Exploratory Analysis to Evaluate Tidal Creek Fish Habitat Preferences in the Context of Larger Tidal Tributaries.

Technical Data Report Prepared for

Sarasota Bay Estuary Program

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Background:

The Sarasota Bay Estuary Program has recently conducted a study to develop management level targets and thresholds as part of a larger management framework for southwest Florida tidal creeks. Bi-monthly fish samples were collected in the estuarine portion of 16 tidal creeks between Tampa Bay and Estero Bay Florida between November 2013 and September 2014. These data were evaluated within the context of establishing relationships between nutrient concentrations and metrics of fish community structure that could be used to set numeric standards for nutrients in SW Florida tidal creeks. The short duration of the study and the objectives to compare catch among creeks means that the data for any particular creek are insufficient for developing population based estimates of habitat preferences while accounting for creek specific interactions. However, long term data in larger tidal rivers of Tampa Bay do provide the opportunity to compare the tidal creek data to a long term dataset, collected using the similar methodologies, to evaluate the potential to identify species-specific habitat affinities in these larger systems and examine the creek data within the context of the finding for these larger systems with a long term period of record. The objective of this effort is to develop a stochastic habitat suitability model for larger tidal tributaries in Tampa Bay, calculating habitat favorability functions for various habitat types (e.g. mangroves, Juncus marsh) using logistic regression, and then evaluate the goodness of fit of those models to the tidal creek data collected as part of the southwest Florida Numeric Nutrients Study. Insights from this investigation can be used to inform conservation and restoration strategies within these creeks as they relate to providing valuable fish habitat and other ecosystem services to tidal creek wetlands in Southwest Florida.

The specific tasks associated with this effort included:

- Data compilation – Datasets will be obtained from the Florida Fish and Wildlife Conservation Commission's Fisheries independent Monitoring program and subset to data collected in tidal tributaries including the Alafia, Little Manatee, Manatee, and Braden Rivers.

- Development of a stochastic habitat suitability model - a habitat suitability model based on the logistic regression (Real et. al. 2006) will be developed for the larger tidal tributary dataset using shoreline habitat characteristics, along with salinity and other attributes, to determine species and potentially size class specific, large scale habitat preferences in larger tidal tributaries. An initial screening analysis will be conducted on a large suite of taxa and 6 - 8 species will be identified for final development of the habitat suitability models.

- Evaluate to tidal creek data – tidal creek data will be evaluated in the context of the findings for the larger tidal tributaries. The creek data will be evaluated to examine the consistency in habitat associations between the creek data and the data from the larger tributaries.

Methods:

The Florida Fish and Wildlife Conservation Commission (FWC) Fisheries Independent Monitoring (FIM) Program has collected routine fisheries information in Tampa Bay Tidal rivers since 1996 though the period of record for individual rivers varies. Fish data used for this study were generated from samples collected monthly using a 21.3 meter, 3mm mesh seine nets deployed along the river banks of the Alafia, Little Manatee, Manatee and Braden Rivers in Tampa Bay. Sites were selected using a probabilistic monitoring design constrained to sites with maximum depths less than 1.8 meters and shoreline banks less than 0.5 meters inundation. These data were used to derive population based estimates of habitat preferences in tidal rivers and compare these estimates to data collected as part of the Southwest Florida tidal creeks nutrient study (Janicki Environmental, Inc. 2016). The creeks data were collected using methods consistent with the 21.3 meter seine data though the seine nets were 9.1 meter raft seines deployed manually. The seine net mesh was the same dimension 3 mm knotless nylon and the wing depths were 1.4 instead of 1.8 meters.

For both data collection methods, the dominant (i.e., Level 1) shoreline habitat type recorded at the time of sampling was used to classify the habitat associated with the sample. A habitat classification scheme was developed to group similar shore habitat types. For example, There are three dominant species of mangrove found in southwest Florida ((*Rhizophora mangle* (Red Mangrove), *Laguncularia racemosa* (White Mangrove), and *Avicennia germinans* (Black Mangrove)) which were categorized as "Mangroves". The 6 shoreline habitat categories used for analysis included:

- Emergent Vegetation
- Terrestrial Grasses
- Mangroves
- None
- Structure (Seawall, docks, etc), and
- Trees

The Rivers data were used to develop population based estimates of fish habitat preferences using logistic regression and the 6 habitat categories described above. The probability of occurrence ($P(y=1|x)$) of a particular taxon was estimated as a function shore category, with covariates including salinity recorded at the time of capture, a quadratic salinity term to capture salinity preferences in the mesohaline to polyhaline range (i.e., 10-25ppt) and season. The effect of shore category and season on the probability of occurrence was modeled as a categorical variable using the effect coding scheme such that the model coefficients of each habitat category represent deviations from the overall average condition. The "Trees" category was coded as the reference category. The seasonal term was included in the model to account for species-specific recruitment and utilization of these rivers and was defined by Winter from October through March and Summer otherwise. The logistic model equation as modeled is written as:

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

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 $_{(1\text{-}12)}$

X_k = Shore habitat $_{(1\text{-}6)}$

Therefore, the logistic model is a linear (additive) model using a link function to relate the explanatory components to the response. To transform the predicted logit estimate into an estimate of the probability of occurrence requires the transformation of the logit estimate to a probability via the equation:

$$P(y = 1 | x) = \frac{\exp^{\hat{y}}}{1 + \exp^{\hat{y}}} \qquad [2]$$

The logistic regression models were implemented using Proc Logistic and the Firth option in the model statement (SAS Institute Inc. 2008) which specifies Fishers scoring optimization. The Firth option is a bias reduction technique used when data may be imbalanced such as when the one habitat type was sampled disproportionately across the study area. To evaluate the logistic regression model performance, the Wald Chi Square Test for significance was used to test the global hypothesis, the concordance statistic was used to evaluate predictive performance, the Hosmer and Lemeshow test was used to test for goodness of fit of the predictions based on observed and expected outcomes, and the likelihood ratio test was used to compare potential models within the same model structure (SAS Institute Inc. 2008). For the Rivers dataset, years associated with a significant red tide event (i.e. 2005-2007) were removed prior to analysis.

Logistic regression is an optimal tool for estimating the probability of occurrence when, at one end of some environmental gradient such as salinity the outcome (i.e. taxa presence) is very likely to occur and at the other end of the gradient, the outcome almost never occurs. This is illustrated in Figure 1 as predicted logit estimates (Figure 1a) and predicted probabilities of occurrence (Figure 1b). Notice that in this case a probability of 0.5 corresponds to the inflection point in the probability curve. Under these conditions, a predicted probability value of 0.5 is generally used as a cut point with which to classify a predicted probability as either a presence or absence. However, in many cases the prevalence of a taxon does not approach 100% at either end of the environmental gradient and therefore the predicted probabilities do not either. In these cases, classification success is affected by the relative proportions of presence and absences (Hosmer and Lemeshow 2000).

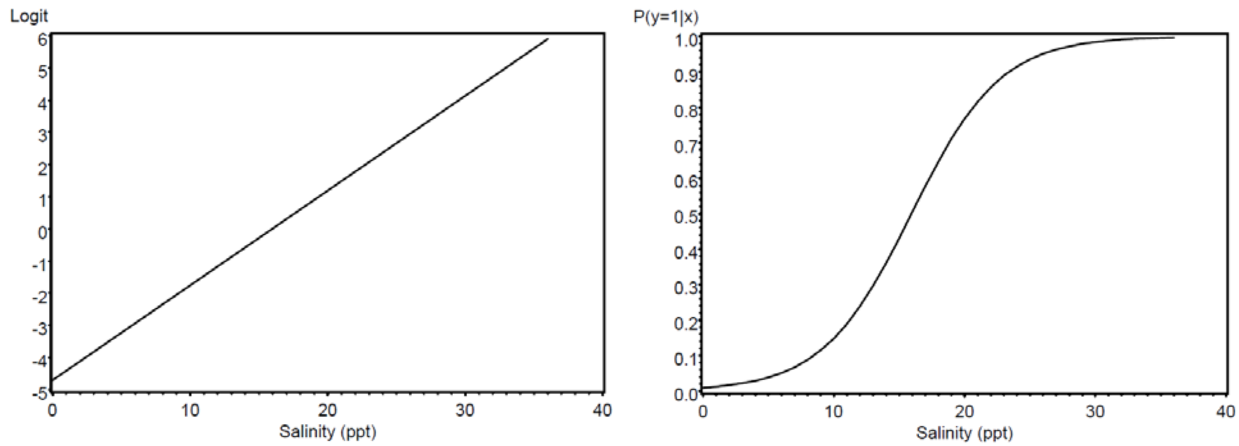

Figure 1. Hypothetical relationship between salinity and the log (odds) of occurrence (left) and the probability of occurrence (right).

When the prevalence proportion is substantially different than 0.5, it is possible that the probability values yielded by the logistic function cannot be considered to reflect actual environmental favorability. In this circumstance, more common taxa will have a higher probability of occurrence independent of actual environmental favorability for the species (Real et. al. 2006). Real et. al. (2006) proposed a modification of the output of the logistic regression equation to compensate for the differences from a prevalence of 0.5 by adjusting the intercept term by the log odds of the empirical occurrence of the taxa being modeled. That is:

$$\hat{y}' = \hat{y} - Ln\left[\frac{n_1}{n_0}\right] \qquad [3]$$

Where :

$n_1 = \#$ of presences

$n_0 = \#$ of absences

This becomes the logit of the favorability model described by Real et. al. (2006). Exponentiation of the logit of the favorability model in a fashion analogous to equation 3 yields *F*, the Environmental Favorability Function (EFF). The Environmental Favorability Function has been used extensively in conservation biogeography to evaluate the potential spatial distribution of species conservation areas (Real et al. 2006), compare distribution among species with different empirical prevalence and assess environmental factors determining favorability of particular habitat within conservation areas (Real et al. 2009; Acevedo et. al. 2010a; Acevedo et al. 2010b). This environmental favorability function was then used to describe habitat preferences when simulating the effects of differential habitat types of favorability of different and aggregates of different fish taxa modeled using the Rivers data in the context of developing tidal creek habitat restoration strategies.

Results:

A total of 9,972 seine collections were used to model habitat preferences of important estuarine dependent fish taxa in four tidal tributaries of Tampa Bay and 570 tidal creek samples were used for comparison to the Rivers data. The percentage of each habitat type sampled for these two studies is provided in Table 1. The distribution of samples among these categories was quite similar with nearly identical percentages collected adjacent to Mangrove habitats and similar percentages for other habitat categories with the exception of an apparent increase percentage of Structure and decreased percentage of the None category in the Rivers data.

Table 1 . Distribution of samples (percentages) among dominant shore type categories for Creeks and Rivers data.

Shore Group	Creeks (570)	Rivers (9,972)
Emergent	15%	21%
Grasses (Terrestrial)	8%	6%
Mangroves	35%	36%
None	18%	3%
Structure	13%	25%
Trees	10%	8%

The sampling frequency breakdown of specific recorded shore types within each category for the Rivers data is provided in Table 2 and for Creeks data in Table 3. Again, the relative proportions for the specific shore types within category were remarkably similar between these two data collection efforts with Juncus marsh occurring in approximately 15% of the samples and red mangrove shorelines accompanying approximately 25% of samples in both data collection efforts.

Table 2. Sampling frequency for shore types by shore group for Tampa Bay Rivers 21.3 meter seine data.

Shore Group	Shore Type	All N	All ColPctN
Emergent	Bulrush	12	0.12
	Cattails	362	3.63
	Juncus spp.	1568	15.74
	Marsh Grasses	17	0.17
	Spartina spp.	124	1.24
	Spatterdock (Nuphar spp.)	5	0.05
	Saw grass	4	0.04
Grasses	Arrowhead	11	0.11
	Aquatic Vegetation mixed	10	0.10
	Leather Fern	103	1.03
	Common reed	5	0.05
	Sedge	3	0.03
	Seagrapes	3	0.03
	Swamp lily	3	0.03
	Exposed SAV	4	0.04
	Terrestrial Grasses	126	1.26
	Terrestrial Vegetation	281	2.82
	Vines	19	0.19
	Algal mat (Wrack)	2	0.02
Mangroves	Black Mangrove	302	3.03
	Buttonwood	16	0.16
	Mangrove	82	0.82
	Overhanging shrubs	122	1.22
	Red Mangrove	2636	26.46
	White Mangrove	380	3.81
	Wax Myrtle	21	0.21
None	null	2	0.02
	None	303	3.04
Structure	Docks	9	0.09
	Dead oyster shells	1	0.01
	Man-made Structure	17	0.17
	Natural Wall	16	0.16
	Oysters	404	4.05
	Rocks	156	1.57
Structure	Rip Rap	797	8.00
	Seawall	1144	11.48
Trees	Australian Pines	11	0.11
	Brazilian Pepper	457	4.59
	Umbrella palm	5	0.05
	Hardwood Swamp	2	0.02
	Palmetto	67	0.67
	Palm Trees	48	0.48
	Cypress Trees	12	0.12
	Dead Trees	77	0.77
	Oak Trees	183	1.84
	Pine Trees	20	0.20
	Unidentified Trees	12	0.12

Table 3. Sampling frequency for shore types by shore group for southwest Florida tidal creeks 9.1 meter seine data.

		All	
		N	ColPctN
shore2	Shore Type		
Emergent	Bulrush	1	0.18
	Cattails	3	0.53
	Juncus spp.	76	13.33
	Marsh Grasses	2	0.35
	Spartina spp.	3	0.53
Grasses	Aquatic Vegetation mixed	1	0.18
	Alligator weed	1	0.18
	Hyacinth	1	0.18
	Leather Fern	34	5.96
	Panic grass	2	0.35
	Terrestrial Vegetation	6	1.05
	Vines	1	0.18
Mangroves	Black Mangrove	21	3.68
	Buttonwood	4	0.70
	Red Mangrove	156	27.37
	White Mangrove	19	3.33
None	None	102	17.89
Structure	Docks	1	0.18
	Man-made Structure	1	0.18
	Natural Wall	26	4.56
	Oysters	1	0.18
	Rocks	3	0.53
	Rip Rap	13	2.28
	Seawall	31	5.44
Trees	Brazilian Pepper	36	6.32
	Overhanging shrubs	9	1.58
	Palmetto	12	2.11
	Dead Trees	1	0.18
	Oak Trees	3	0.53

A screening level analysis was used to evaluate all taxa collected in the Rivers dataset where over 100 individuals had been captured over the nearly 10, 000 samples. This resulted in a subset of 70 taxa with a statistically significant (alpha=0.10) habitat effect (Appendix A). From this list, 8 estuarine dependent taxa of commercial or recreational value or their prey were selected to represent a group of estuarine dependent taxa termed "Transients". These taxa included Pinfish (*Lagodon rhomboides*), Pink Shrimp (*Farfantepenaeus duorarum),* Blue Crab (*Callinectes sapidus*), Red Drum (*Sciaenops ocellatus*), Common Snook (*Centropomus undecimalis*), Sheepshead (*Archosargus probatocephalus*), Irish Pompano (*Diapterus auratus*), and Gray Snapper (*Lutjanus griseus*). A second group of taxa representing "Tidal River Resident" included several species of killifishes including Sheepshead Minnow (*Cyprinodon variegatus*), Marsh Killifish (*Fundulus confluentus*), Gulf Killifish (*Fundulus grandis*), Longnose Killifish (*Fundulus similis*), Rainwater Killifish (*Lucania parva*), Goldspotted Killifish (*Floridichthys carpio*), and the Eastern Mosquito Fish (*Gambusia holbrooki*). The full model significance table for these taxa is listed in Table 4.

Table 4. Significance table for species of interest indicating statistical significance of parameters used in full main effects logistic regression model.

Fish Taxon		P value				
Scientific Name	Common Name	Season	Salinity	Quadratic Sailinty	Habitat Group	River
Anchoa hepsetus(T)	Striped Anchovy	<.0001	<.0001	<.0001	0.0009	<.0001
Archosargus probatocephalus (T)	Sheepshead	<.0001	0.0156	0.0815	<.0001	<.0001
Bairdiella chrysoura(T)	Silver Perch	<.0001	<.0001	<.0001	<.0001	<.0001
Callinectes sapidus(T)	Blue Crab	<.0001	<.0001	<.0001	<.0001	<.0001
Centropomus undecimalis(T)	Common Snook	0.0189	0.428	0.0002	<.0001	<.0001
Cynoscion arenarius(T)	Sand Seatrout	<.0001	<.0001	<.0001	<.0001	<.0001
Cynoscion nebulosus(T)	Spotted Seatrout	<.0001	<.0001	<.0001	<.0001	<.0001
Cyprinodon variegatus(R)	Sheepshead Minnow	0.0003	<.0001	<.0001	<.0001	<.0001
Farfantepenaeus duorarum(T)	Pink Shrimp	0.0109	<.0001	<.0001	<.0001	<.0001
Floridichthys carpio(R)	Goldspotted Killifish	<.0001	<.0001	<.0001	<.0001	<.0001
Fundulus grandis(R)	Gulf Killifish	<.0001	<.0001	<.0001	<.0001	<.0001
Fundulus seminolis(R)	Seminole Killifish	0.4405	<.0001	<.0001	<.0001	<.0001
Fundulus similis(R)	Longnose Killifish	0.7092	<.0001	<.0001	<.0001	<.0001
Gambusia holbrooki(R)	Eastern Mosquito Fish	<.0001	<.0001	<.0001	<.0001	<.0001
Lagodon rhomboides	Pinfish	<.0001	<.0001	0.2502	<.0001	<.0001
Lucania goodei(R)	Bluefin Killifish	0.3325	<.0001	<.0001	0.0026	0.2617
Lucania parva(R)	Rainwater Killifish	0.0018	<.0001	0.0024	<.0001	<.0001
Lutjanus griseus(T)	Gray Snapper	0.0527	0.274	0.0658	<.0001	<.0001
Orthopristis chrysoptera(T)	Pigfish	<.0001	<.0001	0.2474	0.0006	<.0001
Sciaenops ocellatus(T)	Red Drum	<.0001	<.0001	<.0001	<.0001	<.0001

*** T = Transient taxon: R = Resident Taxon**

The habitat category-specific effects for each species are provided in Table 5. The coefficients provided in the table represent an odds ratio relative to the overall average odds of occurrence. For example, the interpretation of the coefficient expressed for the Sheepshead, suggests that the odds of capturing a Sheepshead while seining against Structured habitats is 1.78 times that of the overall average while the odds for bare sand (None) and terrestrial grass (Grasses) habitats are less than the overall average (i.e. less than 1). Not all levels were significant and those non-significant levels are represented by empty cells in Table 5.

Table 5. Odds ratio estimates relative to the overall average odds of occurrence. Cells without coefficients are not statistically significantly different from the average odds of occurrence.

Scientific Name	Common Name	Emergent	Grasses	Mangroves	None	Structure	Trees
Anchoa hepsetus	Striped Anchovy		0.50	1.49			
Archosargus probatocephalus	Sheepshead	1.28	0.71		0.66	1.78	
Bairdiella chrysoura	Silver Perch	1.66		1.29			
Callinectes sapidus	Blue Crab	1.17	0.83	0.71	1.67	0.72	1.22
Centropomus undecimalis	Common Snook	1.61	0.52				
Cynoscion arenarius	Sand Seatrout	1.98	0.66	1.40	0.43		
Cynoscion nebulosus	Spotted Seatrout	1.56	0.74	1.40			
Cyprinodon variegatus	Sheepshead Minnow	1.70		0.62	1.47	0.50	
Farfantepenaeus duorarum	Pink Shrimp		0.65	1.37			
Floridichthys carpio	Goldspotted Killifish	0.76			2.37		0.75
Fundulus grandis	Gulf Killifish	1.46		0.71	1.76	0.65	
Fundulus seminolis	Seminole Killifish	0.74	2.67	0.47		0.61	1.66
Fundulus similis	Longnose Killifish		1.64	0.66	3.03	0.33	
Gambusia holbrooki	Eastern Mosquito Fish	0.83	2.25	0.47		0.70	1.80
Lagodon rhomboides	Pinfish	1.35	0.79	0.85	0.78	1.27	
Lucania goodei	Bluefin Killifish		1.92			0.54	1.64
Lucania parva	Rainwater Killifish	1.51		0.60		0.75	1.39
Lutjanus griseus	Gray Snapper	0.67	0.39	1.61		2.27	
Orthopristis chrysoptera	Pigfish					1.98	
Sciaenops ocellatus	Red Drum	1.95	0.72			0.65	

*** Coefficients greater than 1 indicate greater than average odds and coefficients less than 1 indicate reduced odds of occurrence relative to the overall average.**

Many of the Transient taxa had higher odds of occurrence in samples adjacent to Emergent shorelines. These taxa included Snook, Red Drum, Sand and Spotted Seatrout, Blue Crab, Silver Perch, and Sheepshead. Mangrove habitats were preferred by Gray (or Mangrove as they are also known) Snapper, Pink Shrimp, Sand and Spotted Seatrout, Silver Perch, and Striped Anchovy.

Another way to view the relative odds of occurrence is by creating an odds ratio plot. An example for Common Snook is provided in Figure 2. All full model contrasts are provided in this figure and the red line indicates the overall average for each effect (i.e. odds of 1: even odds). For the Habitat category, the odds of capturing snook adjacent to emergent vegetation (Emergent) were significantly greater than average while the odds near terrestrial grasses were significantly less than average. All other categories were not different from the average expectation s indicated by the confidence intervals including 1.

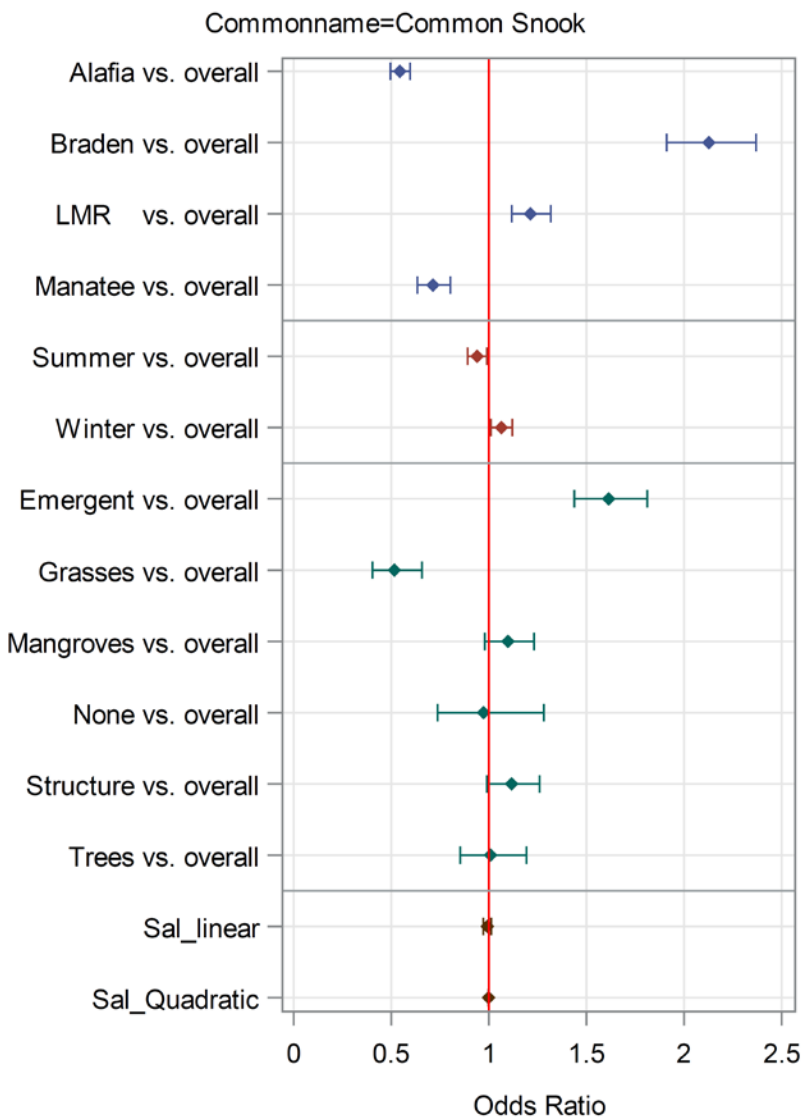

Figure 2. Odds ratio plot for coefficients associated with full model logistic regression using effect parameterization and contrast statements to compare levels to overall average.

For continuous variables such as salinity, the odds ratio is expressed as the change in odds for each unit change in the continuous variable. In the Case of Snook, the linear component of salinity was not significant indicating that salinity did not significantly affect the probability of occurrence of snook in these systems once other factors were considered. Snook are widely known as a euryhaline species with a life cycle that can include overwintering in freshwater portions of rivers, and spawning in coastal passes. These plots are available for all taxa listed in Table 5 in Appendix B. The parameter estimates table output for Common Snook is provided in Table 6. These parameter estimate are relative to the reference categories for categorical variables. So, for example, the estimate of -0.0622 for summer is the log odds of occurrence relative to the reference level "Winter". Exponentiating the estimate yields the Odds Ratio estimate of 0.939. indicating that the odds of capturing snook during Summer are less than the odds of capturing Snook in the Winter months with all other variables being equal. Because the "effects" parameterization was used in the model development, the average log odds of occurrence for any salinity in the observed domain can be calculated as: $\text{Logit} = -1.0708-0.00814*\text{sal}-0.00146*\text{Sal}^2$.

Table 6. Parameter estimates table for logistic regression on Common Snook in Tampa Bay rivers.

Analysis of Penalized Maximum Likelihood Estimates						
Parameter		**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	**Pr > ChiSq**
Intercept		1	-1.0708	0.0621	296.8760	<.0001
season	**Summer**	1	-0.0622	0.0265	5.5148	0.0189
Salinity		1	-0.00814	0.0103	0.6283	0.4280
sal2		1	-0.00146	0.000386	14.3693	0.0002
shore2	**Emergent**	1	0.4789	0.0591	65.6749	<.0001
shore2	**Grasses**	1	-0.6629	0.1243	28.4565	<.0001
shore2	**Mangroves**	1	0.0934	0.0586	2.5392	0.1111
shore2	**None**	1	-0.0278	0.1411	0.0390	0.8435
shore2	**Structure**	1	0.1101	0.0616	3.1946	0.0739
River	**Alafia**	1	-0.6099	0.0474	165.2547	<.0001
River	**Braden**	1	0.7551	0.0549	189.1293	<.0001
River	**LMR**	1	0.1930	0.0420	21.0948	<.0001

While the linear component of salinity was not significant in the model, that component was retained because the quadratic component was significant in this case. Individual contrasts can be calculated for any level of the categorical variables. For example, to calculate the odds of occurrence for Snook over Emergent vegetation relative to the overall average would be exp(0.4789) = 1.61. To compare Emergent relative to the "Grasses" level, the difference between the parameter estimates is calculated and then exponentiated. That is: exp(0.4789-(-0.6629)) = 3.132. This infers that one is 3.132 times as likely to capture Snook adjacent to emergent vegetation shorelines compared to shorelines with terrestrial grasses. It should be noted that the odds can increase dramatically even if the overall probability of capture remains low; however, the objective of the modeling effort was to identify "favorable" habitat defined as being higher than its overall average probability of occurrence. These results have important implication with respect to identifying restoration opportunities in tidal tributaries. Importantly, In this case if shoreline habitats composed of those riparian habitats grouped in the Grasses level were replaced by Emergent vegetation, the expectation would be that habitat favorability would increase significantly for Snook, all other variables being equal.

To illustrate the effects of the different habitat groups on habitat favorability of tidal tributary fishes, a simulated tributary was constructed using a 60 grid cell model with the 6 habitat group types assigned to 10 consecutive cells each (Figure 3). Salinity was assigned to each cell in a linearly decreasing fashion to simulate the salinity distribution in a typical tidal tributary in southwest Florida (blue number at bottom of each panel plot). Three different simulations were conducted over which the habitat categories were manipulated. For example, the habitat categories in the top panel served as the baseline, representing the typical (though artificially monotonic) gradient of shoreline habitats in tidal tributaries with mangrove fringe near the mouth, transitioning to emergent vegetation and then to the trees category that occur principally in low salinity oligohaline habitats. The Structure, None, and Grasses categories can be found throughout the tributary and tend to be distributed based on the level of development of the particular tributary under study. For the second simulation (Sim2), the Grasses category was replaced by the Emergent category to simulate a shift from a developed shoreline to one where restoration may occur. In the third simulation (Sim3), the Structure category was replaced by the None category to estimate the change on favorability associated with removing structure such as seawalls, Rip Rap, or docks.   For this simulation, the salinity values were held constant among the three simulations.

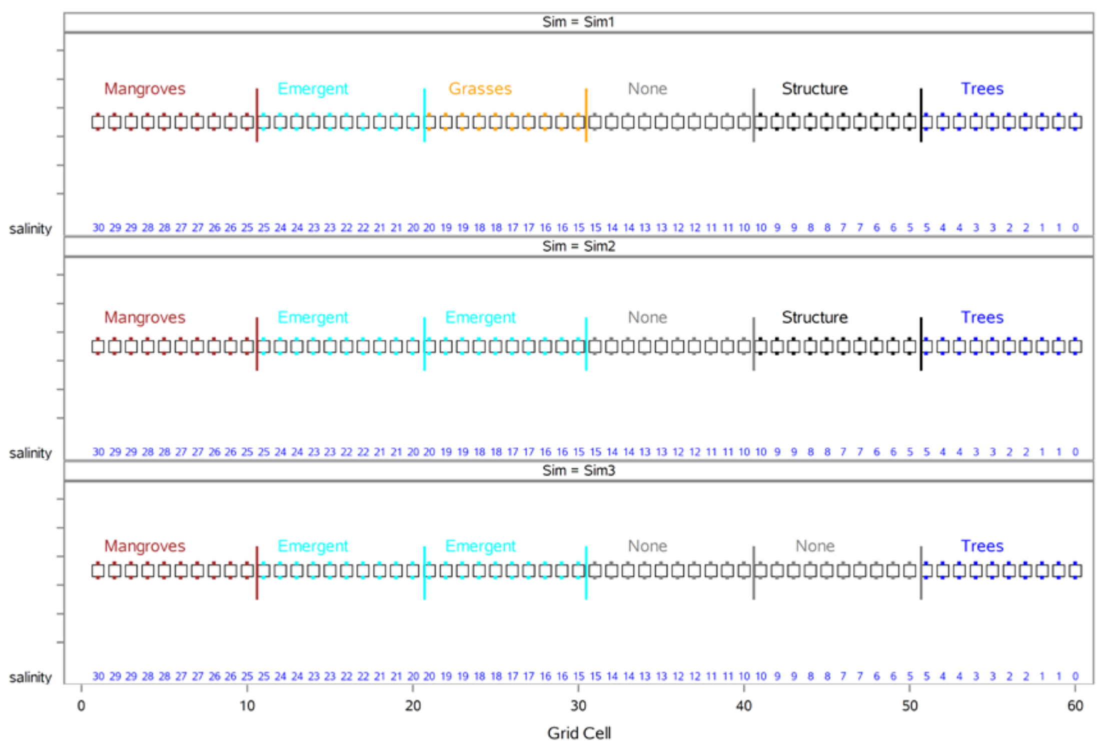

Figure 3. Grid cell structure for a simulation model used to predict environmental favorability of fish taxa found in southwest Florida tributaries as a function of habitat and salinity.

For each taxa, the full model logistic regression coefficients were applied to the simulation dataset and the EFF was calculated to illustrate the potential effects of habitat restoration efforts on habitat favorability for the taxon of interest. For example, the contrast plot from the full model regression for Red Drum is provided in Figure 4 below. The Emergent category was significantly favored relative to the overall average while the Grasses and Structure categories had significantly lower odds of occurrence relative to the overall average. This model was then applied to predict habitat favorability for Red drum under each simulated condition (Figure 5).

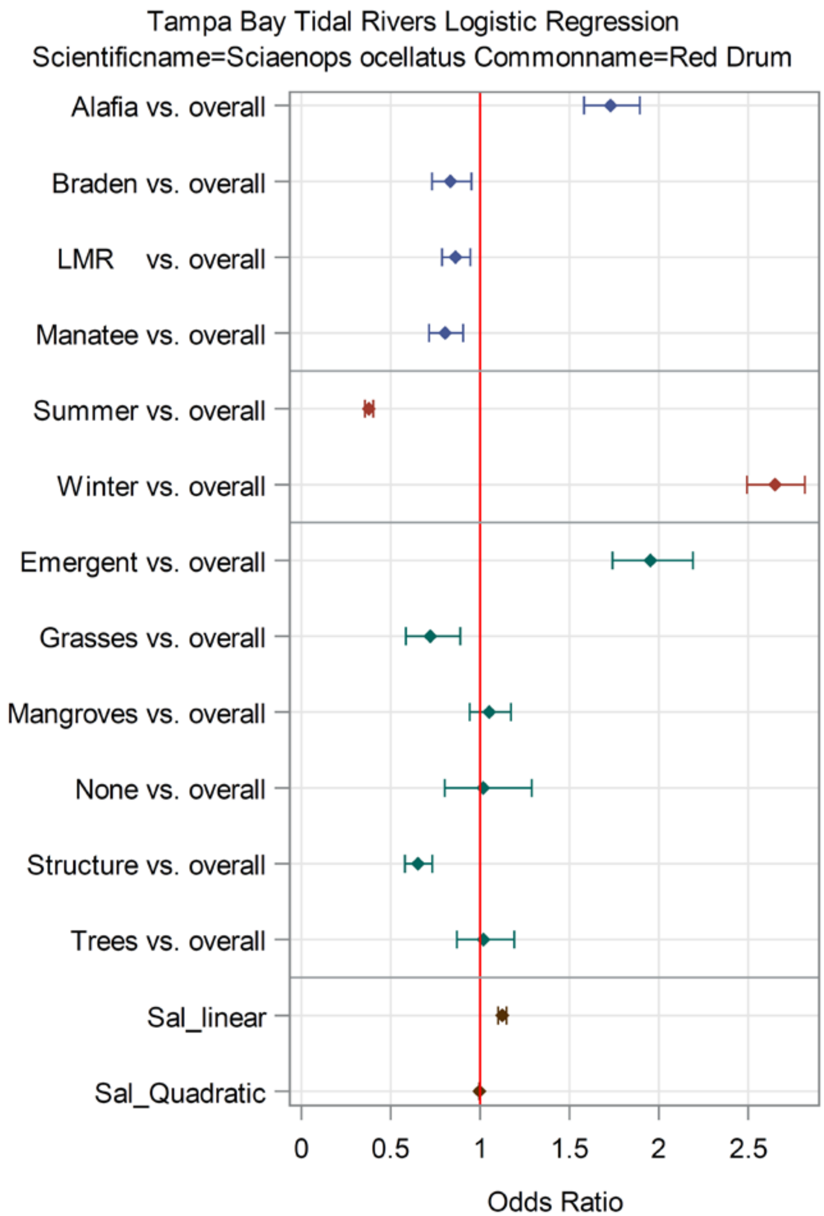

Figure 4.

The green cells in Figure 5 represent conditions favorable for occurrence of Red Drum. For Sim1, only the Emergent and None categories were favorable for occurrence of Red Drum. Changing the Grasses category to Emergent (Sim2: middle plot in Figure 5), resulted in those cells also becoming favorable habitat for Red Drum, increasing the amount of favorable habitat by 50 percent. Changing the Structure category to None (Sim3: bottom plot in Figure 5) further increased the number of favorable cells but only for those cells where salinity was higher than 7 ppt (red arrow in bottom panel). This is due to the quadratic salinity effect on Red Drum occurrence (Figure 6).

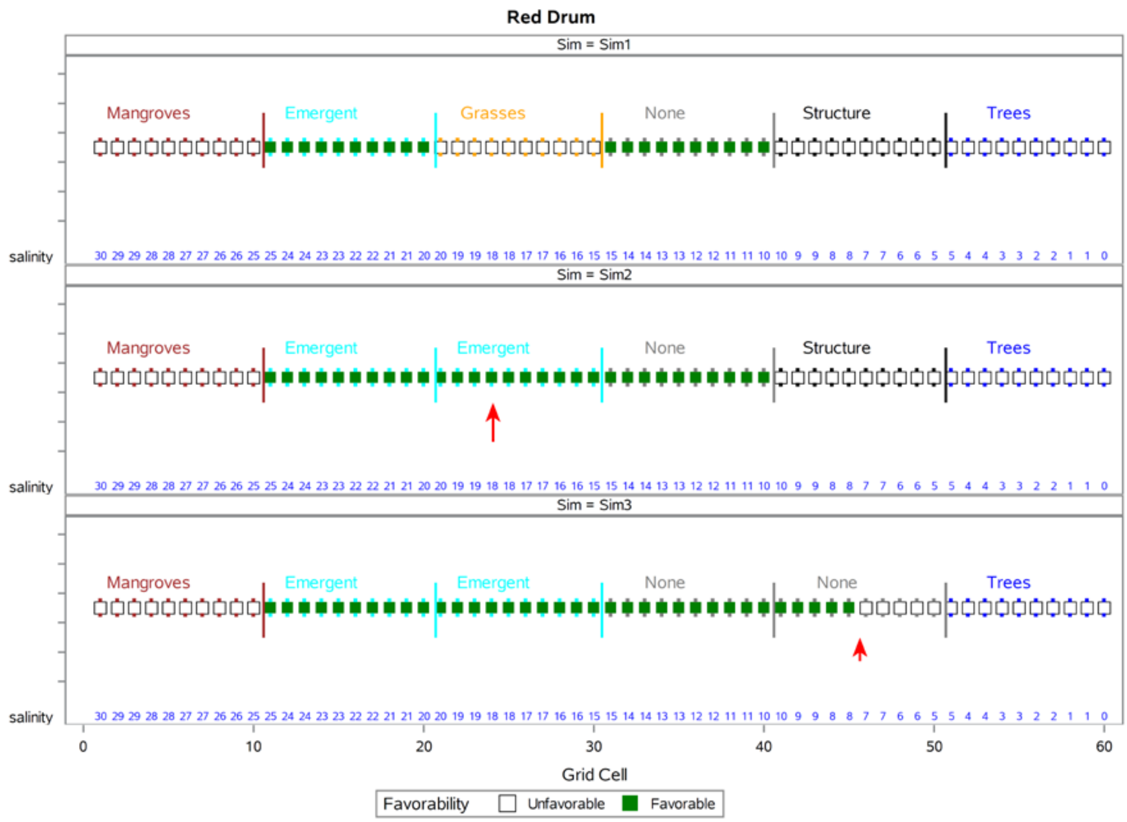

Figure 5. Results of application of Red Drum EFF model to simulation dataset.

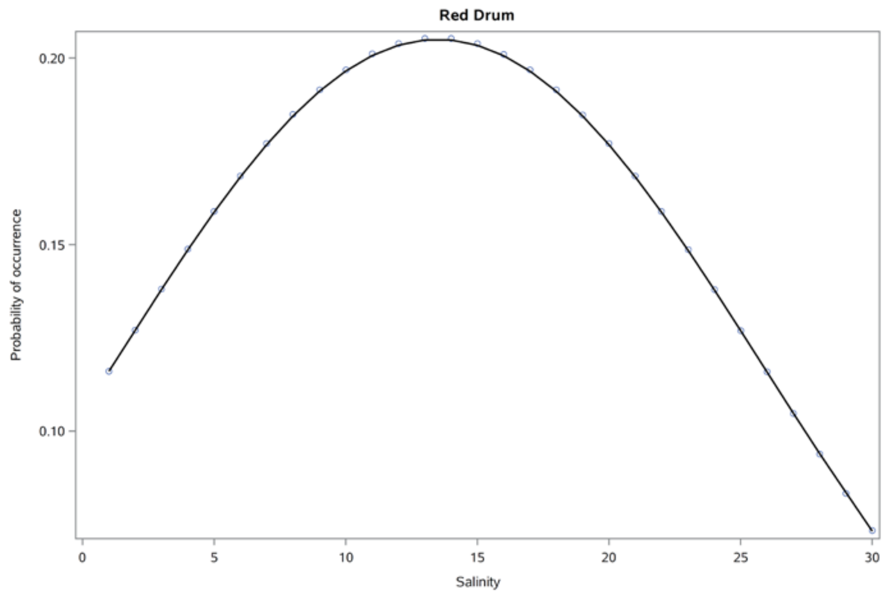

Figure 6. Probability of occurrence of Red Drum as a function of salinity in southwest Florida tidal tributaries.

To evaluate the potential applicability of the models to tidal creek restoration efforts, the data collected during the tidal creek study were used to predict the probability of occurrence of Red Drum, Snook, and Sheepshead in tidal creeks and then evaluated against the actual catch data. That is, the salinity, shore category and season were used to predict the probability of occurrence for each creek sample. To evaluate the goodness of fit of the model to the empirical data, the predicted probability of occurrence for each of the 570 samples were divided into deciles and the mean probability of occurrence was calculated for the predicted probabilities and compared to the observed proportion of occurrences in that decile. Hosmer and Lemeshow (2000) suggested that the relationship between the expected and observed values in each decile is a good indication of how well the model fits the empirical data. An example of this comparison for Red Drum is presented in Figure 7 where the x axis is order by increasing decile (and correspondingly, by increasing probability of occurrence). The expected proportion of occurrence is displayed as the solid blue bars while the observed proportion across all 16 creeks is displayed as the green hatched bars. The expectation of these plots is that the observed proportions match those predicted by the model (i.e. the expected proportions). As can be seen in the plot, the observed proportions of Red Drum are lower than expected based on the Rivers model. However, the observed proportions do increase with increasing expected proportions indicating that a higher proportion of samples had positive occurrences when the model predictions suggested a higher probability of capture. The Sheepshead model predictions fit more closely with the observed data (Figure 8) though in the 7th, 8th and 10 decile the observed proportions were again less than expected. For Snook, the opposite trend was present where the observed occurrence of Snook was higher than expected based on the Rivers model for all deciles (Figure 9).

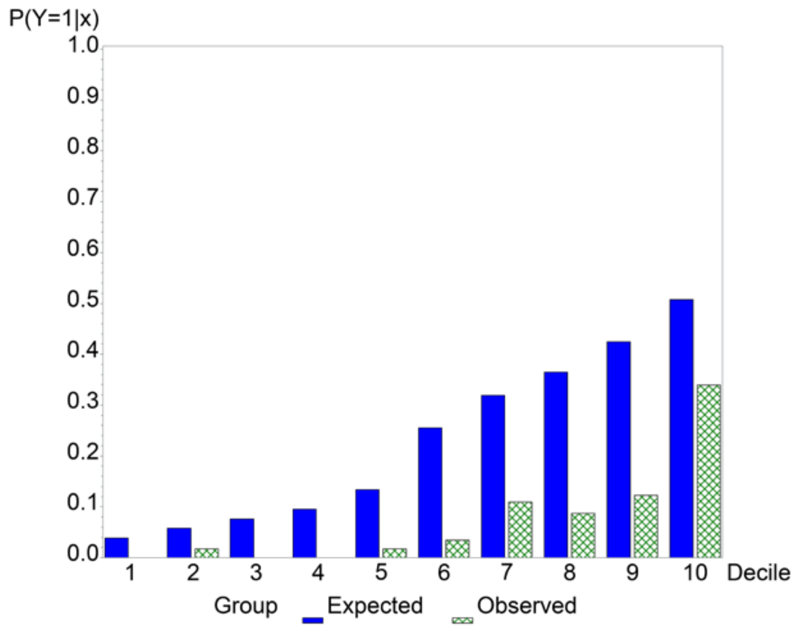

Figure 7. Observed and expected probability of occurrence of Red Drum using Rivers model to predict occurrences in southwest Florida tidal creeks.

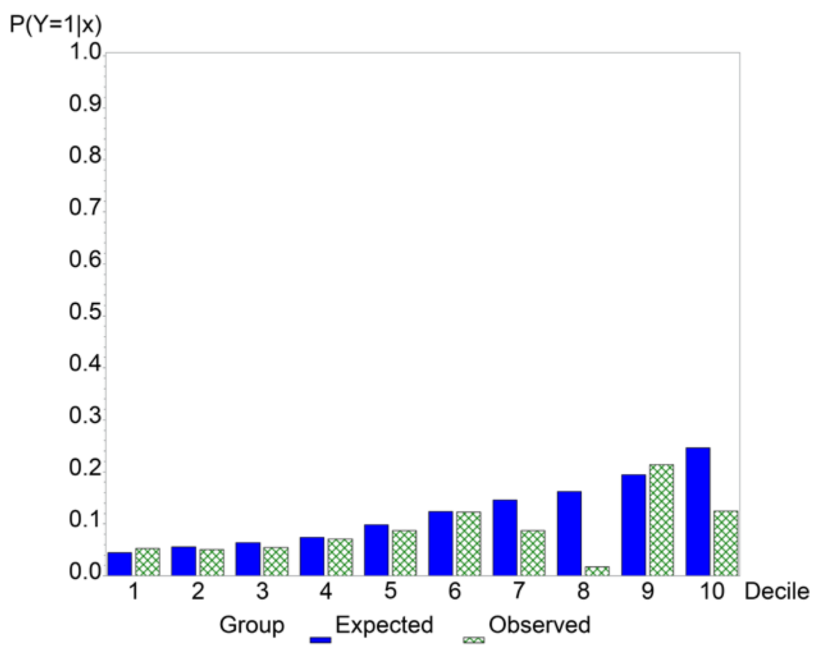

Figure 8. Observed and expected probability of occurrence of Sheepshead using Rivers model to predict occurrences in southwest Florida tidal creeks.

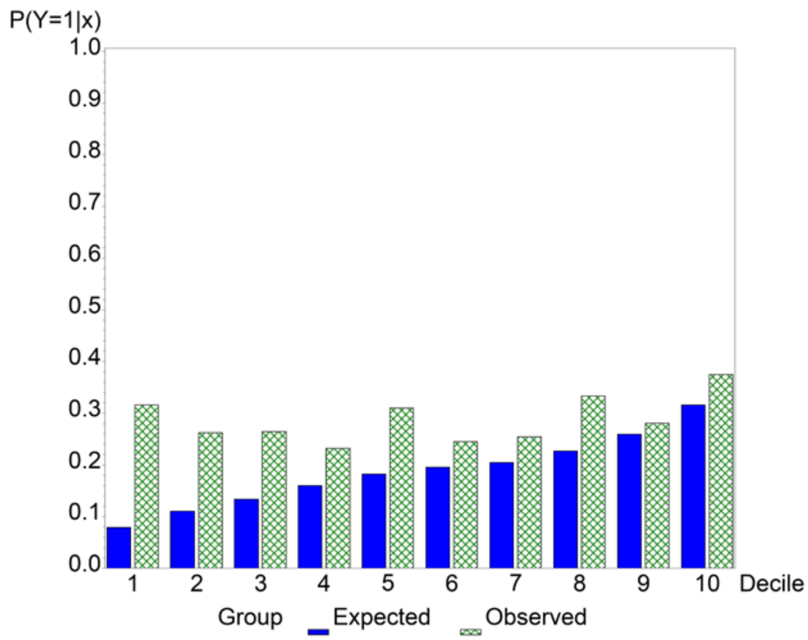

Figure 9. Observed and expected probability of occurrence of Common Snook using Rivers model to predict occurrences in southwest Florida tidal creeks.

Discussion:

This study has demonstrated that several estuarine dependent fish taxa utilizing Tampa Bay tidal tributaries have preferences for certain shoreline types. The shoreline category that included Juncus marsh was disproportionately favored by a number of estuarine dependent taxa including Red Drum and Common Snook, two prized gamefish species in Tampa Bay. This outcome suggests that juncus marsh and other emergent vegetation types are important habitats for juvenile estuarine dependent taxa and their prey and supports restoration strategies to convert altered shorelines such as those with terrestrial grasses to juncus marsh to improve habitat quality for Common Snook and Red Drum. Killifish taxa were included to represent more resident taxa that are typically found throughout the year and several taxa in the resident group were found to be less prevalent in samples associated with mangroves and structure. While it is impossible to rule out differences in catch efficiencies among these shoreline habitats types, the FIM program goes to great length to restrict sampling along shorelines that are inundated beyond 0.5 meters to limit the potential for escapement in these conditions. Catchability is assumed to be constant across habitat types and taxa.

The application of the logistic regression models to predict species occurrence in tidal creeks had mixed results. The models generally reflected the same tendencies for observed probability of occurrence to increase with predicted probability of occurrence but the relationships generally reflected the fact that there is limited data collected from tidal creeks from which to validate these models. Application of the models suggested that the probability of capturing Snook in tidal creeks was higher across all deciles compared to the larger tidal tributaries. Few Red Drum were captured overall in the tidal creek study compared to the larger Tampa Bay rivers but there was a tendency for observed probabilities to increase in the higher deciles of predicted probabilities. The Sheepshead model predictions were most closely aligned with observed predictions despite that not all deciles corresponded exactly.

Currently the logistic regression models were run as full models meaning that the term in the regression was kept in some cases even though it was not statistically significant. While all models presented were statistically significant, it is possible that the predictive capacity of these models could be improved on a species specific basis by including interaction terms, limiting the temporal domain of the Rivers models to the period of Creks data collection, or limiting the geographic scope to compare geographically like systems. However, these adjustments may also limit the generalizability of these models to larger areas which was the goal of the study. The coefficients represent the best unbiased estimates of changes in probability of occurrence associated with both continuous and discrete habitat attributes and the EFF adjustment allowed for habitat favorability to be compared across multiple species. More fish data collected in southwest Florida tidal creeks would enhance population estimates for those creeks and may eventually enable creek specific models to be developed. Irrespective, the current models represent the best available information from which to inform habitat restoration efforts that increase habitat favorability for estuarine dependent fish taxa and their prey in southwest Florida tidal tributaries.

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Appendix 1.

Scientific Name	Common Name	Scientific Name	Common Name
Achirus lineatus	Lined Sole	*Lepomis auritus*	Redbreast Sunfish
Adinia xenica	Diamond Killifish	*Lepomis macrochirus*	Bluegill
Anchoa hepsetus	Striped Anchovy	*Lepomis microlophus*	Redear Sunfish
Anchoa mitchilli	Bay Anchovy	*Lepomis punctatus*	Spotted Sunfish
Archosargus probatocephalus	Sheepshead	*Lepomis spp.*	Sunfishes
Bairdiella chrysoura	Silver Perch	*Lucania goodei*	Bluefin Killifish
Bathygobius soporator	Frillfin Goby	*Lucania parva*	Rainwater Killifish
Brevoortia spp.	Menhadens	*Lutjanus griseus*	Gray Snapper
Callinectes sapidus	Blue Crab	*Membras martinica*	Rough Silverside
Centropomus undecimalis	Common Snook	*Menidia spp.*	Menidia Silversides
Chasmodes saburrae	Florida Blenny	*Menticirrhus americanus*	Southern Kingfish
Cynoscion arenarius	Sand Seatrout	*Microgobius gulosus*	Clown Goby
Cynoscion nebulosus	Spotted Seatrout	*Micropterus salmoides*	Largemouth Bass
Cyprinodon variegatus	Sheepshead Minnow	*Mugil cephalus*	Striped Mullet
Elops saurus	Ladyfish	*Mugil curema*	White Mullet
Eucinostomus gula	Silver Jenny	*Mugil trichodon*	Fantail Mullet
Eucinostomus harengulus	Tidewater Mojarra	*Notropis petersoni*	Coastal Shiner
Eucinostomus spp.	Eucinostomus	*Oligoplites saurus*	Leatherjacket
Eugerres plumieri	Striped Mojarra	*Opsanus beta*	Gulf Toadfish
Farfantepenaeus duorarum	Pink Shrimp	*Oreochromis/Sarotherod on spp.*	Tilapias
Floridichthys carpio	Goldspotted Killifish	*Orthopristis chrysoptera*	Pigfish
Fundulus confluentus	Marsh Killifish	*Palaemonetes intermedius*	Brackish Grass Shrimp
Fundulus grandis	Gulf Killifish	*Palaemonetes pugio*	Daggerblade Grass Shrimp
Fundulus seminolis	Seminole Killifish	*Paralichthys albigutta*	Gulf Flounder
Fundulus similis	Longnose Killifish	*Poecilia latipinna*	Sailfin Molly
Gambusia holbrooki	Eastern Mosquito Fish	*Pogonias cromis*	Black Drum
Gobiesox strumosus	Skilletfish	*Sciaenops ocellatus*	Red Drum
Gobiosoma bosc	Naked Goby	*Strongylura marina*	Atlantic Needlefish
Gobiosoma robustum	Code Goby	*Strongylura notata*	Redfin Needlefish
Gobiosoma spp.	Gobiosoma Gobies	*Strongylura spp.*	Needlefishes
Heterandria formosa	Least Killifish	*Strongylura timucu*	Timucu
Labidesthes sicculus	Brook Silverside	*Syngnathus louisianae*	Chain Pipefish
Lagodon rhomboides	Pinfish	*Syngnathus scovelli*	Gulf Pipefish
Leiostomus xanthurus	Spot	*Synodus foetens*	Inshore Lizardfish
		Trinectes maculatus	Hogchoker