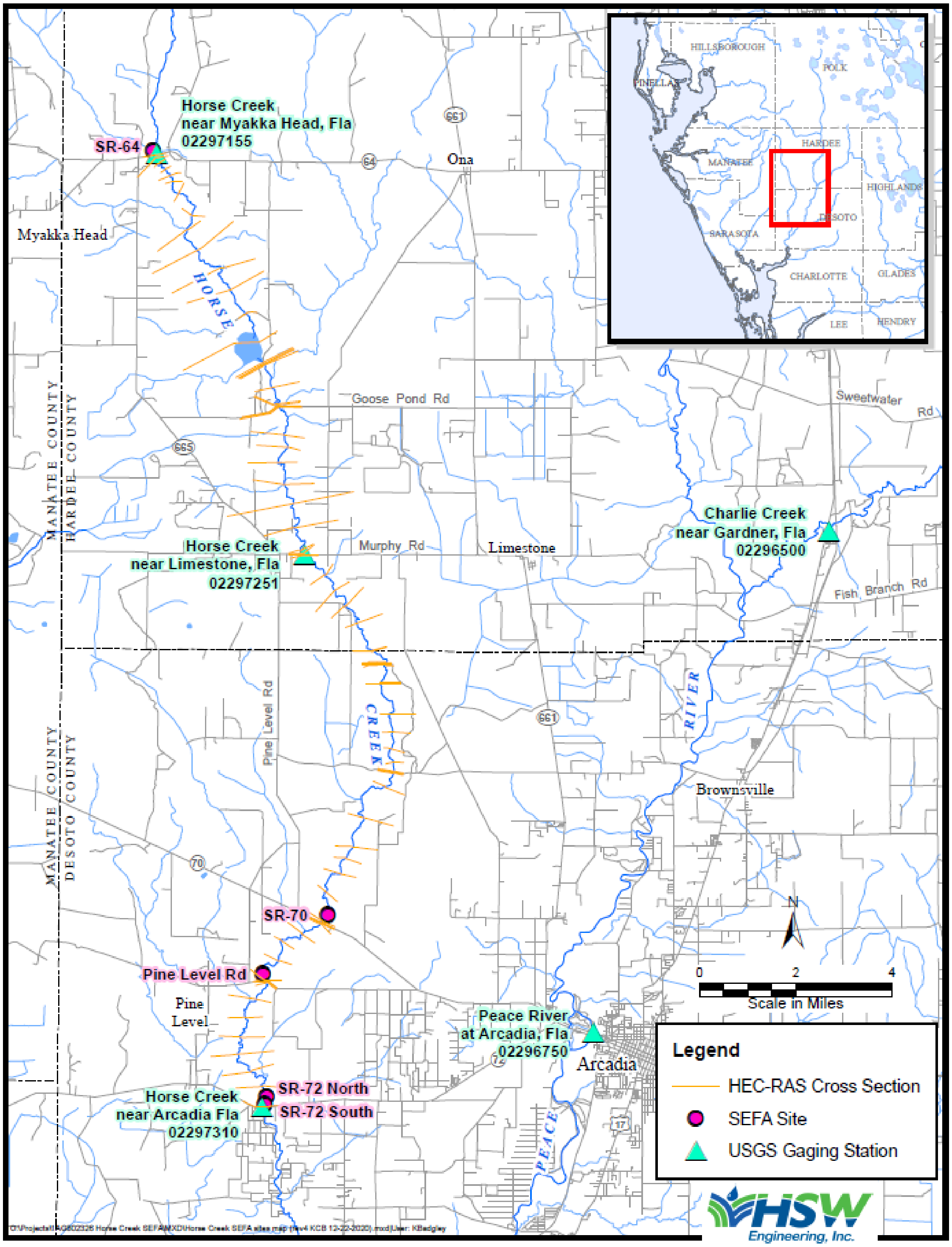

Figure 3. Locations of five sites

Table 1. Stage and flow at low, medium, and high data collection events at five sites. Reproduced from HSW (2021).

Site ID (Latitude Longitude) Upstream to downstream	Transect type (Upstream to downstream)	Low flow		Medium flow		High flow	
		Flow (cfs)	Stage (NAVD88 ft)	Flow (cfs)	Stage (NAVD88 ft)	Flow (cfs)	Stage (NAVD88 ft)
SR64 (27.48818 -82.02445)	Pool	1.12	66.17	7.79	66.64	77.1	69.08
	Run	1.37	66.16	8.63	66.62	79.3	69.16
	Shoal	1.32	66.15	8.45	66.60	82.5	69.13
SR70 (27.25700 -81.96550)	Pool	1.45	28.40	28.1	29.42	127.8	31.62
	Run	1.83	28.39	29.8	29.42	131.3	31.62
	Shoal	2.11	28.39	28.1	29.42	134	31.62
Pine Level Road (27.24000 -81.98750)	Pool	3.22	21.90	43.4	23.10	156.8	25.41
	Run	3.66	21.89	47.5	23.06	162.2	25.39
	Shoal	3.99	21.86	48.3	23.06	160.8	25.38
SR72N (27.20260 -81.98620)	Pool	4.25	12.20	106.6	14.75	284.7	17.56
	Run	5.66	12.21	97.5	14.74	273.3	17.53
	Shoal	6.04	12.18	103.1	14.73	277.7	17.45
SR72S (27.20069 -81.98680)	Pool	4.95	5.66	77.5	7.39	225.6	10.19
	Run	5.01	5.62	78	7.35	228.5	10.16
	Shoal	6.01	5.54	76.3	7.33	234.1	10.11

Table 2. Linear model results including flow max and increment for apportioning flows based on comparison of flows measured at individual sites compared with flows at the Arcadia gage.

Site	Residual Standard Error	Adjusted r-squared	Slope	p-value	Max	Increment
SR64	11.51965	0.937905	0.304848	0.020917	34	0.34
SR70	35.57626	0.788985	0.381503	0.073003	43	0.43
PLR	32.01747	0.889151	0.46097	0.037659	52	0.52
SR72N	4.02756	0.999448	0.890255	0.000184	100	1
SR72S	7.285213	0.997284	0.863473	0.000906	97	0.97

Table 3. Rating curve equations from log-log regression.

Site ID	Transect type (Upstream to downstream)	α	β	SZF	Mean error of Q (%)
SR64	Pool	14.9	1.46	66	0.26
	Run	16.8	1.36	66	0.97
	Shoal	16.7	1.39	66	0.41
SR70	Pool	19.4	1.58	28.2	3.0
	Run	22.7	1.40	28.2	2.6
	Shoal	20.9	1.45	28.2	3.9
Pine Level Road	Pool	30.9	1.17	21.8	5.3
	Run	32.9	1.24	21.7	1.1
	Shoal	32.6	1.22	21.7	0.09
SR72N	Pool	21.53	1.49	11.9	0.61
	Run	22.4	1.44	11.8	0.36
	Shoal	19.9	1.51	11.7	0.03
SR72S	Pool	33.8	1.25	5.44	2.0
	Run	36.4	1.17	5.44	0.63
	Shoal	29.2	1.31	5.24	0.75

Table 4. Flow non-exceedance percentiles for baseline flow record at Arcadia.

Min	P10	P20	P30	P40	P50	P60	P70	P80	P90	Max
0	0	5	11	22	39	70	127	239	489	10688

Table 5. Habitat suitability curves used in this analysis with 4-letter abbreviations.

Code	Species	Stage
REDA	Redbreast Sunfish	Adult
REDJ	Redbreast Sunfish	Juvenile
REDS	Redbreast Sunfish	Spawning
REDF	Redbreast Sunfish	Fry
SHSL	Shallow	Slow
SHFA	Shallow	Fast
DPSL	Deep	Slow
DPFA	Deep	Fast
DART	Darters	Adult
PHEM	Ephemeroptera	Larvae
TRIC	Tricoptera	Larvae
TINV	Total Invertebrates	Larvae
PSEU	Pseudocloeon ephippiatum	Larvae
HYDR	Hydropsychidae	Total
TVET	Tvetenia vitracies	Larvae
LMBA	Largemouth Bass	Adult
LMBJ	Largemouth Bass	Juvenile
LMBS	Largemouth Bass	Spawning
LMBF	Largemouth Bass	Fry
BLUA	Bluegill	Adult
BLUJ	Bluegill	Juvenile
BLUS	Bluegill	Spawning
BLUF	Bluegill	Fry
SPOA	Spotted Sunfish	Adult
SPOJ	Spotted Sunfish	Juvenile
SPOS	Spotted Sunfish	Spawning
SPOF	Spotted Sunfish	Fry
CYPA	Cyprinidae	Adult
CCAD	Channel Catfish	Adult
CCJU	Channel Catfish	Juvenile
CCSP	Channel Catfish	Spawning
CCFR	Channel Catfish	Fry
CCJP	Channel Catfish	Juvenile (Spring)
CCJS	Channel Catfish	Juvenile (Summer)
CCJF	Channel Catfish	Juvenile (Fall)

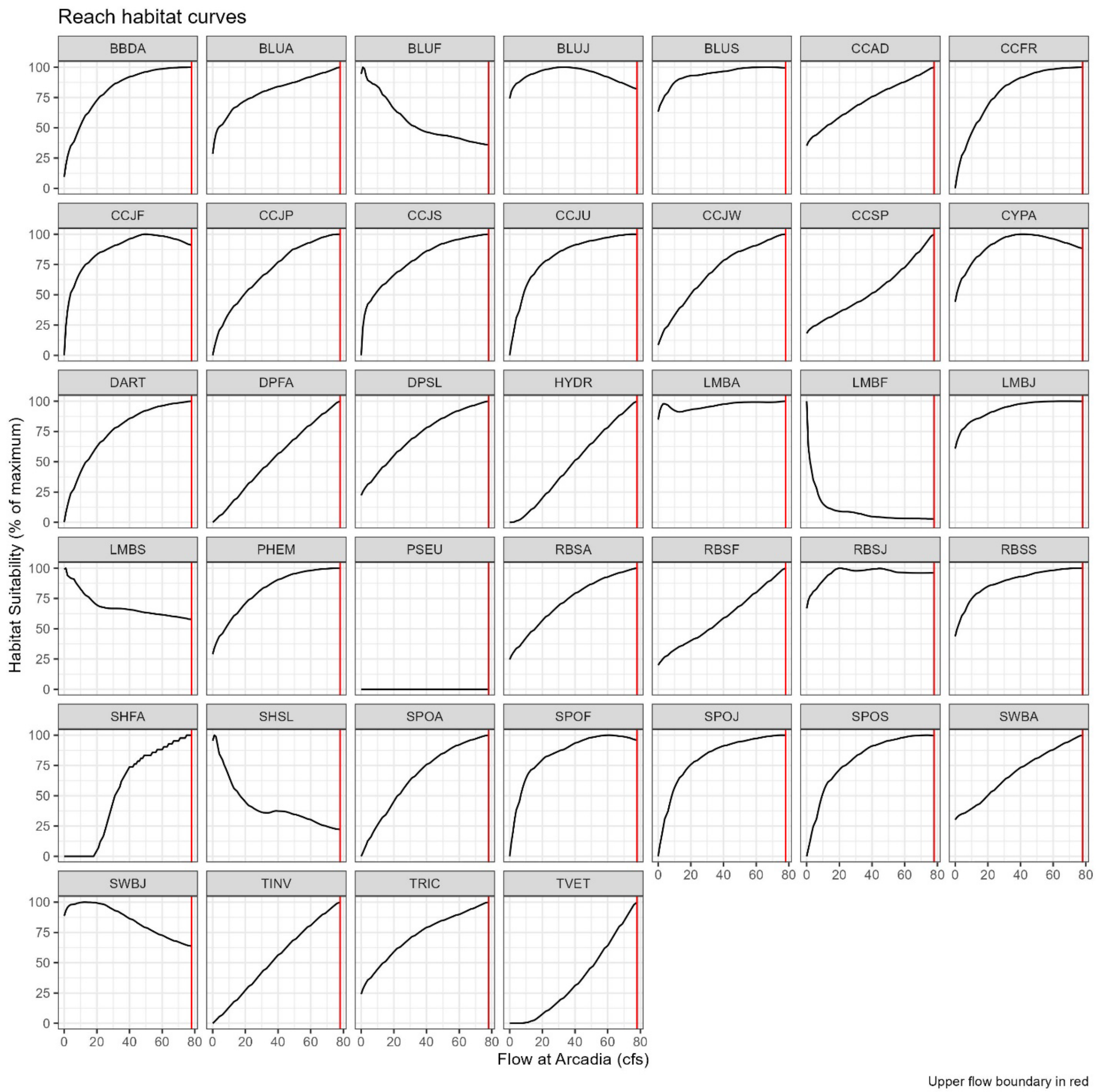

Figure 4. Reach habitat curves for species/life history stages/niche guilds. Red line is 78 cfs at Arcadia corresponding to beginning of floodplain inundation flows and the upper limit of instream habitat flows.

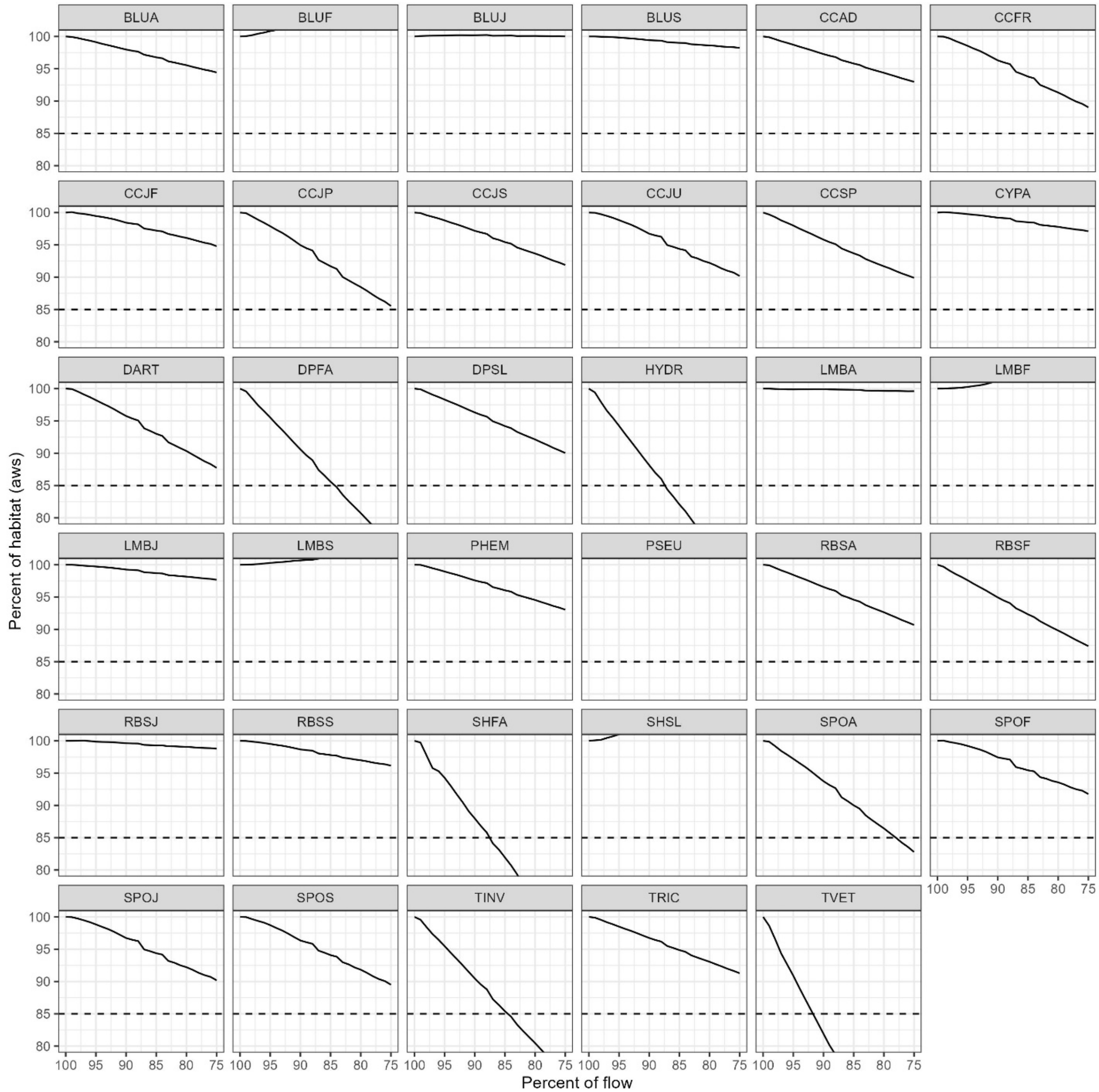

Figure 5. Loss of habitat associated with reduced flow scenarios. The x-axis is reversed such that 100 percent is on the left. The dashed line shows the 85 percent of habitat threshold.

Conclusions and Discussion

Significant harm is defined as a loss of habitat greater than or equal to 15% of the total available under baseline flow conditions. Four species are predicted to experience habitat losses that occur at flow reductions less than or equal to 25% (Figure 6). The net-spinning caddisflies of the family Hydropsychidae (HYDR) are the most sensitive group with a 15% loss of habitat occurring at flow reductions greater than 12%.

We might reasonably ask what is it about HYDR that causes it to be the most sensitive habitat suitability group for this range of flows from 0 to 78 cfs?

The average depth for all 15 cross sections surveyed increases with flow (Figure 7). These average depths increase from 0.76 ft at zero flow to 1.88 ft at 65 cfs. These depths correspond to the rising arm of the habitat suitability curve for HYDR (Figure 2). This means that over the range of flows we are interested in, the relationship between flow and depth results in a positive relationship between flow and habitat suitability of HYDR. This relationship is based on the geometry and hydrology of the cross sections surveyed as well as the habitat suitability curves for HYDR.

The average velocity for all 15 cross sections surveyed also increases with flow (Figure 8). These average velocities correspond to the rising arm of the habitat suitability curve for HYDR (Figure 2). This means that over the range of flows we are interested in, there is a steep increase in habitat suitability for velocity associated with an increase in flows, based on the geometry and hydrology of the cross sections surveyed.

The habitat suitability curves for HYDR were based on data collected by Warren and Nagid (2008) in the northern Withlacoochee River, Florida. The curves for depth and velocity (Figure 2) are directly translated from the northern Withlacoochee data, converted from cm to ft (Figure 9). Substrate suitability was modified from the data collected on the northern Withlacoochee river (Figure 10) to match the categorization of other habitat suitability curves (Figure 2).

Based on the depths, velocities, and substrate types found in the surveyed river reach, and their corresponding habitat suitabilities for HYDR, it makes sense that this taxonomic group is sensitive to reduced flows, and the instream habitat suitability modeling bears this out.

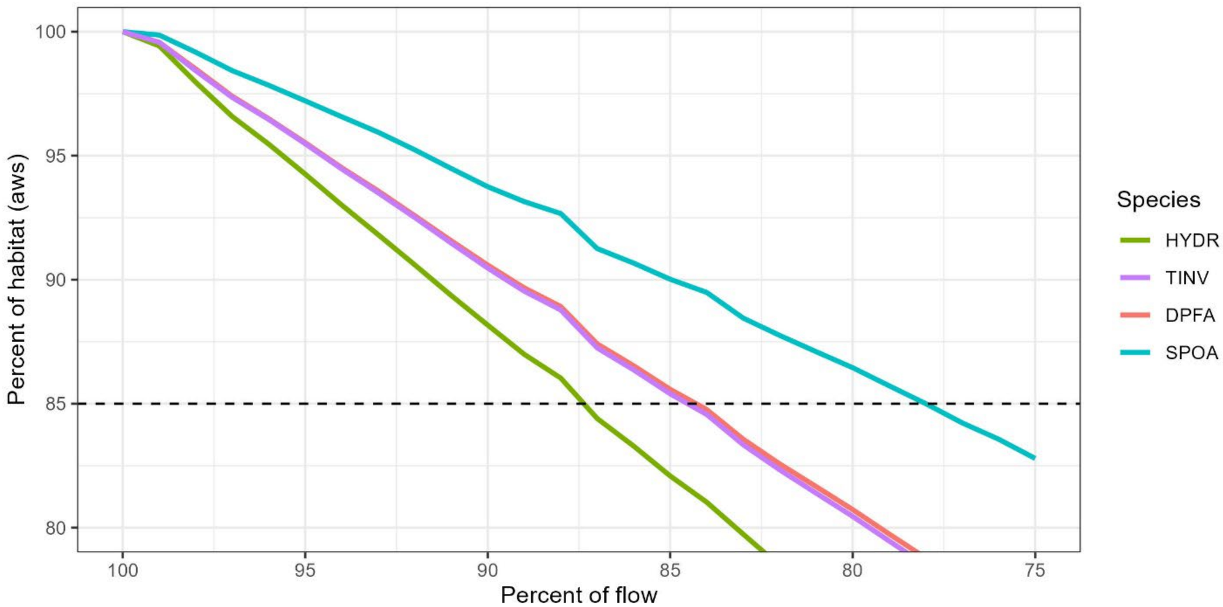

Figure 6. Habitat loss of the most sensitive species. The significant harm threshold shown as dashed line at 85% of habitat that would occur with unimpacted flows. The minimum allowable percent of flow occurs where the line for each species crosses this dashed threshold. Only shown are species where flow reductions less than 25% will result in 15% or greater loss in habitat.

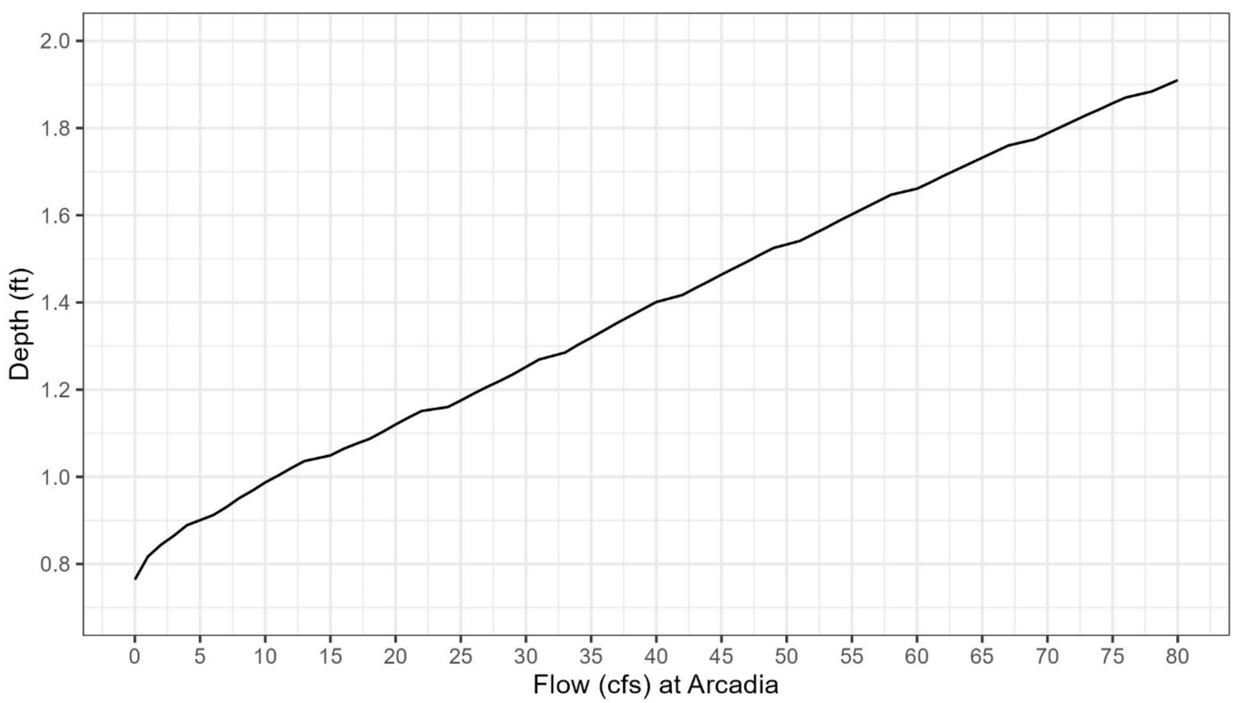

Figure 7. Average depth across all sites.

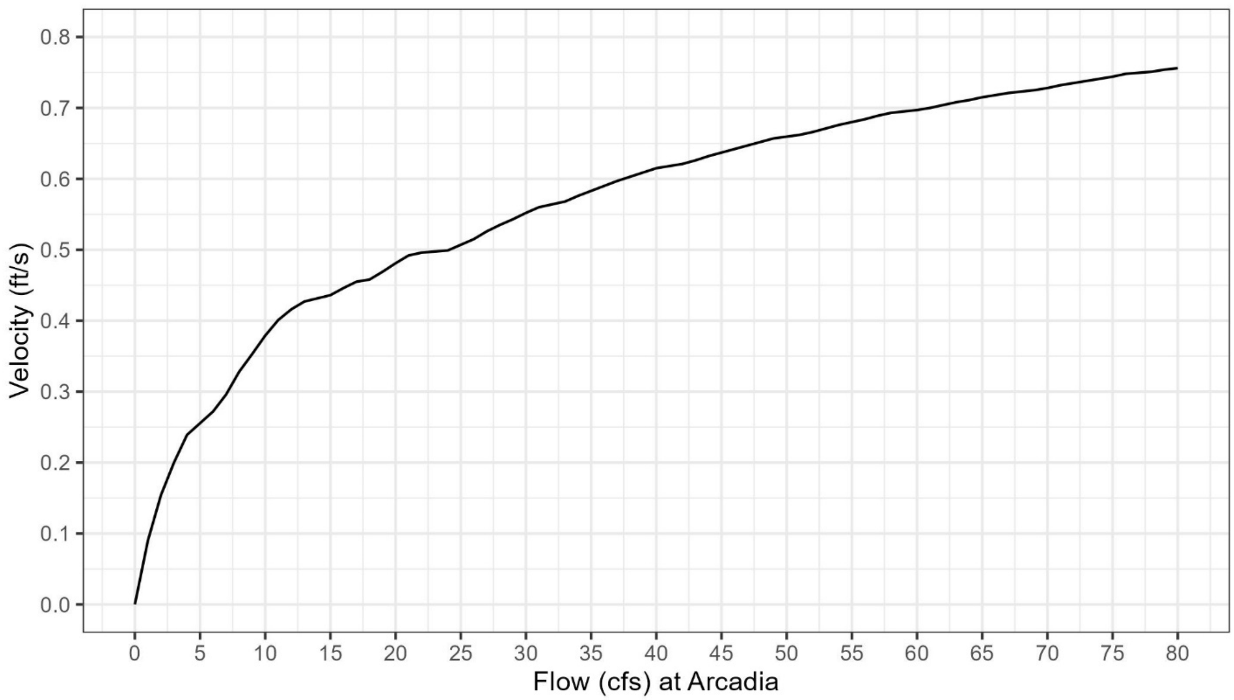

Figure 8. Average velocity across all sites.

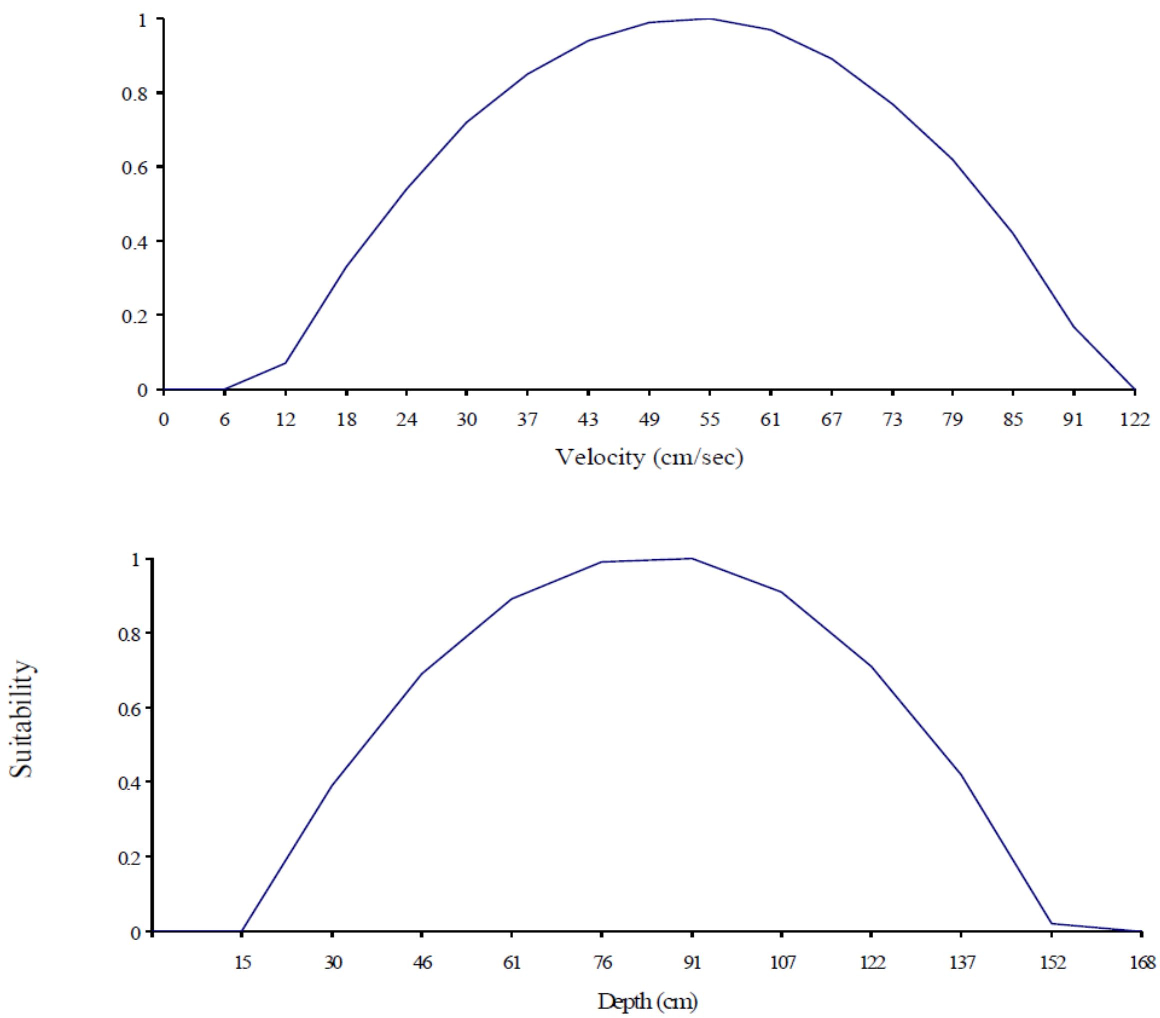

Figure 9. Depth and velocity habitat suitability curves for Hydropsychidae based on northern Withlacoochee River data (Warren and Nagid 2008).

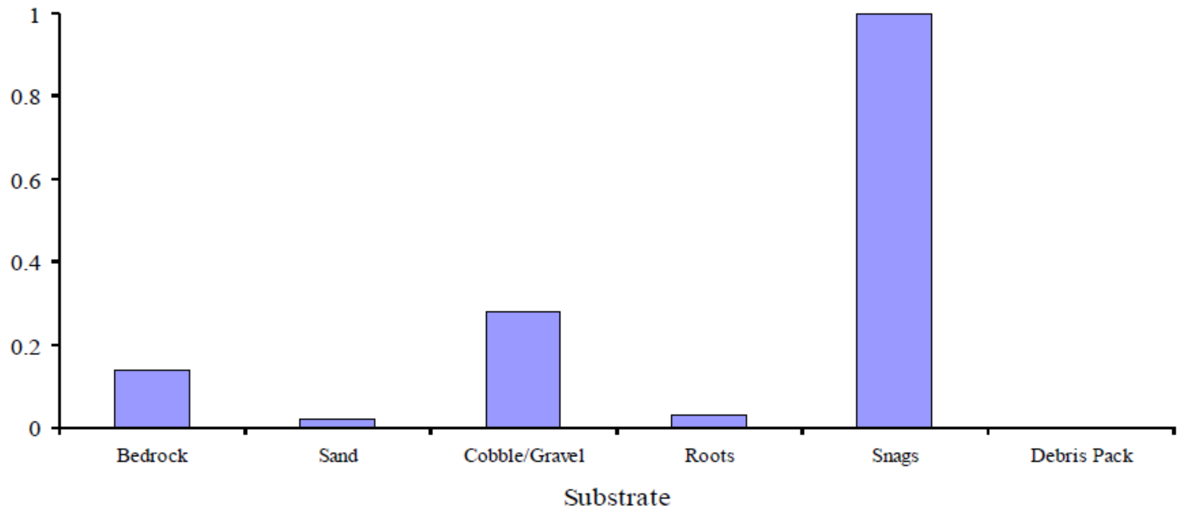

Figure 10. Substrate suitability for Hydropsychidae from northern Withlacoochee data from Warren and Nagid (2008).

Differences with HSW (2021)

The results and conclusions provided here differ somewhat from HSW (2021), because of methodological and interpretive reasons (Table 6). Field data collection was the same in both analyses.

HSW did not edit velocity distribution factors above the medium survey flow. In contrast, this District analysis did edit velocity distribution factors in accordance with recommendations of the SEFA documentation (Jowett et al. 2020). In addition, this district analysis uses modified habitat suitability curves for invertebrates as described in Warren and Nagid (2008).

In the HSW analysis, block boundaries were less than 17cfs as Block 1 flows and flows between 17 and 54 cfs were characterized as Block 2 flows. These differ from the analysis provided in this report, and will result in different results.

Furthermore, HSW values given in results HSW Tables 7 and 8 are the flow reductions that correspond to a 15% loss of habitat. To prevent significant harm at 15% loss, the flow reduction corresponding to the minimum flow should be the flow reduction percentage below the significant harm threshold, not at the threshold. If the minimum flow is the limit at which further reductions would be significantly harmful, and significant harm occurs at a 15% loss of habitat, then the minimum flow occurs at the flow reduction percentage just below (and not equal to) that which causes 15% loss in habitat.

HSW apportioned flows to individual sites by equating them with the nearest gage; SR64 was assigned flows at Myakka, based on regression between Myakka and Arcadia, while the other 4 sites were assigned flows equal to gaged flows at Arcadia. In contrast, the District performed linear regression of each sites' measured flows with gaged flows at Arcadia on the same date to apportion flows based on the best available data.

Lastly, HSW discounted habitat suitability groups with average or median AWS < 1. This report recommends against doing this, given that AWS is a dimensionless index when using habitat suitability curves that have values in between 0 and 1 on a dimensionless scale. As it states in the SEFA help documentation, “If habitat suitability curves are specified with weights of between 0 and 1, AWS is an index of suitability and not a measure of physical area” (Jowett et al. 2020). The habitat suitability curves used here are weighted between 0 and 1, and therefore AWS should be considered a dimensionless index, not an area. However, we eliminated PSEU, SHFA, and TVET because they had less than 10% of their maximum AWS by the time they reach the fish passage flow of 15 cfs, which was used as an indicator of non-linearity in the flow-habitat response (Figure 4).

Table 6. Comparison between HSW (2021) analysis and current District analysis

Item	**District**	**HSW (2021)**
Field data collection	Described in HSW (2021)	Described in HSW (2021)
Habitat suitability curves	Invertebrate curves modified based on Warren and Nagid (2008)	District Curves
Velocity Distribution Factors	Edited above survey flow	Not edited
Blocks (Arcadia flows)	0 to 78 cfs	B1 < 17 cfs, B2 ≥ 17 cfs and ≤ 54 cfs
Significant harm threshold	Further withdrawals cause significant harm	Equaled withdrawals cause significant harm
Flow apportionment	Site-specific regressions with gaged flows	Sites assigned nearest gage flow
Filtering out species based on habitat response to flow	Excludes relative AWS < 5% of maximum at fish passage of 15 cfs	Excludes mean values less than 1

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