Appendix D3
Technical Memorandum

Subject	TWA 20TW0002949 P274 Little Manatee River System MFLs Development Support – Task 4.6
Attention	Kym Holzwart, Southwest Florida Water Management District
From	Mike Wessel, Janicki Environmental, Inc.
Date	March 31, 2021
Through	James Greco, Jacobs Engineering Group

Dear Kym – On behalf of Janicki Environmental, Inc. (JEI) and Jacobs Engineering Group, we present this modified technical memorandum (TM) in fulfillment of Task 4.6 of Task Work Order Number 20TW0002949 describing the results of application of the habitat suitability analysis to recently collected data in the Little Manatee River System using the District's new flow-based blocks. We hope that this will serve the Southwest Florida Water Management District (District) well in its efforts to develop minimum flows for the Little Manatee River System. Please feel free to contact us for any reason.

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1. Background

Environmental favorability analyses are used in conservation biogeography to evaluate the spatial distribution of species in conservation areas (Real et al. 2006), compare distribution among species with different empirical prevalence (Real et al. 2009), and assess environmental factors determining favorability of particular habitat within conservation areas (Acevedo et al. 2010a, 2010b). Previously, JEI developed a habitat suitability index for fishes inhabiting the tidal portion of the Little Manatee River System (JEI 2018) using an Environmental Favorability Function (EFF) similar to the one developed by Real et al. (2006). For the 2018 report, JEI used the EFF as an index of habitat suitability to evaluate the potential effects of hypothetical flow reduction scenarios and reported results based on calendar-based seasonal “blocks” that had been identified for the system as described in Hood et al. (2011). The process involved:

- Developing species-specific logistic regression models evaluating the probability of occurrence as a function of salinity with habitat and seasonal covariates.
- Adjusting the model outputs to derive the EFF.
- Using salinity predictions from existing estuarine salinity prediction models to evaluate changes in EFF associated with a series of flow reduction scenarios.

Two salinity models were evaluated including output from the Environmental Fluid Dynamics Code (EFDC) hydrodynamic model (Huang and Liu 2007) for the period of record from 2000 through 2004 (the model was executed through June of 2005, but only full years were used for the analysis), and a locally weighted (LOESS) regression model that generated daily predictions of salinity throughout the river over the entire period or record of fish data collection (i.e., 1996-2014). Flow reduction scenarios included a Baseline condition and flow reductions between 10% and 40%, in 10% increments from the Baseline condition. Results were presented by year and by seasonal (calendar-based) blocks in the 2018 report.

Results of the evaluation for both salinity prediction models were very similar and suggested that reductions in favorable habitat did not generally approach a 15% change threshold typically used by the District to support minimum flows evaluations at flow reductions of less than 30% when evaluated either by year across seasonal blocks or by seasonal block across years. However, there were specific time periods within both model prediction periods when changes in favorable habitat were predicted to be

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greater than 15% at flow reductions less than 10%. These periods typically occurred during the dry seasons and during periods of lower than average flows (e.g., during the low flow Block 1, in 2000).

For this update of the 2018 analysis, the District was interested in supplementing the previous analysis described above by including data on flows and water quality since 2014 [the end of the period of record of the analysis performed in JEI (2018)]. Because the EFDC and LOESS model results were so similar in JEI (2018), this TM describes an update to only the LOESS model. Therefore, the objectives of the current analysis were to update the LOESS salinity-flow prediction model with available information on flows and water quality collected in the tidal portion of the Little Manatee River System since 2014 and use the updated LOESS model to predict the potential effects of flow reduction scenarios on salinity and habitat suitability, as defined by the EFF, for the time period of 2015-2019 (the 5 years since the last analysis). In addition, the District requested that the analysis include additional flow reduction scenarios to "infill" the previous flow reductions by generating reductions between 5% and 35% in 10% increments, and to report results by newly developed "flow-based" blocks (described below) instead of the previously used calendar-based blocks.

2. Methods

2.1 LOESS Regression Model Update

The following bullets provide details on the approach taken to update the salinity predictions using the LOESS model:

- The discharge record reported for the US Geological Survey (USGS) Little Manatee River at US 301 near Wimauma gage (No. 02300500) was updated with data through 2019 and flow reduction scenarios were recreated as described in Section 5.1.1 of JEI (2018) with the addition of the 5% flow-reduction increments between the 0% and 40% reduction scenarios. That is, flow reductions scenarios considered now include reductions between 5% and 40% in 5% increments.

- New flow-based "block" definitions developed by the District in 2020 were used for the analysis, as follows:

    - Block 1 – Baseline flows at USGS Gage No. 02300500 less than or equal to 35 cubic feet per second (cfs).
    - Block 2 – Baseline flows at USGS Gage No. 02300500 greater than 35 cfs and less than or equal to 72 cfs.

- Block 3 – Baseline flows at USGS Gage No. 02300500 greater than 72 cfs.

- Salinity data for the model were updated using available information collected in the tidal Little Manatee River by the Hillsborough County Environmental Protection Commission since 2014. All stations were assigned a river kilometer (Figure 1) to associate location with the salinity value and water column average salinities were used to be consistent with previous analysis using the LOESS model.

- The LOESS salinity-flow relationship was updated by including the additional salinity and flow data into the previous analysis. Water column average salinity was the model response variable, and independent variables included river kilometer, the same day flow, the 3-day lag average flow (i.e. the average of the flow on the day of sampling and the preceding two days flows) and water surface elevation at the time of sample based on tides at St. Petersburg, were included, identical to the previous analysis.

- The updated LOESS model was used to predict salinity throughout the tidal portion of the Little Manatee River at a water surface elevation of 1.48 ft above MLLW (the mean tidal stage during fish sampling) for each date between 2015 and 2019.

- The updated LOESS model salinity predictions were then used to as inputs into the fish EFF models to predict favorable habitat for the fish species under the Baseline condition and each of the flow reduction scenarios at 0.1 river kilometer increments for the time period of 2015-2019.

- The total area of predicted favorable habitat from the EFF was calculated for each date between 2015 and 2019.

- The average favorable area for each of the flow reduction scenarios was then calculated for each of the new flow-based blocks, by year, and by block and year combinations between 2015 and 2019.

- The difference in favorable area for each model scenario relative to the Baseline condition was then calculated by the new flow-based blocks, by year, and by block and year combinations to evaluate the expected effect of each flow reduction scenario on changes in EFF.

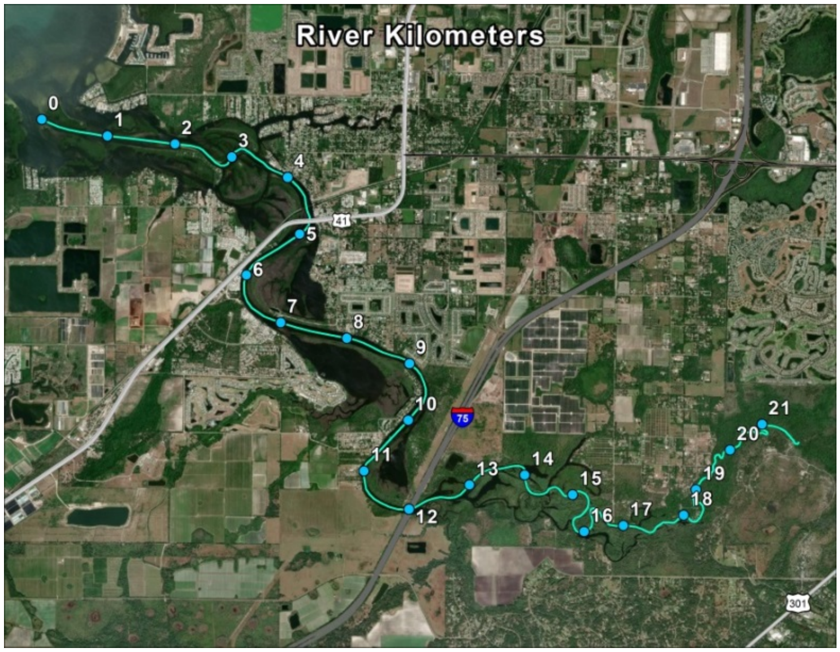

Figure 1. River kilometer system used for several analytical objectives associated with supporting the development of minimum flows for the Little Manatee River System.

2.2 EFF Updates

The EFF models described in JEI (2018) were used for this updated analysis. The probability of occurrence (P(y=1|x)) of a particular species collected in a shore seine was estimated as a function of environmental variables including site-specific salinity recorded at the time of capture, season, and shoreline habitat classifications where a seine was used to sample fish. A quadratic salinity term was evaluated within the model to capture salinity preferences in the mesohaline to polyhaline range (i.e., 10-25 part per thousand [or practical salinity units, psu]).

A logistic regression equation for each species (i) was derived in the form:

$$\hat{y}_{ijk} = Ln\left[\frac{P}{1-P}\right] = \alpha + \beta_1 X_1 + \beta_2 X_1^2 + \beta_j X_j + \beta_k X_k + \beta j_k X j_k$$

Where:

$\hat{y}$ = logit estimate (log odds)

Ln = Natural log

P = Probability of occurrence

α = Intercept

$\beta_{1...k}$ = Regression coefficients

X_1 = Salinity (ppt)

X_j = Season

X_k = Shore habitat

X_{jk} = Shore* Season interaction

The EFF is a post-hoc modification of the output of logistic regression to compensate for the differences in species prevalence (i.e., how often a species occurs) by adjusting the intercept term by the log odds of the empirical occurrence of the species being modeled (Real et al. 2006). The adjustment was defined as:

$$\hat{y}' = \hat{y} - Ln\left[\frac{n_1}{n_0}\right]$$

Where:

n_1 = # of presences

n_0 = # of absences

Ln = natural log transformation

$\hat{y}$ = predicted value

$\hat{y}'$ = EFF predicted value

This is the logit of the favorability model described by Real et al. (2006). When categorical effects are present then adjustment was performed for each categorical effect. Exponentiation of the logit of the favorability, ŷ', yields the EFF. Since the EFF standardizes the outcomes to their average log odds of occurrence, a cut-point value of 0.5 was used to assign "favorable" (i.e., values greater than the overall average) and "unfavorable" (values less than the overall average) predictions for each species.

Only those species with negative responses to salinity (linear coefficient) were considered for the analysis. These species, which exhibit a higher probability of occurrence at lower or mid-range salinities than at higher salinities, were considered most useful for assessing potential flow-related habitat favorability changes.

The final set of species evaluated in JEI (2018) and re-evaluated for this update included: *Archosargus probatocephalus* (Sheepshead)), *Centropomus undecimalis* (Common Snook), *Eugerres plumieri* (Striped Mojarra), *Gambusia holbrooki* (mosquitofish), *Gobiosoma bosc* (Naked Goby), *Lucania parva* (Rainwater Killifish, *Microgobius gulosus* (Clown Goby), *Poecilia latipinna* (Sailfin Molly), *Trinectes maculatus* (Hogchoker), and gobies less than 20 millimeters (termed “Small gobies” for this report). The term “species” is used throughout this memorandum even though Small gobies are not a single species.

3. Results

This section provides the results of analysis of the potential habitat reductions between the years 2015 and 2019 using the updated LOESS salinity model and new flow-based block definitions described above as inputs into the EFF models.

3.1 Discharge

Statistics were generated for observed discharge at USGS Gage No. 02300500 for several different time periods, including: the period of record used in the original analysis (1940-2014), the updated full period or record (1939-2019), the EFDC model period (2000-2005), and the period of record of fish collections (1996-2019). Percentile values of the distribution of observed flows over these periods of record are provided in Table 2 and as cumulative distribution curves with the y axis on the log base 10 scale (Figure 2). The distributional flow statistics over this period were similar, although inter-quartile statistics for the more recent periods of records were higher than those for the full period of record.

Table 1. Distributional percentile values for observed discharge at the USGS Little Manatee River near Wimauma gage (No. 02300500) for periods of record considered for environmental favorability analyses based on a LOESS regression for predicting salinity.

Percentile	1940-2014	1940-2019	1996-2019	2000-2005
Min	0.92	0.92	3.8	3.8
5th	12	12	16	16
10th	18	18	24	21
25th	31	32	37	39
50th	61	62	75	81
75th	145	152	167	165
90th	379	387	375	380
Max	11100	11100	10400	10400

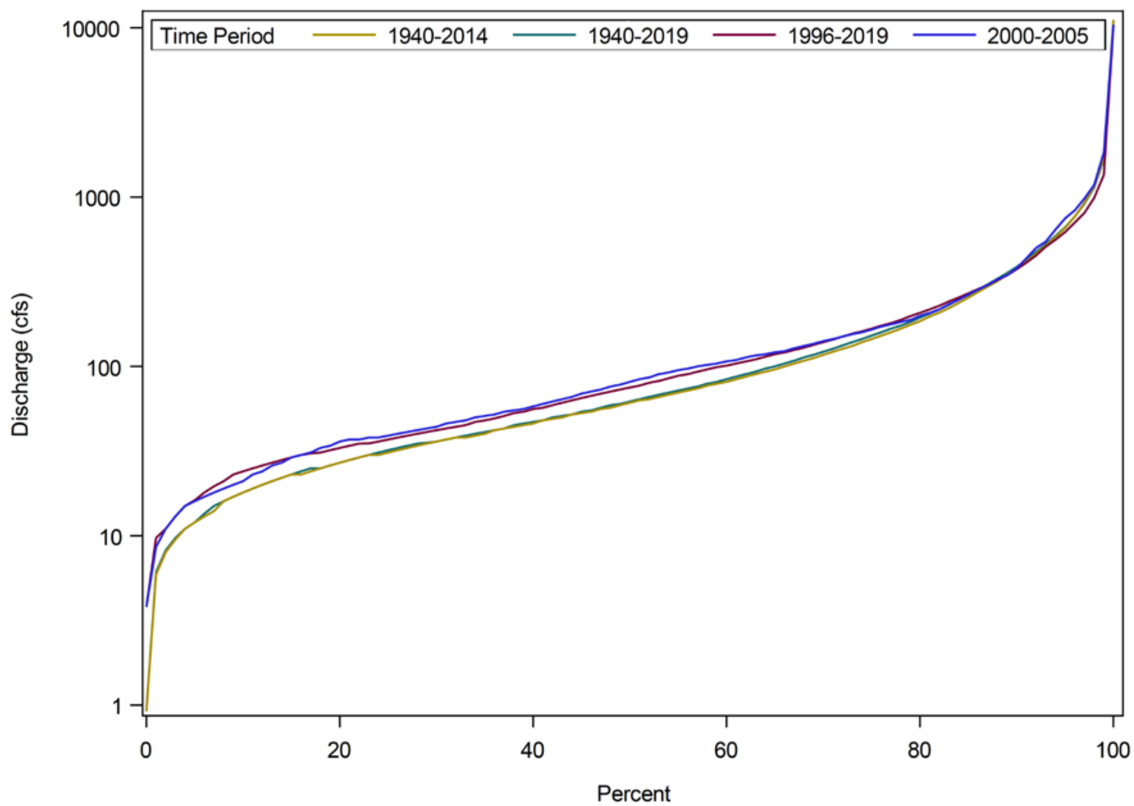

Figure 2. Cumulative distribution curves for observed discharge at USGS 02300500 for periods of record considered for environmental favorability analyses based on a LOESS regression for predicting salinity.

3.2 Salinity

The additional salinity data incorporated into the model since 2014 did not change the general trend in model predictions from those reported previously by JEI (2018). The predicted water column average salinity associated with the updated period of record is compared to the previous period of record in Figure 3 in which the location of the expected salinity isohaline is plotted as a function of natural log transformed discharge and river kilometer. As portrayed in Figure 3, the 20 psu isohaline was predicted to occur below the US Highway 41 Bridge (see Figure 1 for river kilometer locations) at all but the lowest assessed flows. Similarly, low salinity habitat (i.e., less than 10 psu) was expected to occur in the lower river above river kilometer 15.

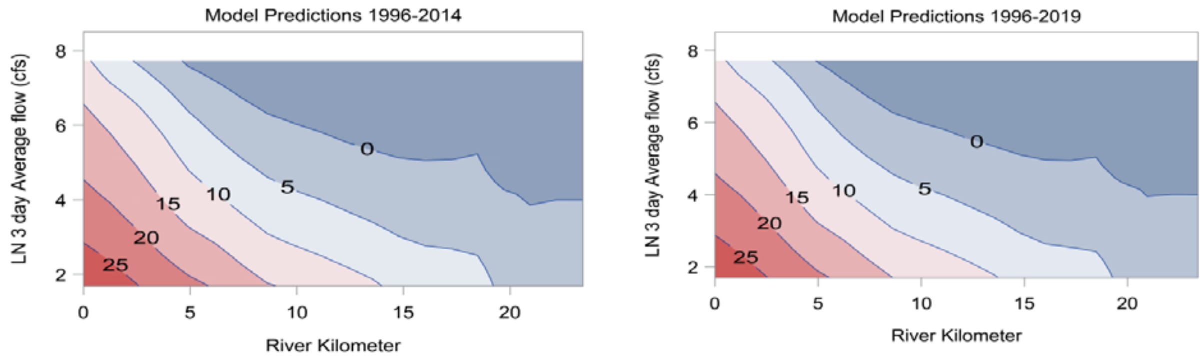

Figure 3. Contour plots of LOESS predicted isohaline location as a function of discharge (natural log transformed) and river kilometer for the previous (left) and updated (right) periods of record for analysis.

3.3 Fish EFF Updates

The EFF model results for the 2015-2019 period confirmed the previous analysis that the species most sensitive to flow reductions were tidal river residents including Sailfin Molly, Naked and Clown Goby, Mosquitofish and Rainwater Killifish (Figure 4). The overall average effects of flow reductions indicated that a 25% reduction in flows was associated with a 15% change in area of favorable habitat (horizontal broken line in plots) for the sensitive species. More transient, estuarine dependent species including Common Snook, Hogchoker, Sheepshead, and Striped Mojarra were less sensitive to flow reductions though all showed negative responses to flow reductions over the evaluation period.

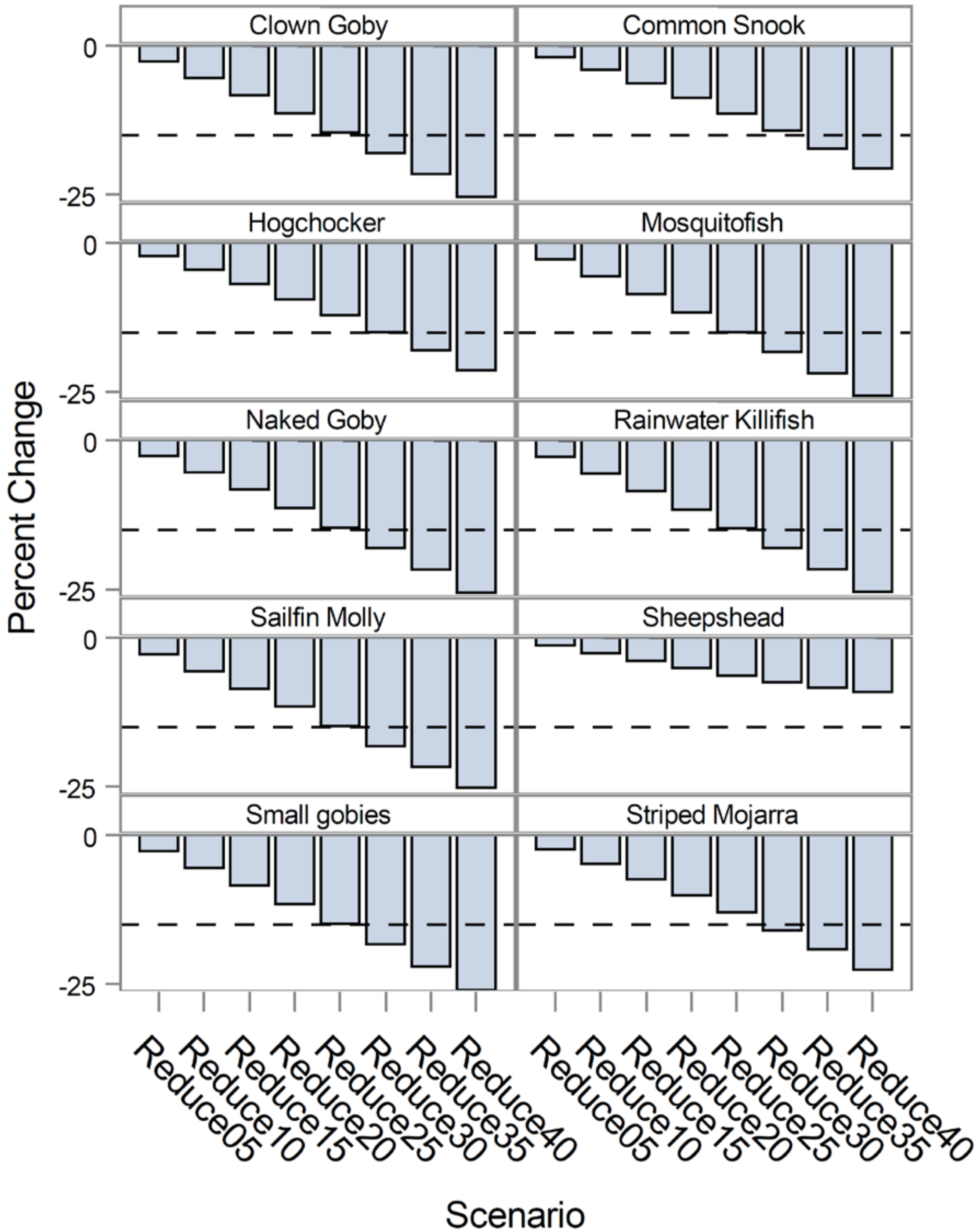

Figure 4. Average percent reduction in favorable habitat between 2015 and 2019 by fish species for each hypothetical flow reduction scenario evaluated between 5% and 40%, based on use of EFF models and salinity predictions derived using an updated LOESS model. Horizontal broken line indicates a 15 percent habitat reduction.

When the species-specific percent reductions are examined by flow-based blocks, the lower flow blocks (Blocks 1 and 2) were more sensitive to changes in flows than the overall average change across all blocks. For Block 1 (i.e., Baseline flows less than or equal to 35 cfs), several species exhibited a 15% reduction in favorable habitat with a 10% reduction in flows (Table 2). These species included Rainwater Killifish, Sailfin Molly, Clown Goby, Naked Goby, and Small gobies less than 20 millimeters. These species are principally tidal river resident species that spend the majority of their lives within the lower river.

The results for Block 2 (Table 3) suggest that three species (Rainwater Killifish, Sailfin Molly, and Small gobies) exceeded the 15% reduction in favorable habitat threshold with a 20% reduction in flows. Again, these are resident species that appear more sensitive to changes in salinity than transient species such as Common Snook that may leave and return to the river during different portions of their life history.

The results for Block 3 suggest that none of the species evaluated would see reductions in favorable habitat of 15% or greater until flows were reduced by 30% (Table 4). As observed for Blocks 1 and 2, tidal river resident species were more sensitive to flow reductions than transient species.

Table 2. Percent reduction across years (2015-2019) for Block 1 (flows < =35 cfs) by fish species.

Fish Species	Flow Reduction Scenario							
	5%	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**
Clown Goby	-7	-15	-23	-30	-39	-47	-54	-61
Common Snook	-4	-9	-14	-19	-25	-32	-39	-46
Hogchoker	-4	-9	-14	-20	-26	-33	-40	-47
Mosquitofish	-7	-13	-21	-29	-36	-43	-50	-57
Naked Goby	-7	-15	-22	-30	-39	-47	-54	-61
Rainwater Killifish	-7	-14	-22	-31	-38	-43	-48	-53
Sailfin Molly	-7	-15	-22	-27	-32	-35	-37	-38
Sheepshead	2	4	7	8	11	14	18	24
Small gobies	-8	-15	-24	-33	-41	-47	-54	-62
Striped Mojarra	-6	-13	-19	-26	-33	-41	-48	-56

Table 3. Percent reduction across years (2015-2019) for Block 2 (flows between 36 cfs and 72 cfs).

Fish Species	Flow Reduction Scenario							
	5%	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**
Clown Goby	-3	-6	-10	-14	-19	-24	-29	-36
Common Snook	-3	-6	-10	-13	-16	-19	-22	-26
Hogchoker	-3	-5	-8	-10	-13	-17	-21	-25
Mosquitofish	-3	-7	-11	-15	-19	-25	-30	-36
Naked Goby	-3	-6	-10	-14	-19	-24	-29	-36
Rainwater Killifish	-3	-7	-11	-16	-20	-26	-32	-39
Sailfin Molly	-4	-8	-12	-17	-23	-29	-36	-42
Sheepshead	-1	-2	-2	-2	-2	-2	-1	-1
Small gobies	-3	-7	-11	-16	-20	-26	-32	-39
Striped Mojarra	-2	-5	-8	-11	-15	-19	-24	-29

Table 4. Percent reduction across years (2015-2019) for Block 3 (flows above 72 cfs).

Fish Species	Flow Reduction Scenario							
	5%	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**
Clown Goby	-2	-5	-7	-10	-12	-15	-18	-21
Common Snook	-2	-3	-5	-7	-10	-12	-15	-17
Hogchoker	-2	-4	-6	-8	-11	-13	-16	-19
Mosquitofish	-2	-5	-7	-10	-13	-15	-18	-22
Naked Goby	-2	-5	-7	-10	-12	-15	-18	-21
Rainwater Killifish	-2	-5	-7	-10	-12	-15	-18	-21
Sailfin Molly	-2	-5	-7	-10	-12	-15	-18	-21
Sheepshead	-2	-4	-6	-8	-11	-13	-15	-17
Small gobies	-2	-5	-7	-10	-12	-15	-18	-21
Striped Mojarra	-2	-4	-6	-9	-11	-14	-16	-19

The positive responses to flow reductions for Sheepshead for Block 1 led to an investigation of the quadratic salinity term in the model for this species. In rare instances, the quadratic term in the model imparted a predicted increased probability of occurrence during low flows at highest salinities for this species. Therefore, the Sheepshead model was dropped from further analysis.

A plot of the EFF results across fish species (after removing Sheepshead) (Figure 5) suggested that on average, between a 25% and 30% reduction in flows would result in less than 15% change for the combined results of all species over the entire evaluation period (2015-2019).

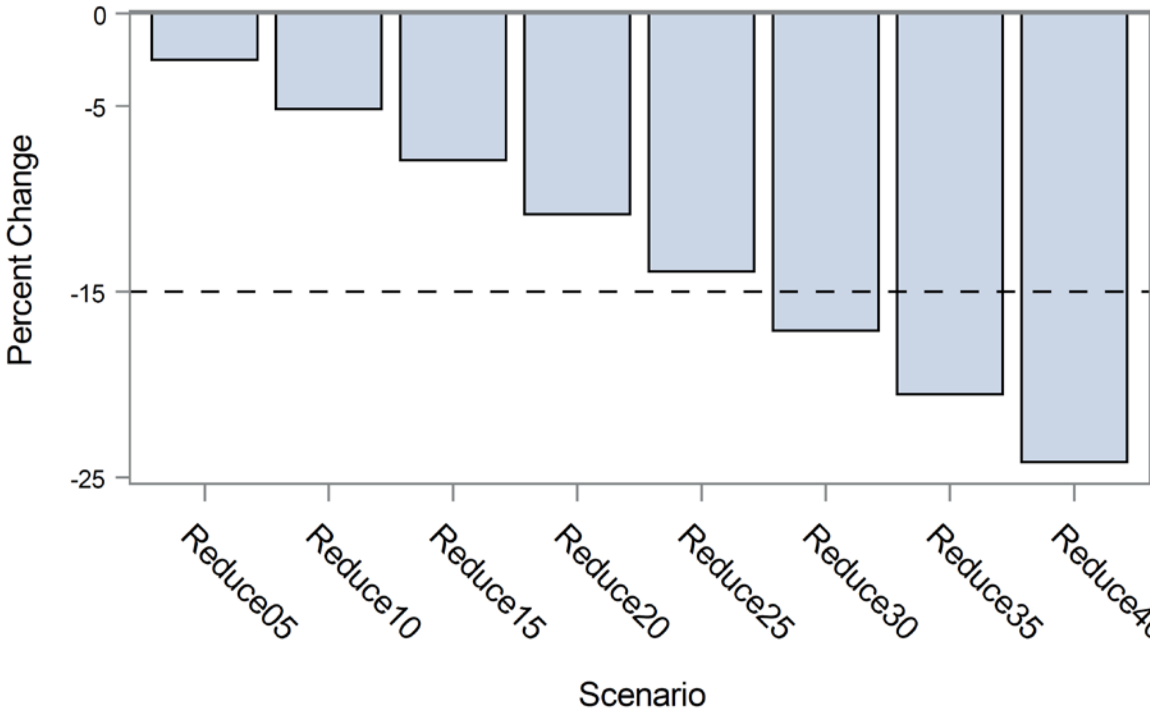

Figure 5. Average percent reduction in favorable habitat between 2015 and 2019 across fish species for each hypothetical flow reduction scenario evaluated between 5% and 40%, based on use of EFF models and salinity predictions derived using an updated LOESS model. Horizontal broken line indicates a 15 percent habitat reduction.

Evaluations by year (across blocks, 2015-2019) suggested that the 20% flow reduction would limit the reduction in favorable habitat for all species to less than 15% (Figure 6).

3.4 Evaluation of Potential Minimum Flow Scenarios

Since the time the District initially contracted the work effort for this TM, a new potential minimum flow scenario has been developed. While not specifically scoped for this work effort, an evaluation of this minimum flow scenario was conducted to evaluate the impact of a low flow threshold (LFT) on EFF in the lower Little Manatee River System. The scenario for the lower segment of the Little Manatee River that includes a 15% flow reduction when flows are greater than 35 cfs and no allowable flow reduction when flows are less than or equal to 35 cfs (the LFT). This scenario is termed “15% LFT” and compared to the 15% reduction without an LFT described above to evaluate the effects of the LFT on protecting habitat favorability during times of low flow.

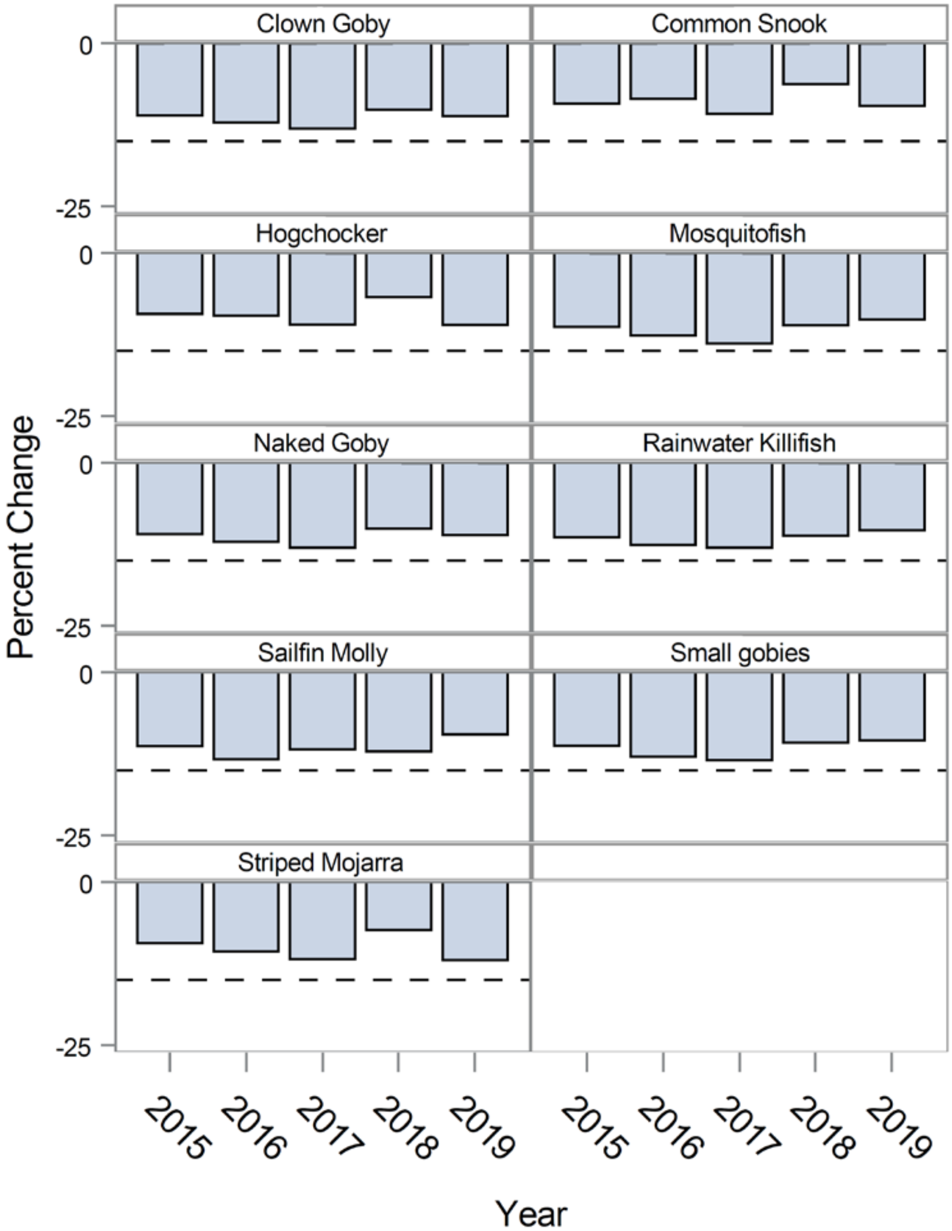

Figure 6. Percent reduction in favorable habitat for each year under the 20% reduction scenario for all species evaluated using EFF models and salinity predictions derived with an updated LOESS model. Horizontal broken line indicates a 15 percent habitat reduction. Reference to scientific names located in the methods section.

The effect of the 15% LFT scenario on reductions in favorable habitat was less than 15% for all flow-based blocks (Table 5 and substantially less in Blocks 1 and 2 than the 15% reduction without the LFT. The reported reductions for the LFT in Block 1 were due to the 3-day lag average flow term in the LOESS salinity model which incorporates antecedent Block 2 reductions of 15% into the Block 1 evaluation. The difference in the

Block 2 comparison is presumably due to reductions in Block 1 flows for the 15% scenario without the LFT, within the Block 2, 3 lag day averaging window used in the LOESS model. The Block 3 reductions were identical for this comparison.

Table 5. Results of potential minimum flow evaluations on EFF results for individual fish species by flow-based block for the time period 2015-2019.

	Block 1		**Block 2**		**Block 3**	
Species	**15%**	**15% LFT**	**15%**	**15% LFT**	**15%**	**15% LFT**
Clown Goby	-23	-5	-10	-9	-7	-7
Common Snook	-14	-1	-10	-9	-5	-5
Hogchoker	-14	-2	-8	-7	-6	-6
Mosquitofish	-21	-4	-11	-10	-7	-7
Naked Goby	-22	-4	-10	-9	-7	-7
Rainwater Killifish	-22	-6	-11	-10	-7	-7
Sailfin Molly	-22	-6	-12	-11	-7	-7
Small gobies	-24	-6	-11	-10	-7	-7
Striped Mojarra	-19	-2	-8	-7	-6	-6

4. Discussion

The results of the EFF evaluation for the 2015-2019 period using the updated LOESS salinity model were consistent with those reported in JEI (2018). When flow reductions were restricted to 20% or less, reductions in favorable habitat were predicted to be 15% or less for all species and all years across blocks. The block-specific evaluations demonstrated the potential sensitivity of flow reductions on favorable habitat during low flow conditions when favorable habitats are small to begin with and are further compressed by flow reductions.

Species with the most sensitive responses to flow reductions included the tidal river resident species Clown Goby, Naked Goby and other Small gobies, in addition to the Rainwater Killifish and Sailfin Molly. Gobies are bottom-dwelling fish that tend to have site fidelity and therefore changes in salinity may more negatively affect their habitat suitability requirements relative to mobile transient species. The results of the potential minimum flow scenario that included a low flow threshold emphasized the importance of a low flow threshold to maintain habitat favorability in the lower river during low flow conditions.

These modeling efforts were performed because fish have been identified as an important resource of the lower segment of the Little Manatee River System. The model results provide “best estimates” of potential changes in favorable habitat for selected fish species as a function of potential flow reductions; however, it is acknowledged that the models used for the analyses include uncertainty that is not fully incorporated into the predicted changes in habitat favorability. For example, the logistic regression models used in the EFF provide coefficients describing the rate of change in the log odds of occurrence as a function of flows. That coefficient has uncertainty (i.e., a standard error), which was not incorporated into the assessment. Instead, the coefficient was accepted as the best estimate of the true underlying relationship, which is common practice in establishing lines of evidence in support of evaluating flow reduction scenarios for management purposes. Likewise, the LOESS salinity-flow model contains uncertainty which was not propagated through the modeling construct. Therefore, it is not possible to state with statistical certainty that the observed changes in favorable habitat were due explicitly to changes in flows associated with the reduction scenarios. Instead, the results are described as best estimates of the potential relative changes that would occur for these species.

Finally, the EFF analyses were used to identify the availability of preferential habitat and are not a determination of adequate habitat for the occurrence of the particular fish species within the lower portion of the Little Manatee River System. For this analysis, reductions in preferential habitat are considered detrimental to the long-term success of tidal river fish species, but these species are adapted to life in an environment that can undergo rapid changes in physical chemistry, even on a daily basis, given tidal exchange, intense rainfall events, and wind driven estuarine mixing. Despite this natural variability, the EFF models are useful indicators of potential flow-related changes in favorable habitat for a number of fish species and provide additional lines of evidence to consider in support of the development of minimum flows.

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