

# An Examination of Fisheries and Water Level Impact from Diversion Models

Dr. Pat Fitzpatrick

Weather CSI

- Diversion model data (netcdf format on model grid) provided by CPRA's Natalie Peyronnin
- Data processing assistance from Yee Lau
- Motivated by May 15 invited presentation to CPRA titled "Concerns About State Master Plan"
  - i. One concern – "impact on fisheries is unclear"
  - ii. Habitat Suitability indexes in datasets provide some measure of expected changes to fishery production
  - iii. Generally, this dataset has not been shown to public in detail
- Kerry St. Pé has also requested some feedback on inundation concerns from diversions during weather events

*Any opinions expressed are strictly my own.*

# Outline of talk

- Speculation on whether diversion outflow can be impeded during wind fetch events and low pressure system, causing inland flooding (brief)
- Background on habitat suitability indexes
- Examples of CPRA simulations of Mid-Barataria (Myrtle Grove) and Upper Breton (Braithwaite) diversions from 2010-2060
- Time series of habitat suitability indexes for speckled trout, oysters, and shrimp
- Results and suggestions for future study

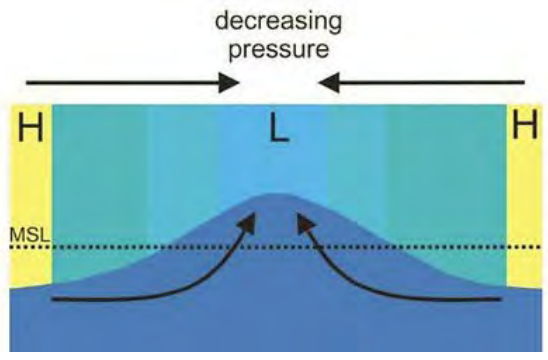
Inundation impacts from diversion activity during weather events

Note: diversions will not be run during a hurricane impact

We are addressing wind fetch situations and weaker low pressure systems, which can still cause water levels 2-3 ft above normal. The physics is the same as that of the hurricane storm surge.

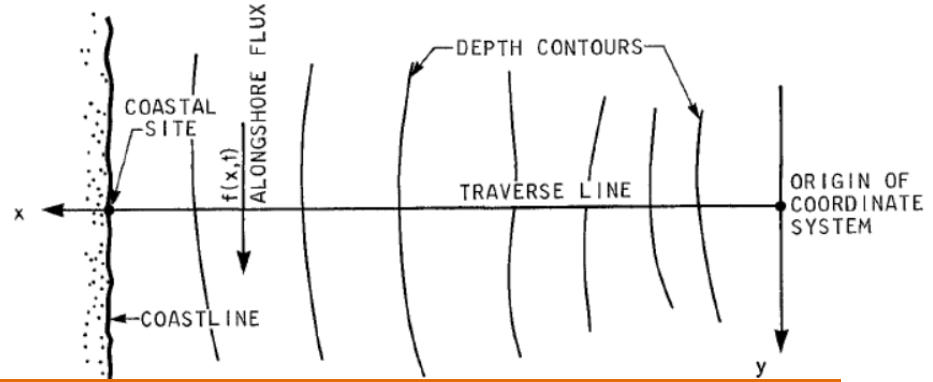
# Pressure effect

(peaks at landfall)



# Surge forerunner

(peaks before landfall, still important at landfall)



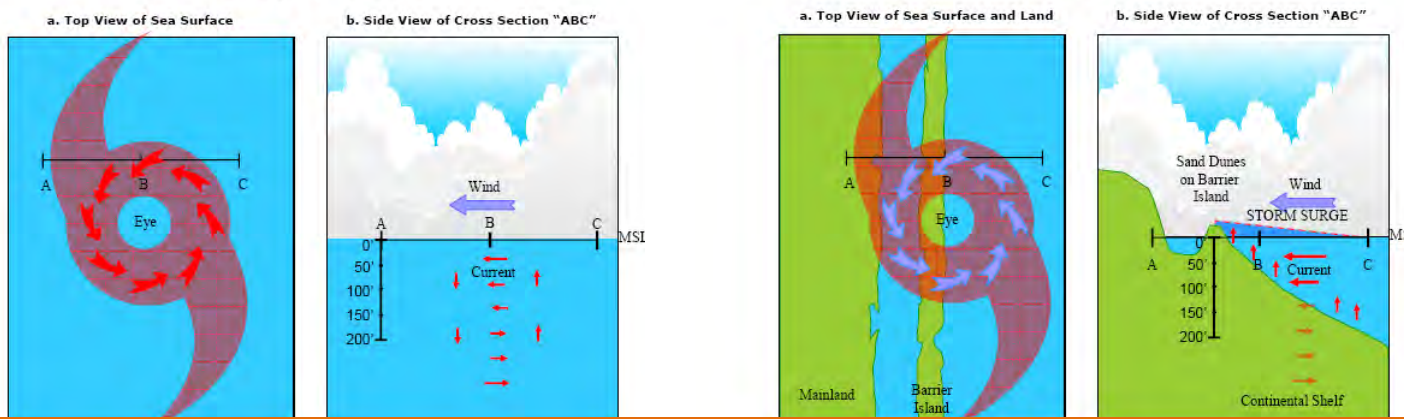
Ocean tilts toward coast to balance wind earth rotation as alongshore current forms while hurricane is offshore

## Deep Water

## Landfall

# Wind effect

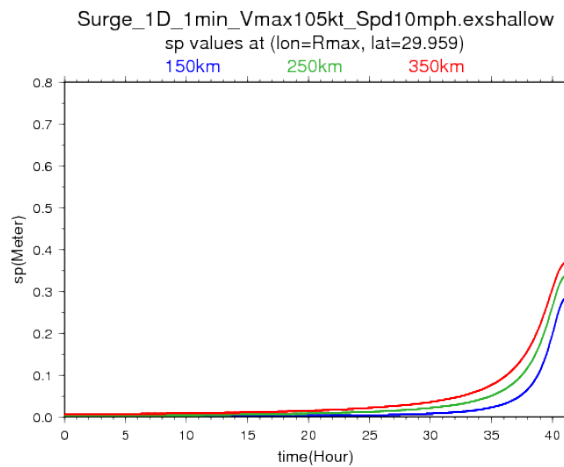
(peaks at landfall)



Ocean circulation disrupted by ocean floor, boundaries  
 Southward extension of LA Delta and shallow continental shelf results in high surge potential

# Pressure effect

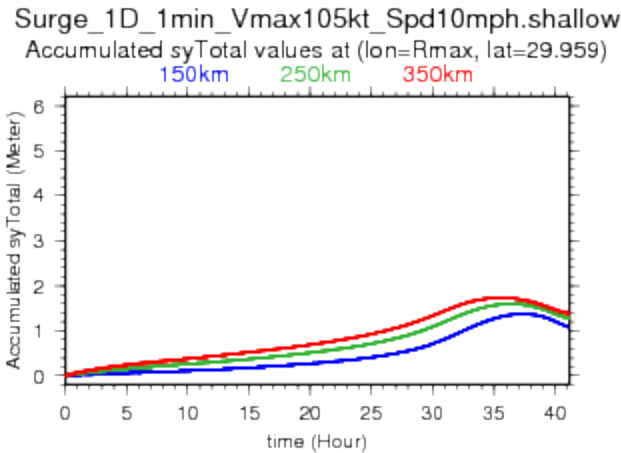
(peaks at landfall)



Time series example for Cat 3 in shallow bathymetry for small, average, and large hurricane moving 10 mph

# Surge forerunner

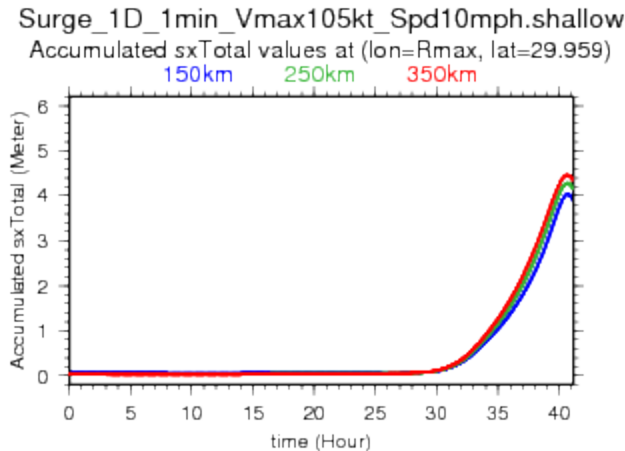
(peaks before landfall)



Surge on coastline

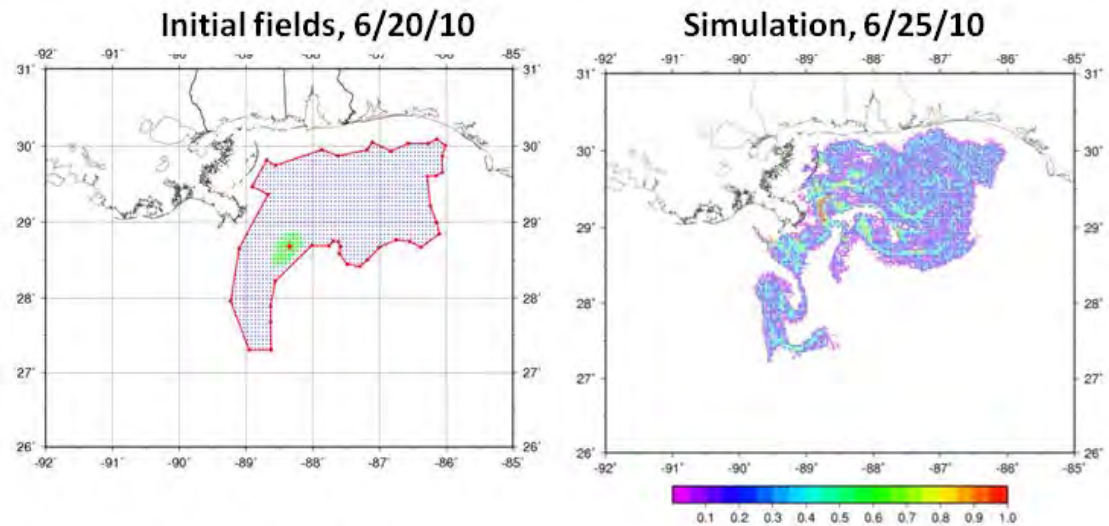
# Wind effect

(peaks at landfall)

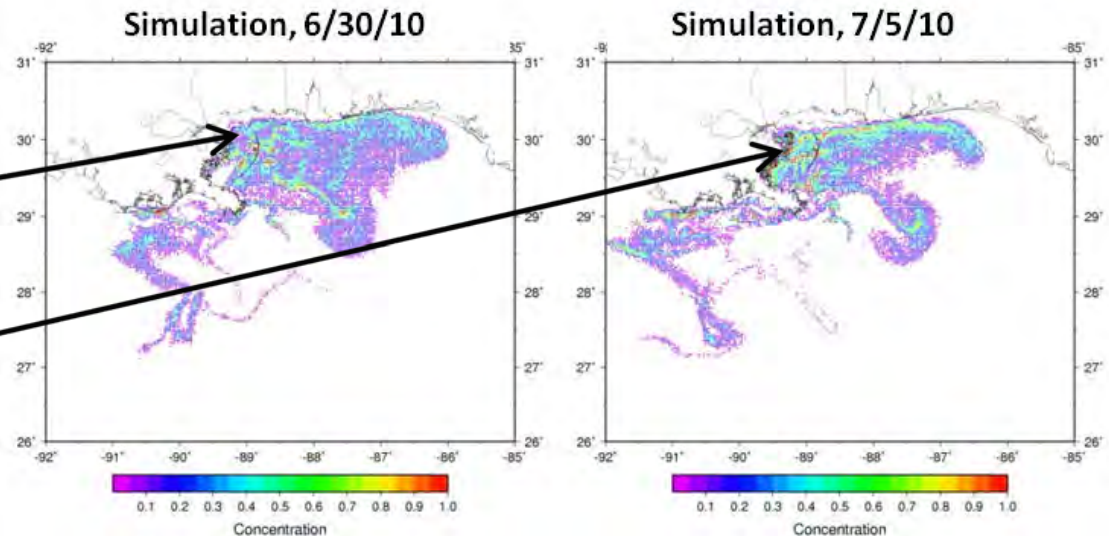


# Example: the influence of two cyclones on the Deepwater Horizon oil spill

Oil spill simulation from  
6/20/10-7/10/10  
using AMSEAS NCOM data

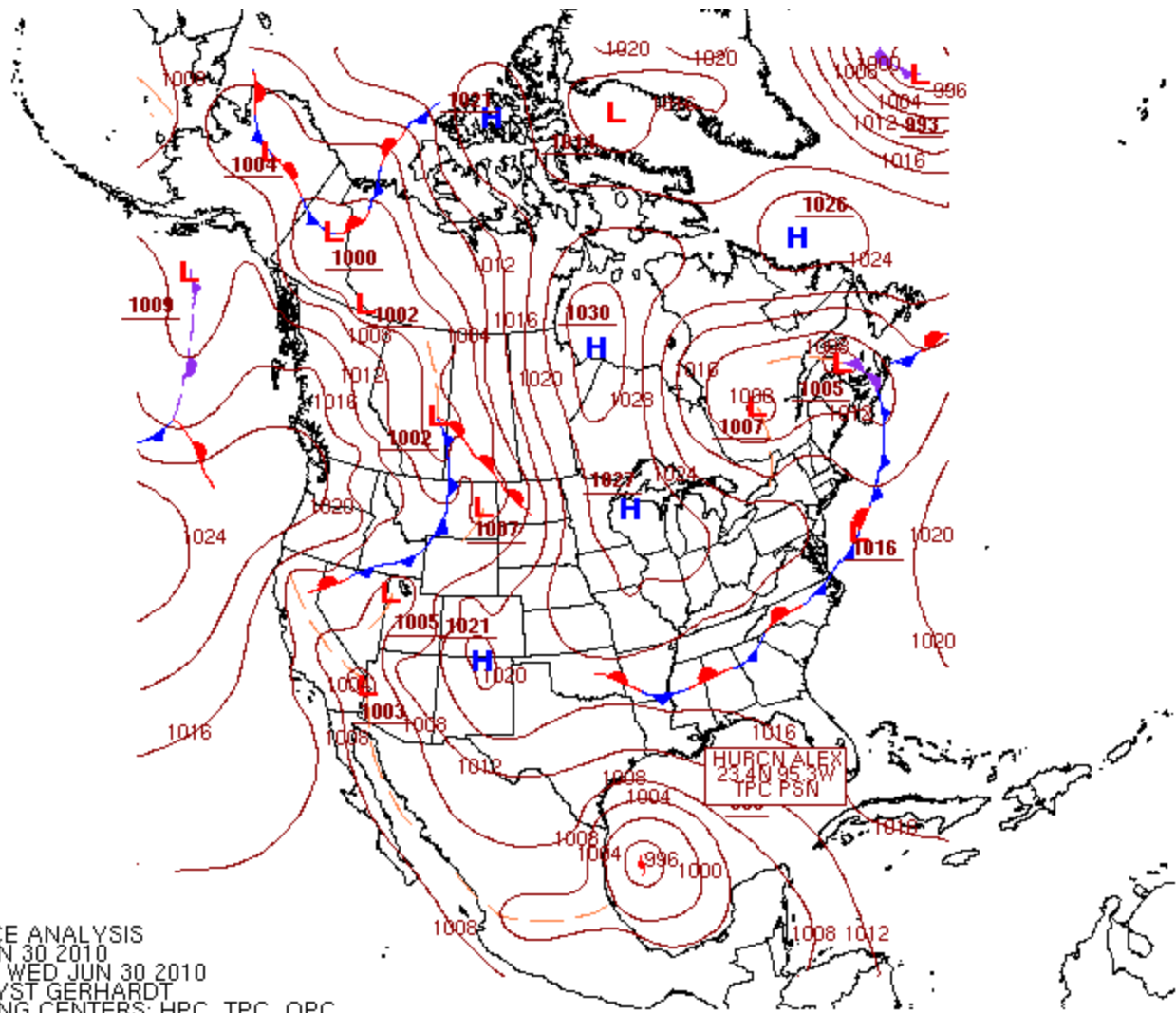


Note inshore  
movement of oil  
starting late June



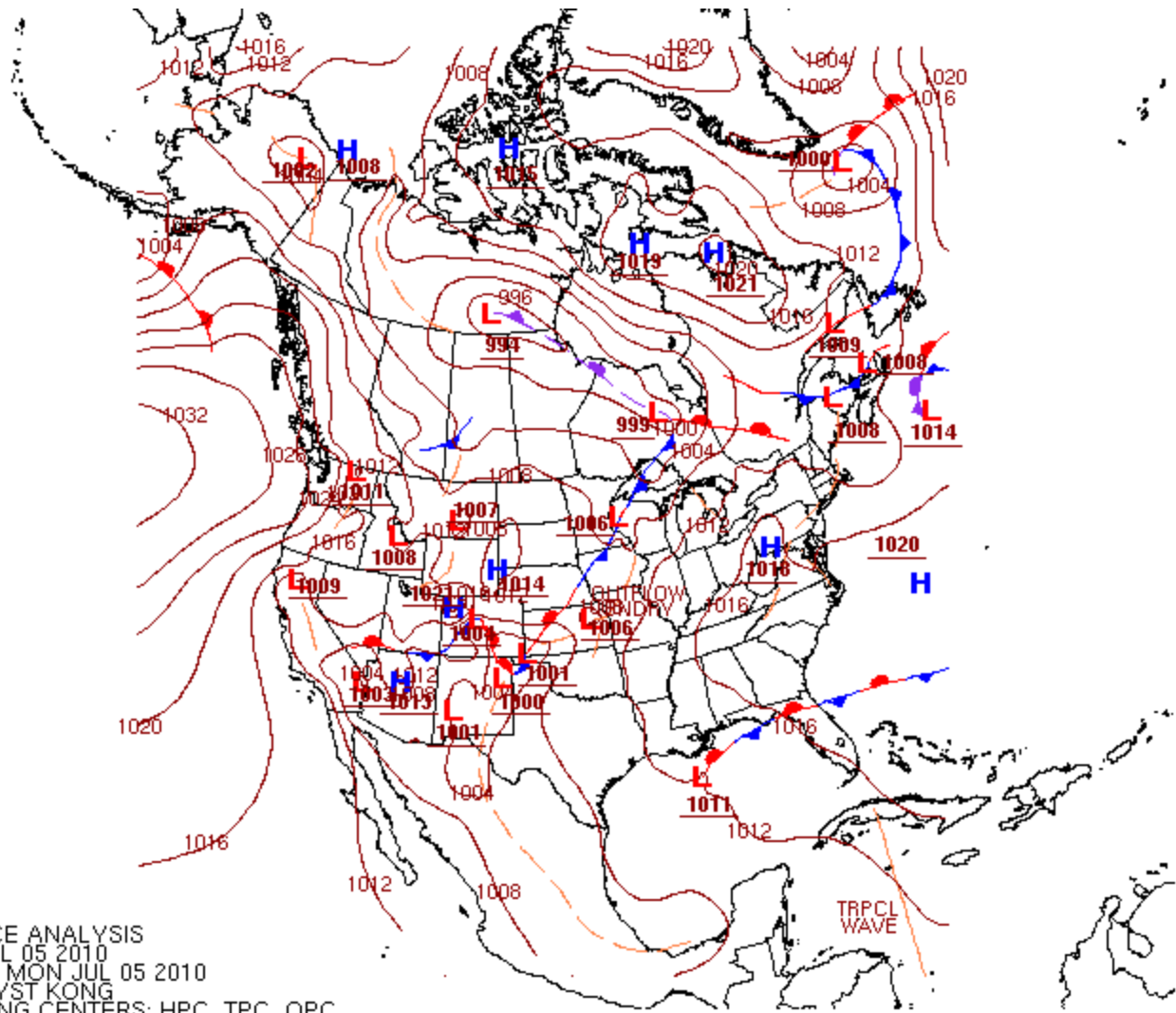
# What caused oil incursion into Mississippi Sound, Lake Borgne, and Lake Pontchartrain?

- Two cyclones (one is fringe effects of a Mexican hurricane)
- Mini-storm surge events occurred

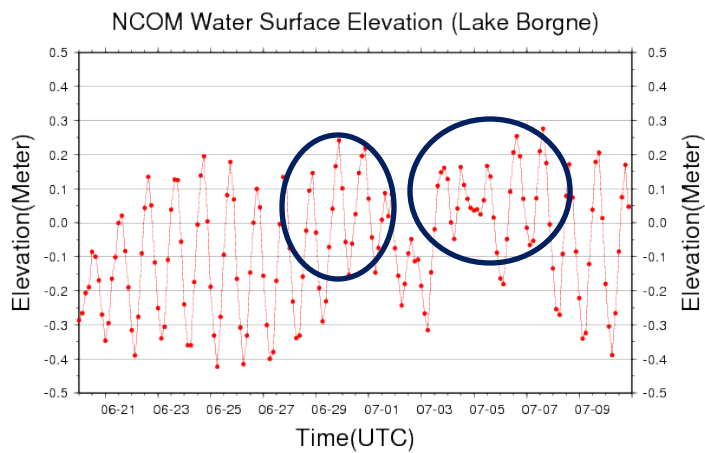
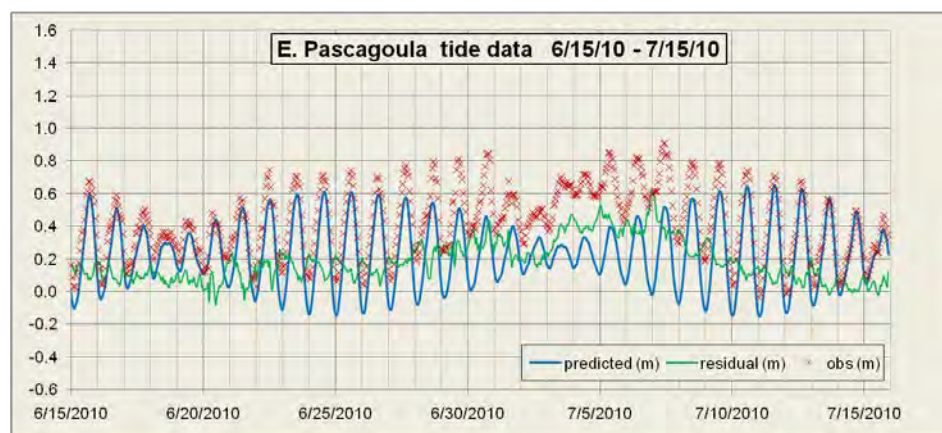
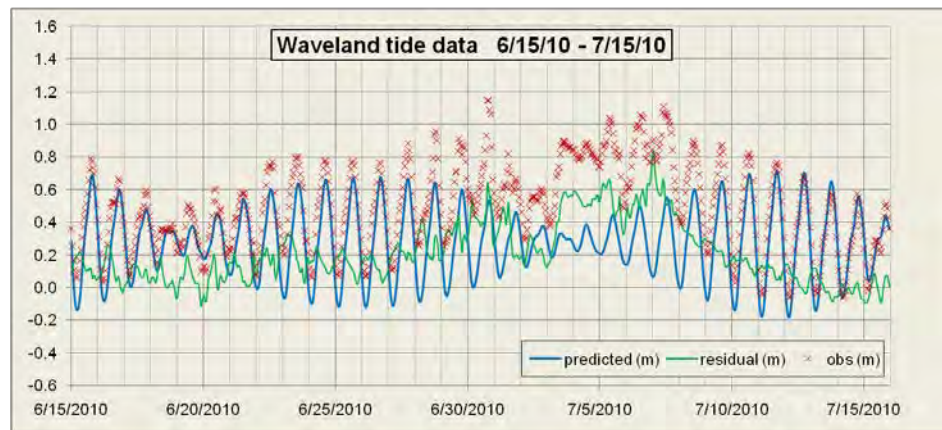
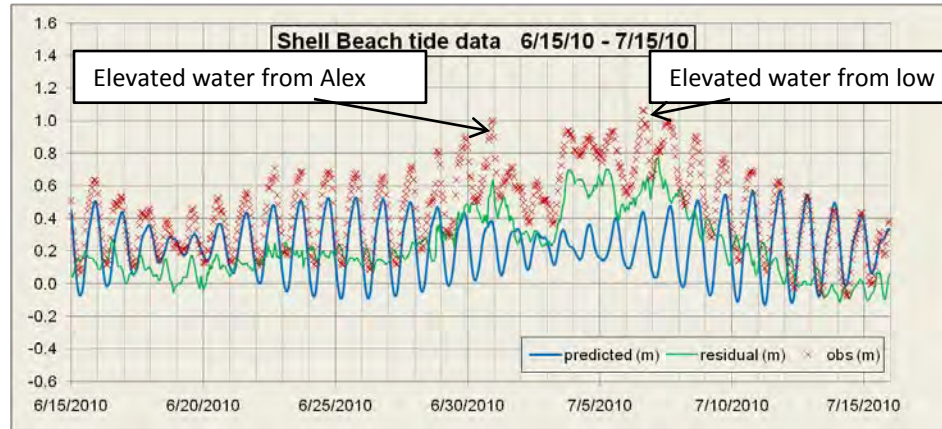
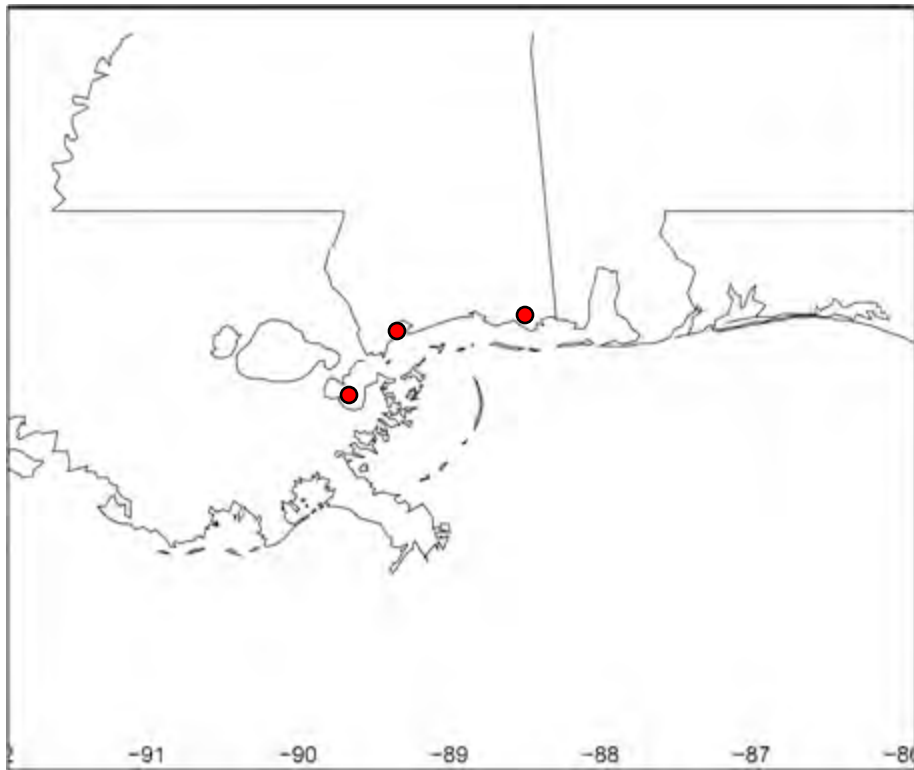


1200Z SURFACE ANALYSIS  
 DATE: WED JUN 30 2010  
 ISSUED: 1335Z WED JUN 30 2010  
 BY HPC ANALYST GERHARDT  
 COLLABORATING CENTERS: HPC, TPC, OPC

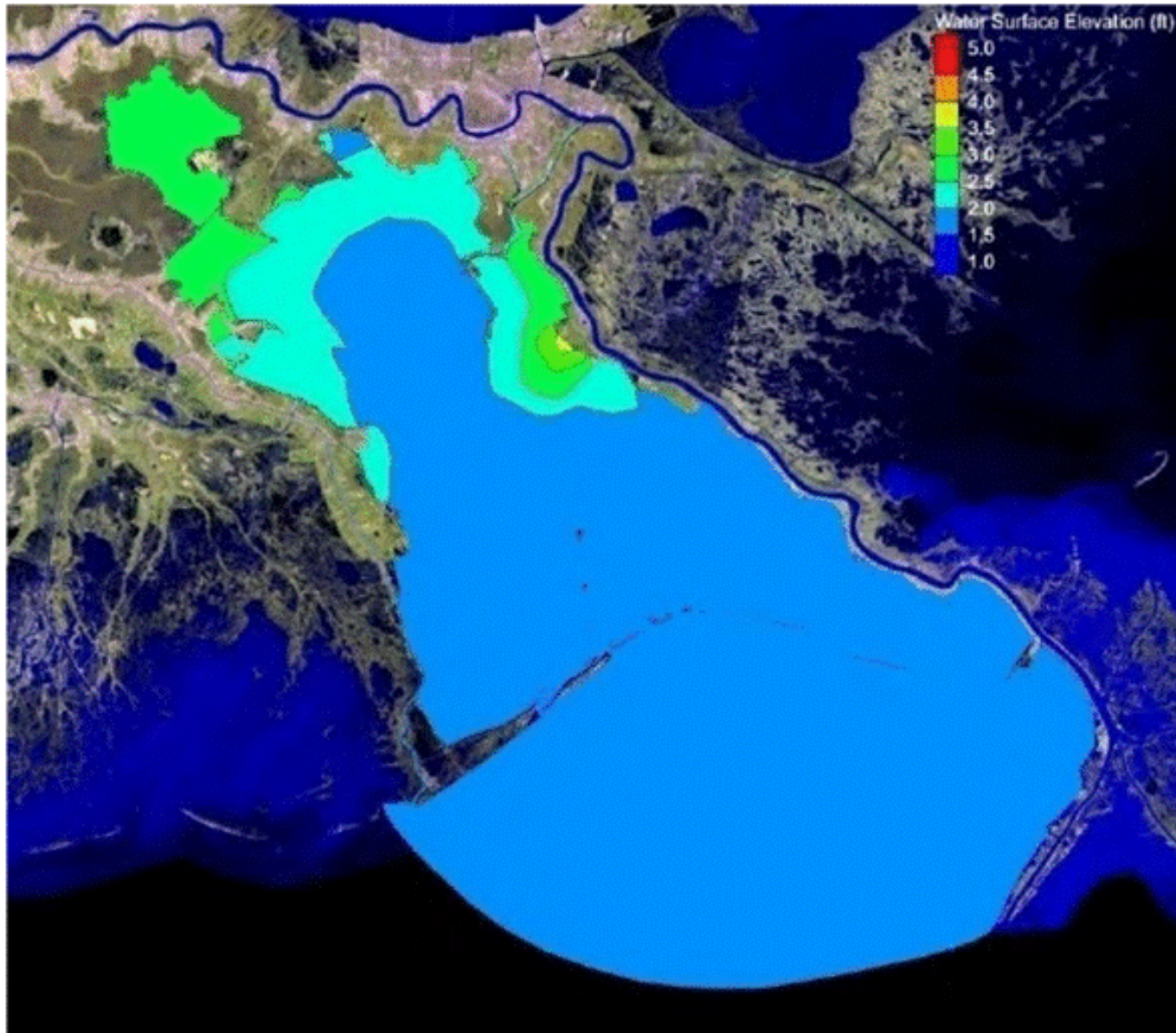




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 DATE: MON JUL 05 2010  
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 BY HPC ANALYST KONG  
 COLLABORATING CENTERS: HPC, TPC, OPC



# Diversion simulation summary



**Figure 5-5. Monthly Maximum Water Surface Elevation**

## **Suggested next steps**

- The possibility that long-term onshore wind fetches, especially associated with a low pressure, can impede diversion outflow and cause residential and street flooding exists
- National Weather Service issues 5-10 “coastal flood warnings” per year from non-hurricane weather events. Generally, community infrastructure is built to handle these. However, the addition of diversion water may overmatch the infrastructure.
- The scenario requires the diversion models be coupled with wind and pressure forcing to assess the possible outcomes and make community preparations.



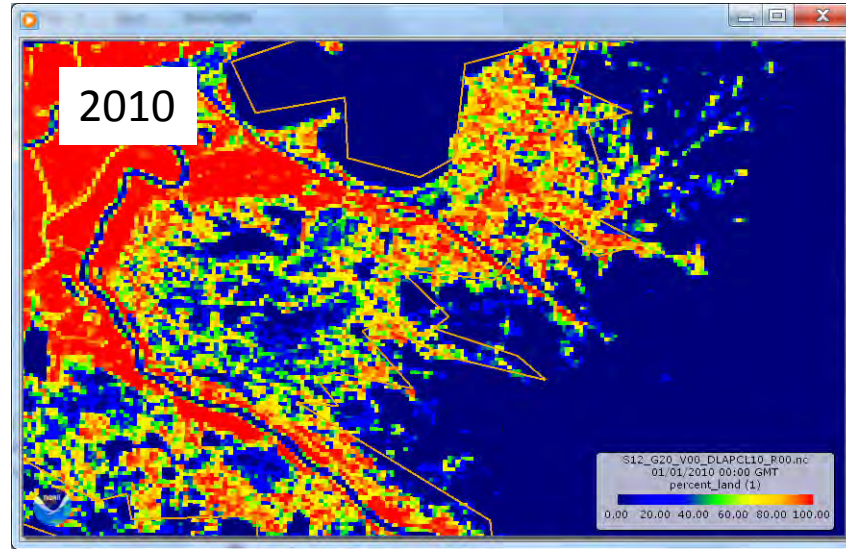
## Diversion simulations

The fidelity of the simulations are controversial, but that's a debate for another day

Next two slides show “moderate” erosion scenarios.

There are also simulations for “less optimistic”, or accelerated erosion (not shown)

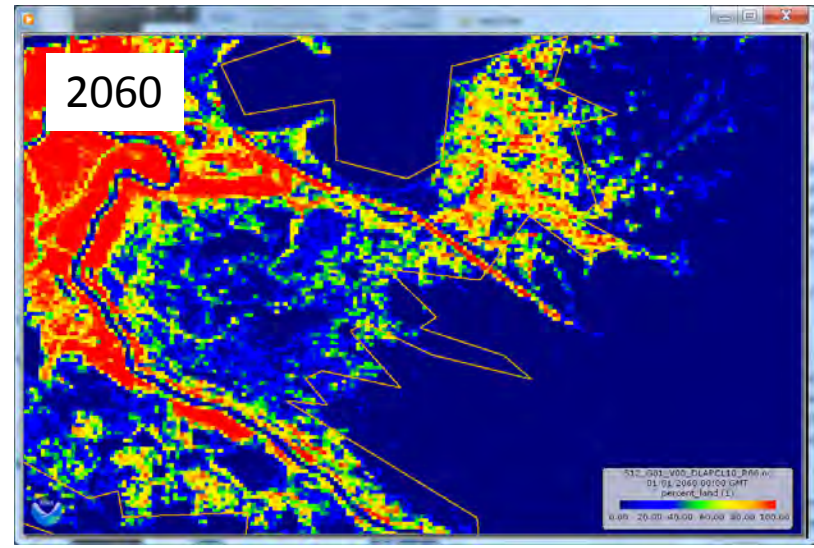
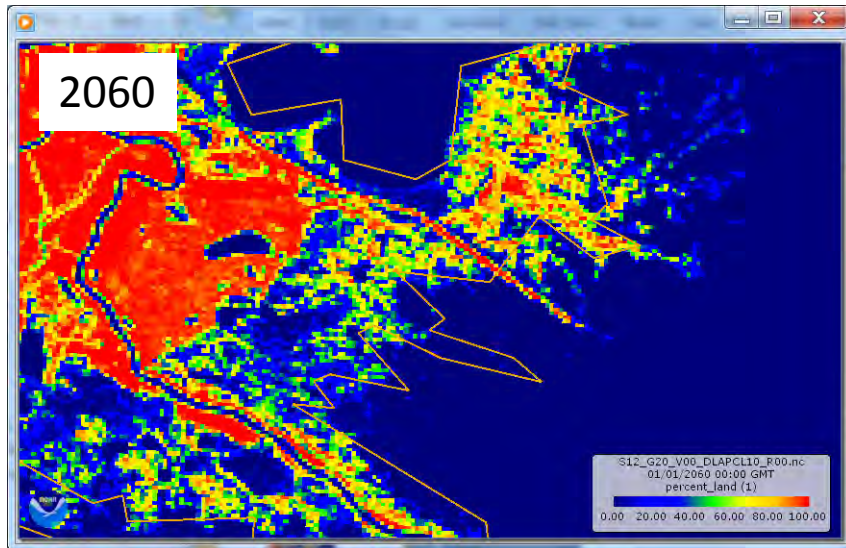
# Possible wetland evolution, moderate erosion scenario, East Bank, 2010-2060



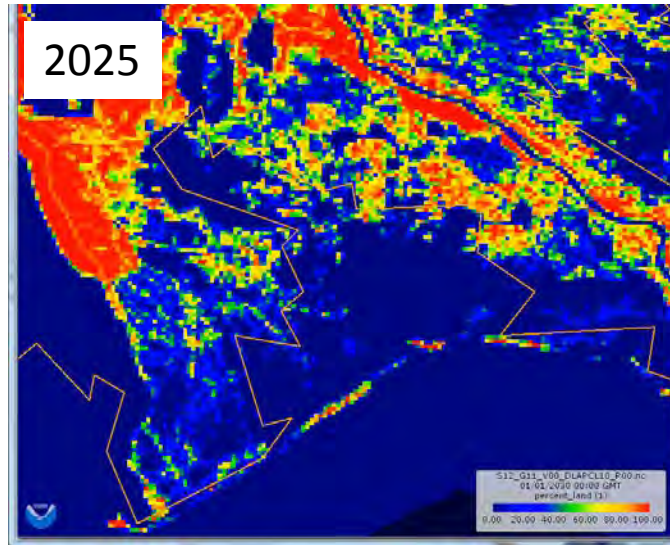
*Percent land*  
*Yellow to Red –70-100%*  
*Blues –0-40%*

Upper Breton (Braithwaite) diversion  
250,000 cfs

No restoration projects



# Possible wetland evolution, moderate erosion scenario, West Bank, 2025-2060

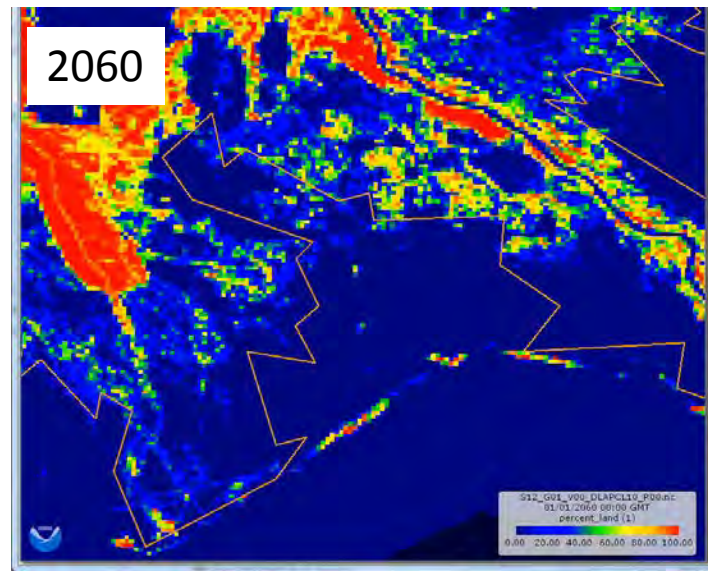
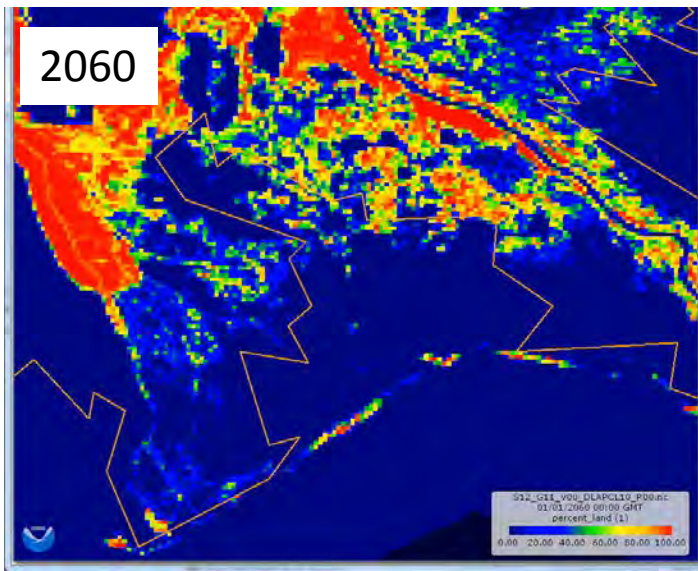


*Percent land*  
*Yellow to Red –70-100%*  
*Blues –0-40%*

Mid-Barataria (Myrtle Grove) diversion

50,000 cfs first 20 yrs; 250,000 cfs afterwards

No restoration projects

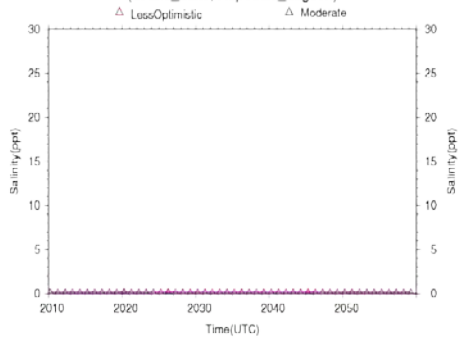


# Salinity time series

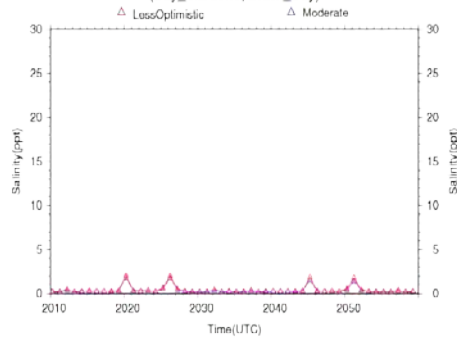


# Braithwaite diversion Salinity time series, East Bank, April and October

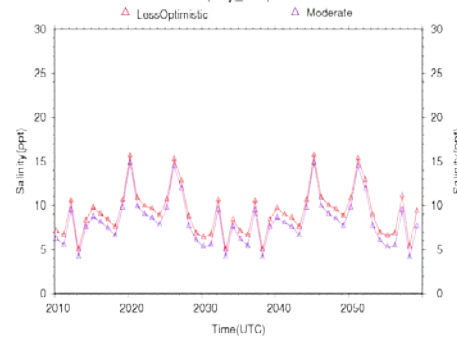
Upper Breton Salinity Changes At PB079 in April  
(Grand\_Lake, Hopedale\_Lagoon)



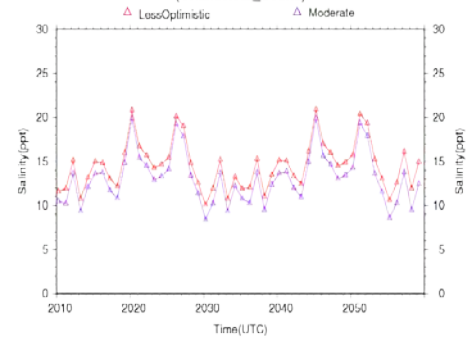
Upper Breton Salinity Changes At PB012 in April  
(Bay\_Gardene, Black\_Bay)



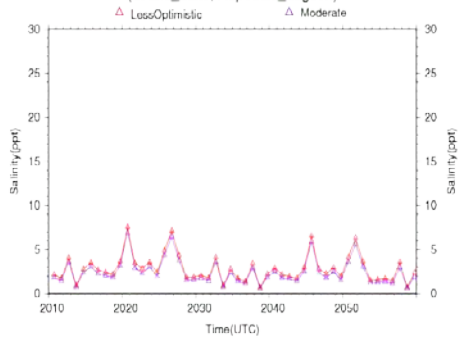
Upper Breton Salinity Changes At PB074 in April  
(Bay\_Eloi)



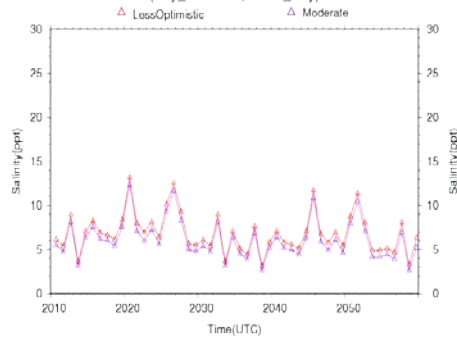
Upper Breton Salinity Changes At PB017 in April  
(Chandeleur\_Sound)



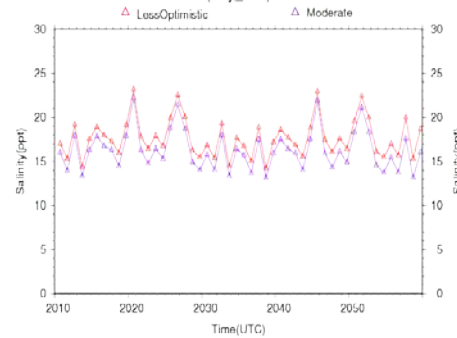
Upper Breton Salinity Changes At PB079 in October  
(Grand\_Lake, Hopedale\_Lagoon)



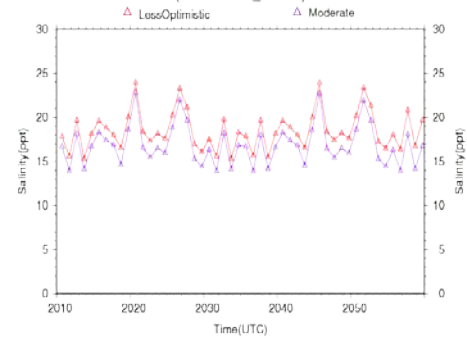
Upper Breton Salinity Changes At PB012 in October  
(Bay\_Gardene, Black\_Bay)



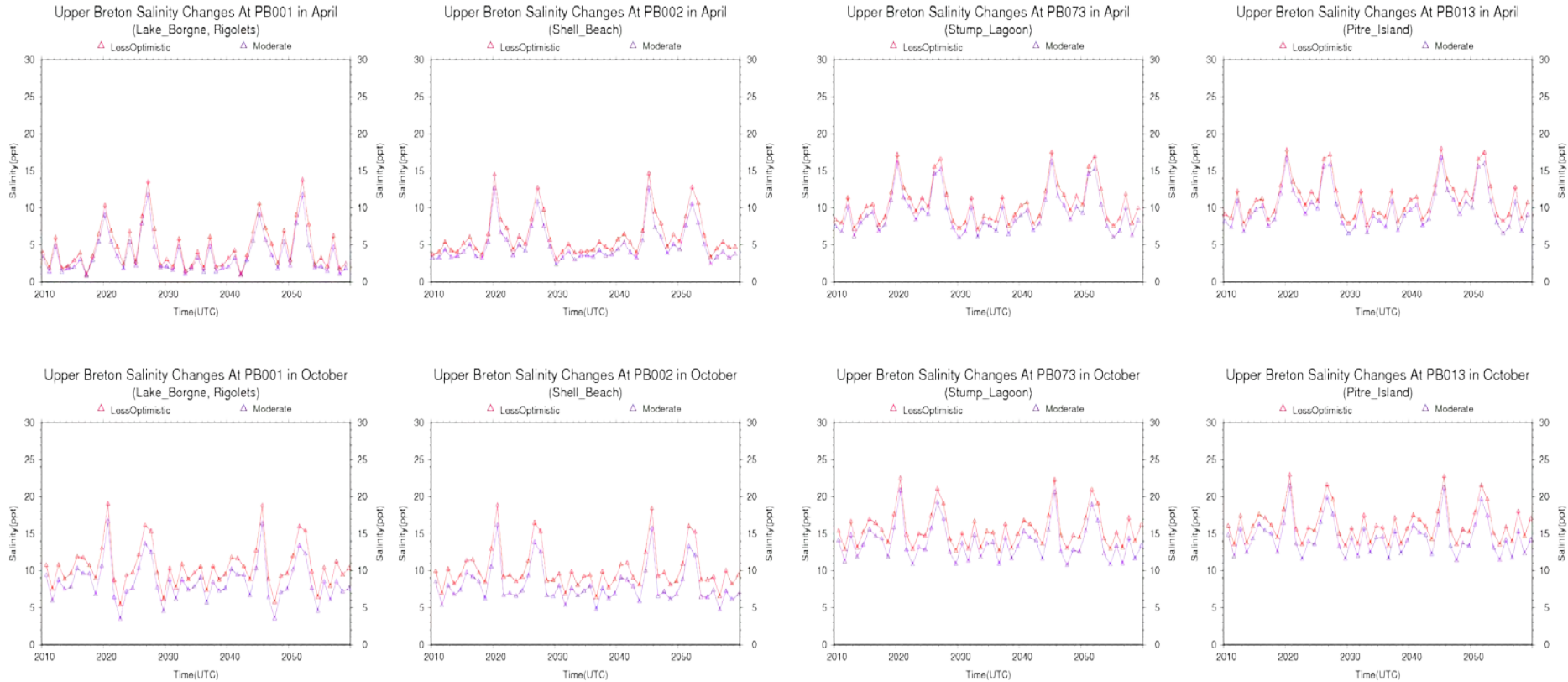
Upper Breton Salinity Changes At PB074 in October  
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Upper Breton Salinity Changes At PB017 in October  
(Chandeleur\_Sound)

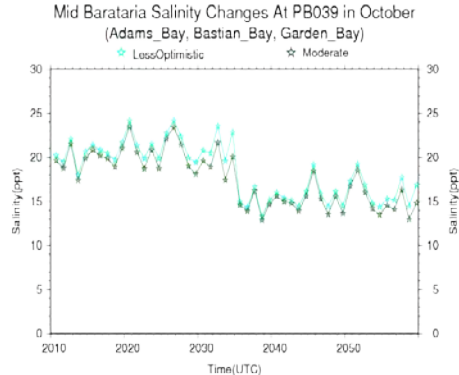
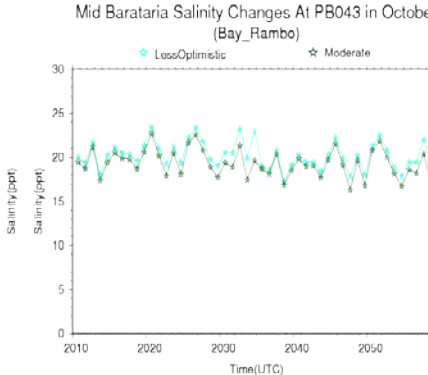
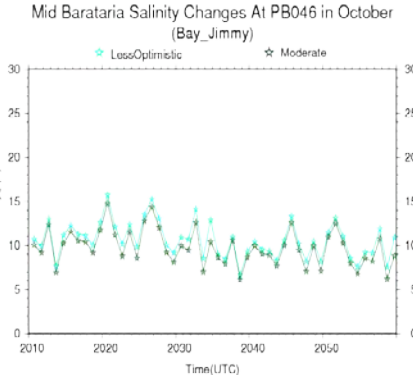
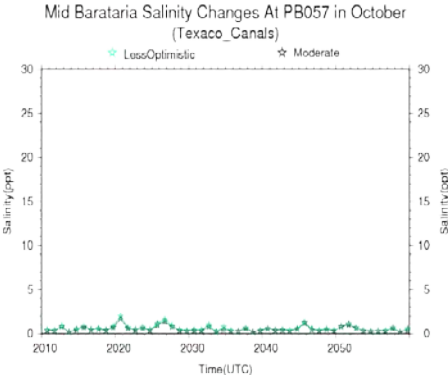
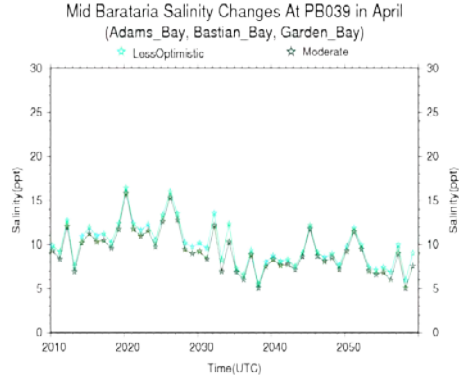
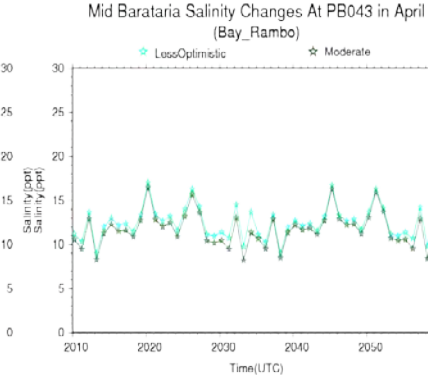
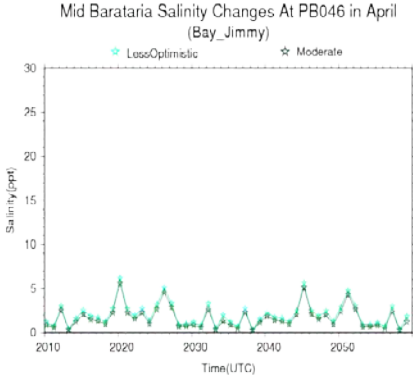
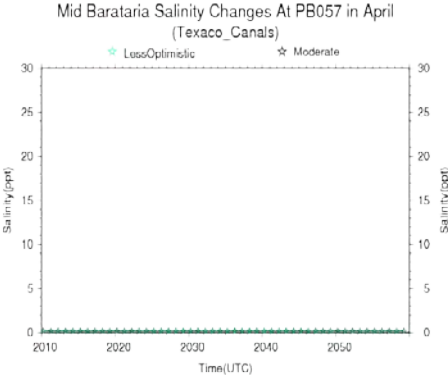


# Braithwaite diversion salinity time series, East Bank, April and October

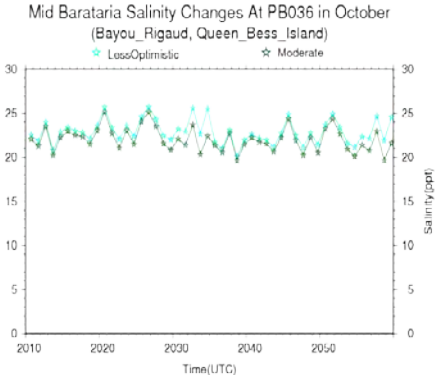
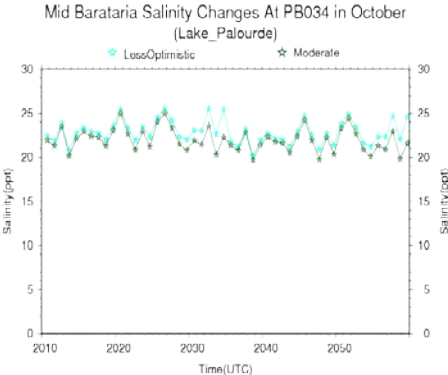
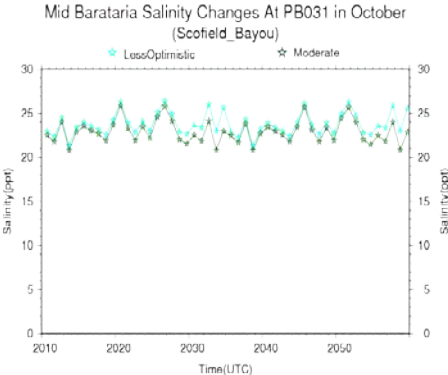
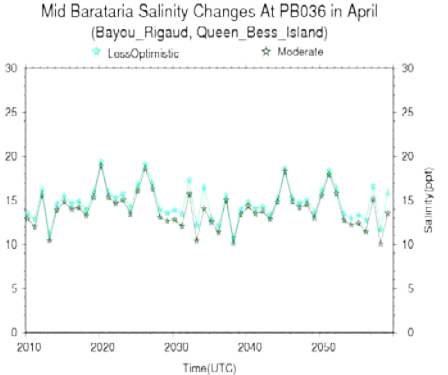
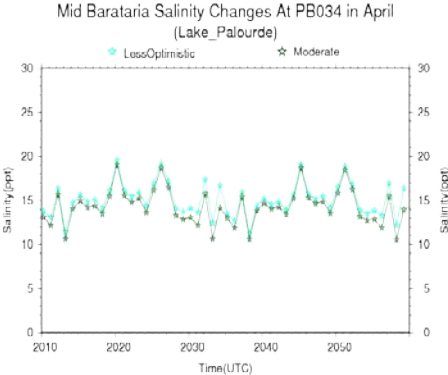
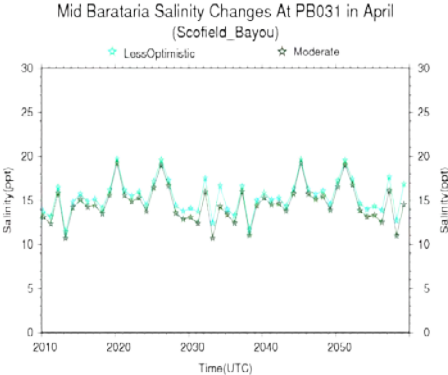


A problem; Pitre Island salinity should be different from Stump Lagoon, probably higher

# Myrtle Grove diversion salinity time series, West Bank, April and October



# Myrtle Grove diversion salinity time series, West Bank, April and October



# Habitat Suitability Indexes (HSI)

## Suitability indexes

- Based on concept of “geometric mean”
- NOT the same as a simple average
- It’s the nth root of the product of n numbers

### **Example:**

What is the geometric mean of 2, 8 and 4?

### **Solution:**

Multiply those numbers together. Then take the third root (cube root) because there are 3 numbers.

$$\sqrt[3]{2 \times 8 \times 4} = 4$$

- One number can disproportionately affect the geometric mean. For example, if one value such as salinity is zero for oysters, the geometric mean is zero. The other factors then do not matter. The habitat is unsuitable.

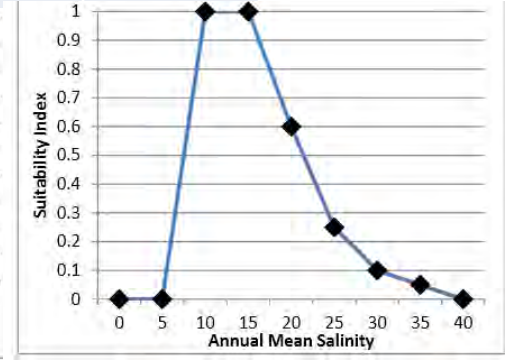
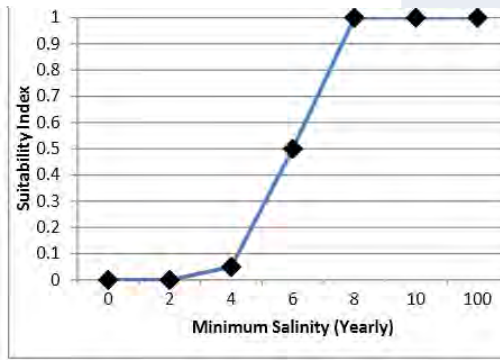
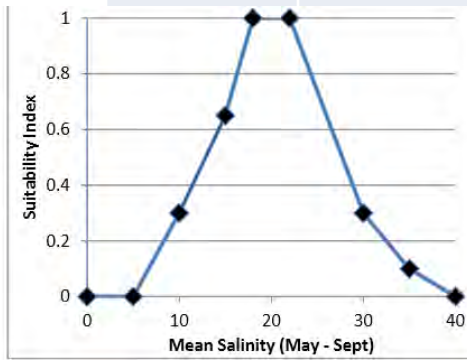
## Example: Oyster habitat suitability index (HSI)

- Generally based on salinity, land/water ratio, and available substrate parameters
- Each parameter is normalized between 0 and 1, multiplied together, then the nth root taken.
- If HSI is zero --- not suitable
- If HSI is one --- optimal
- In between less clear, but can infer results from nearness to 0 or 1

# Oyster suitability index equation

$$HSI = \sqrt[5]{(\% \text{ substrate}) \times (\text{mean salinity summer}) \times (\text{minimal annual salinity}) \times (\text{annual mean salinity}) \times (\% \text{ land})}$$

Normalized	Percent Substrate	Normalized	Mean Salinity Summer (ppt)	Normalized	Minimal Annual Salinity (ppt)	Normalized	Annual Mean Salinity (ppt)	Normalized	Percent Land
0	0	0	≤ 5	0	≤ 2	0	≤ 5	1	0
0.4	10	0.3	10	0.05	4	1.0	10	0.8	20
0.6	20	0.65	15	0.5	6	1.0	15	0.6	40
0.8	30	1.0	18	1.0	≥ 8	0.6	20	0.4	60
0.9	40	1.0	22			0.25	25	0.2	80
1.0	50 to 100	0.3	30			0.1	30	0	100
		0.1	35			0.05	35		
		0	≥ 40			0	≥ 40		

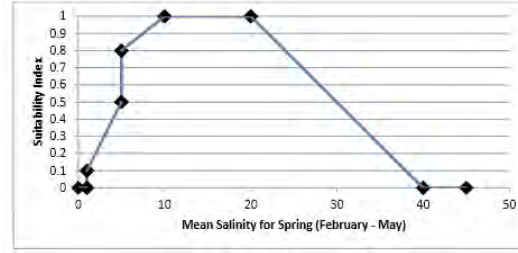




Question for fishery experts: Does not consider 3 years of supportable salinity for oysters to reach marketable size?

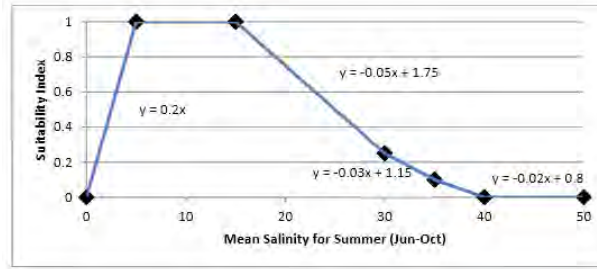
# Brown shrimp habitat suitability index equation

$$HSI = \sqrt[4]{(coverage\ marsh\ area)^2 \times (mean\ salinity\ spring) \times (mean\ spring\ water\ temperature)}$$



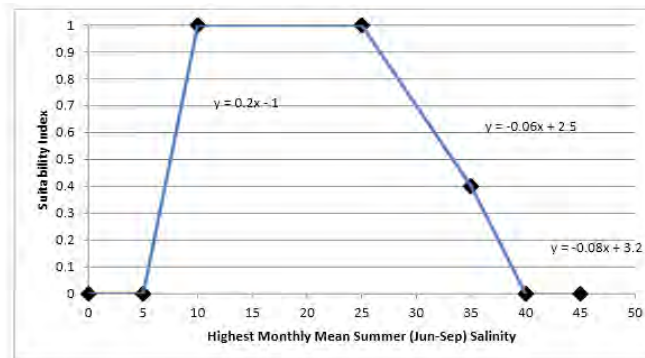
# White shrimp habitat suitability index equation

$$HSI = \sqrt[4]{(coverage\ marsh\ area)^2 \times (mean\ salinity\ summer) \times (mean\ summer\ water\ temperature)}$$



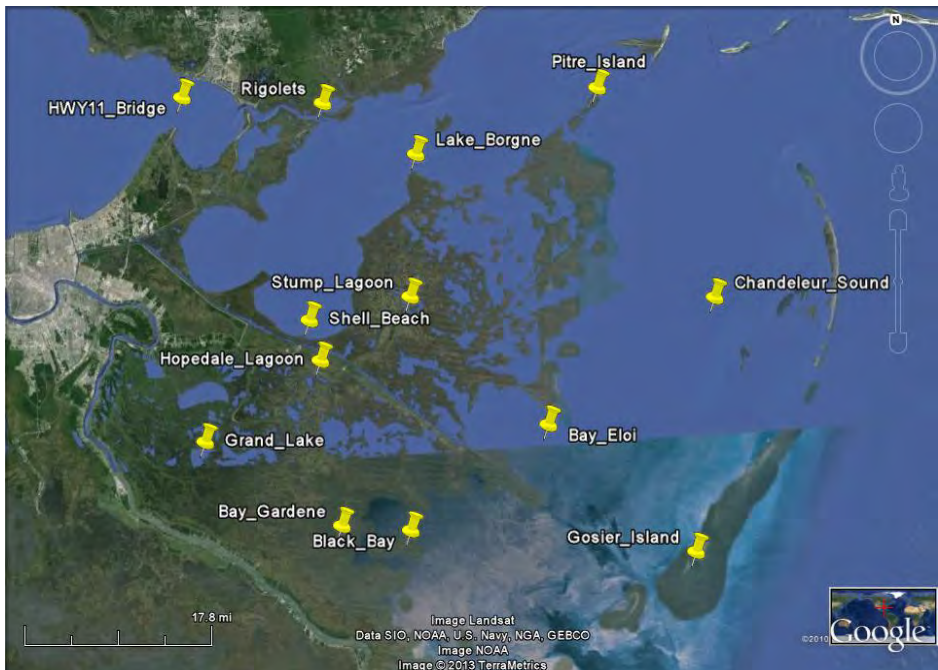
# Speckled trout habitat suitability index equation

$$HSI = \sqrt[4]{(coverage\ marsh\ area) \times (max\ monthly\ mean\ salinity\ summer) \times (max\ monthly\ mean\ summer\ water\ temperature) \times (min\ monthly\ mean\ winter\ water\ temperature)}$$

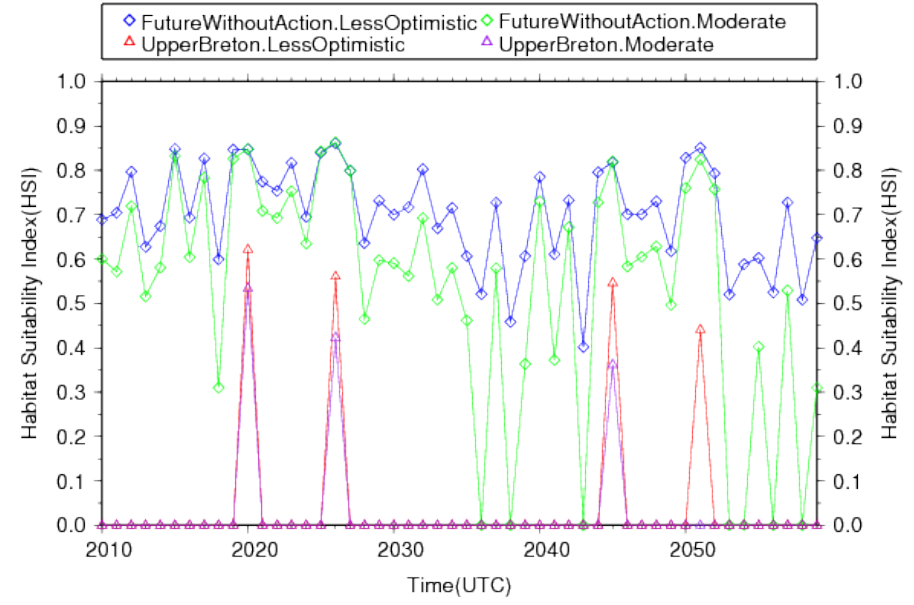


Spawning and larval impact not Considered. Eggs need high salinity to float into marsh.

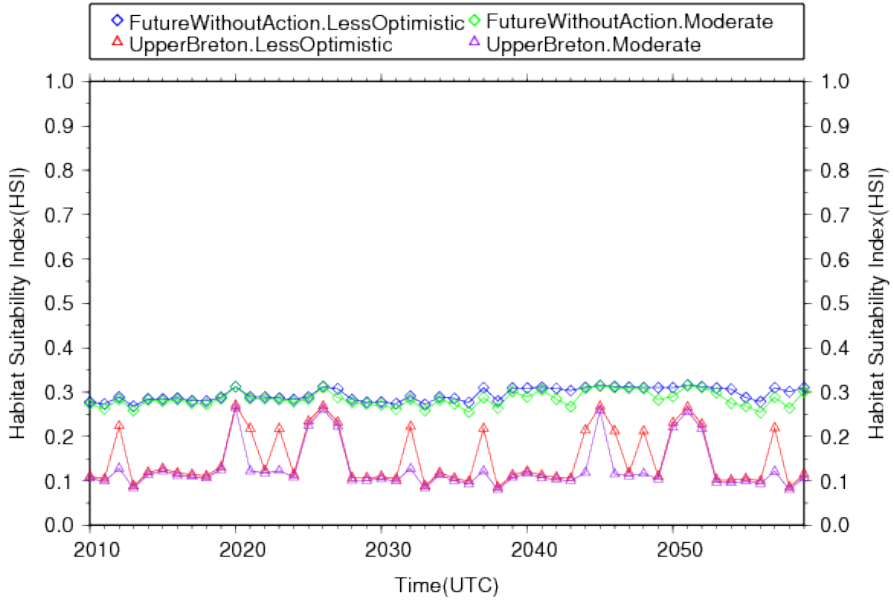
# HSI results, East Bank



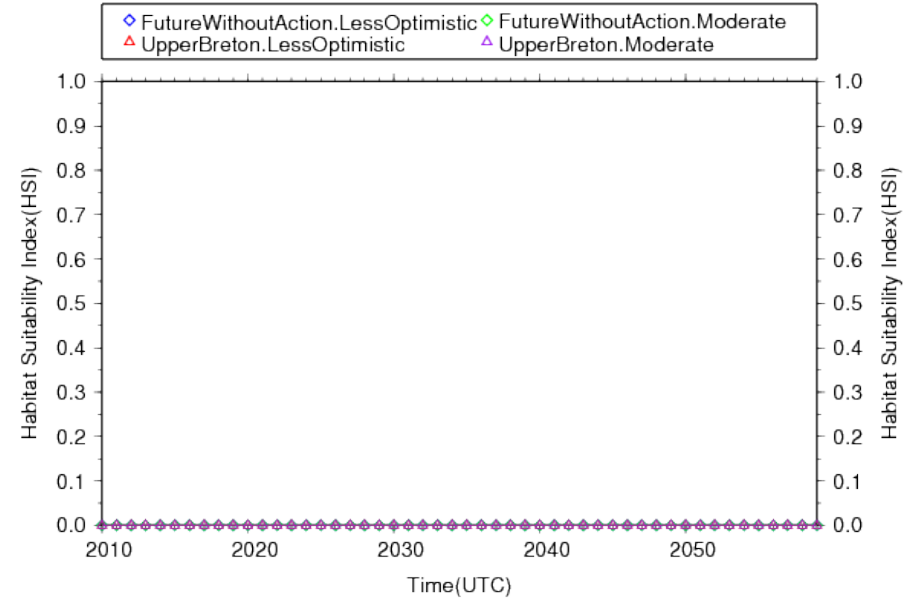
SpottedSeatroutHSI Changes At Grand\_Lake

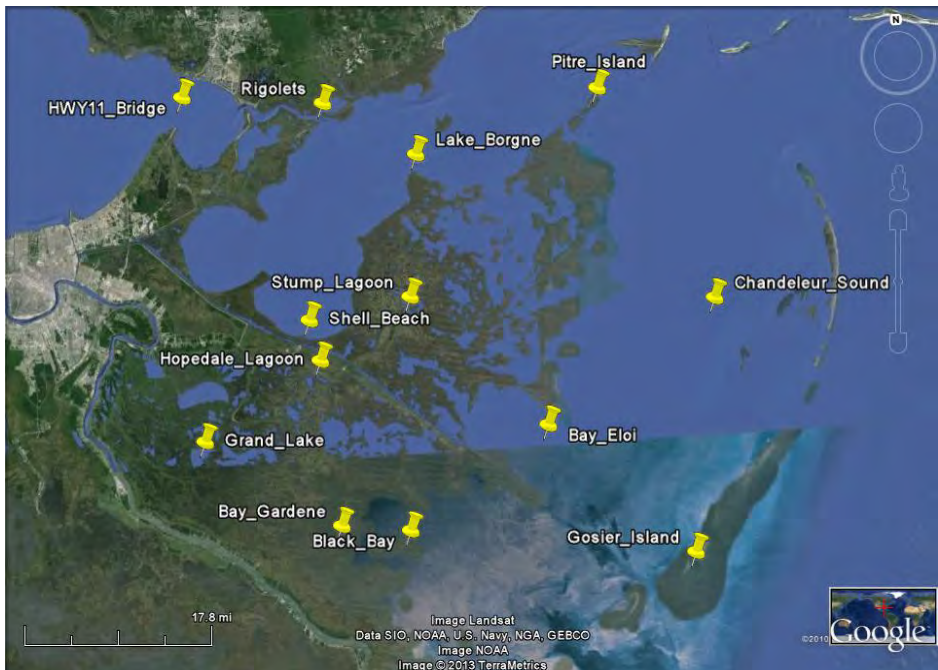


ShrimpHSI Changes At Grand\_Lake

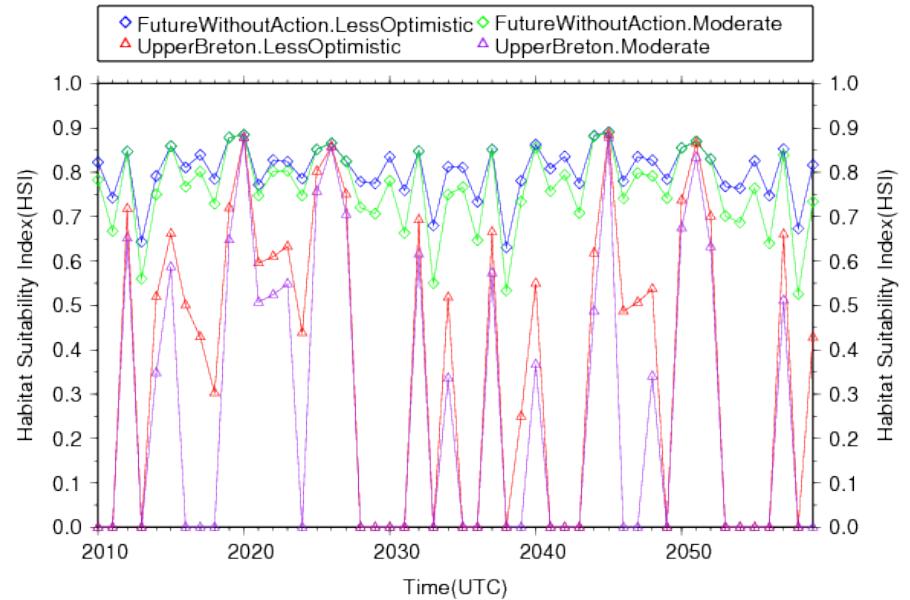


OysterHSI Changes At Grand\_Lake

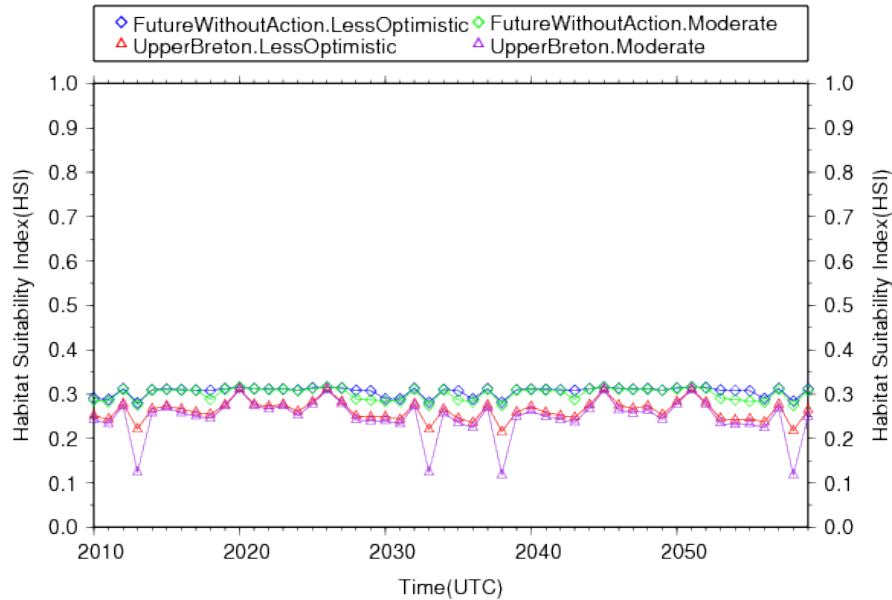




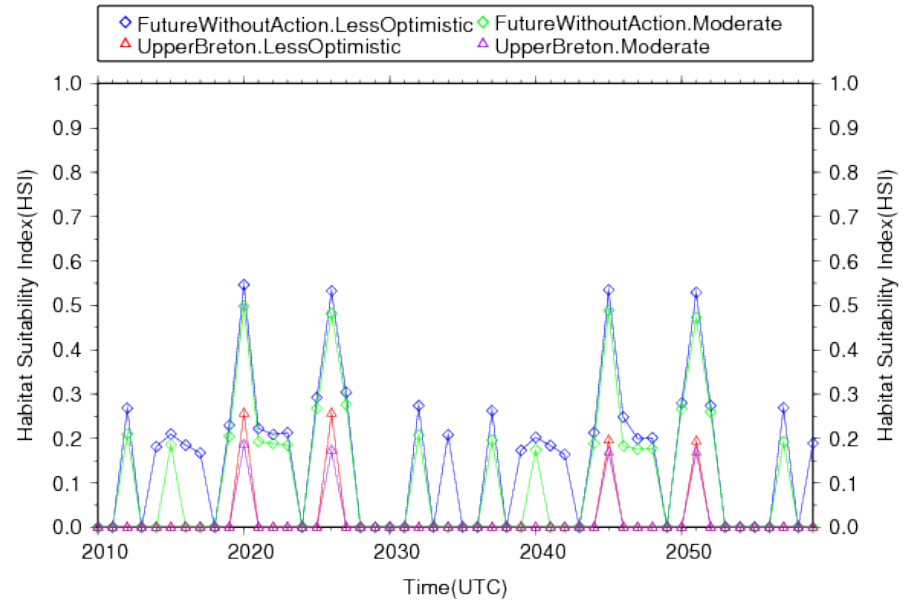
SpottedSeatroutHSI Changes At Black\_Bay



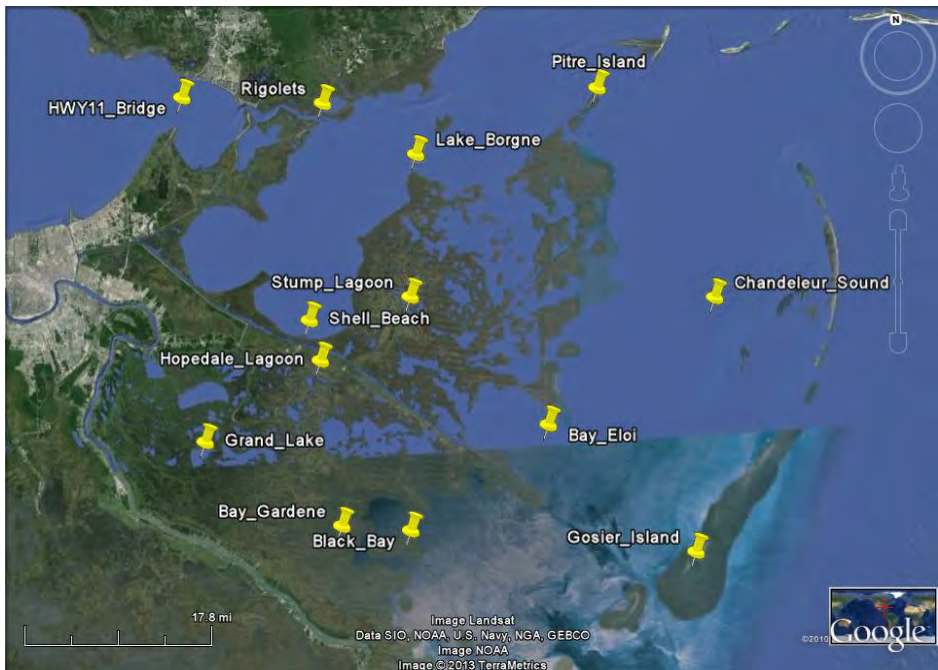
ShrimpHSI Changes At Black\_Bay



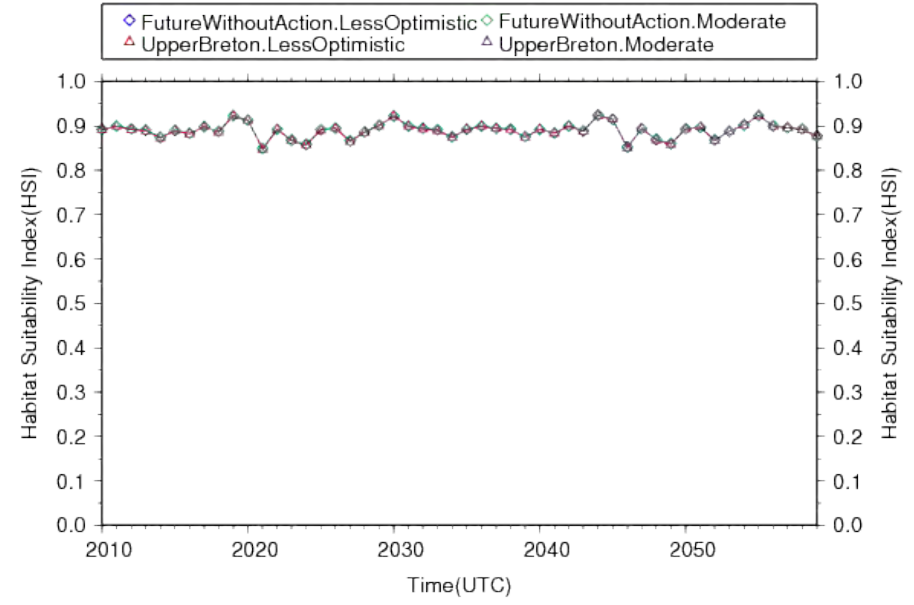
OysterHSI Changes At Black\_Bay



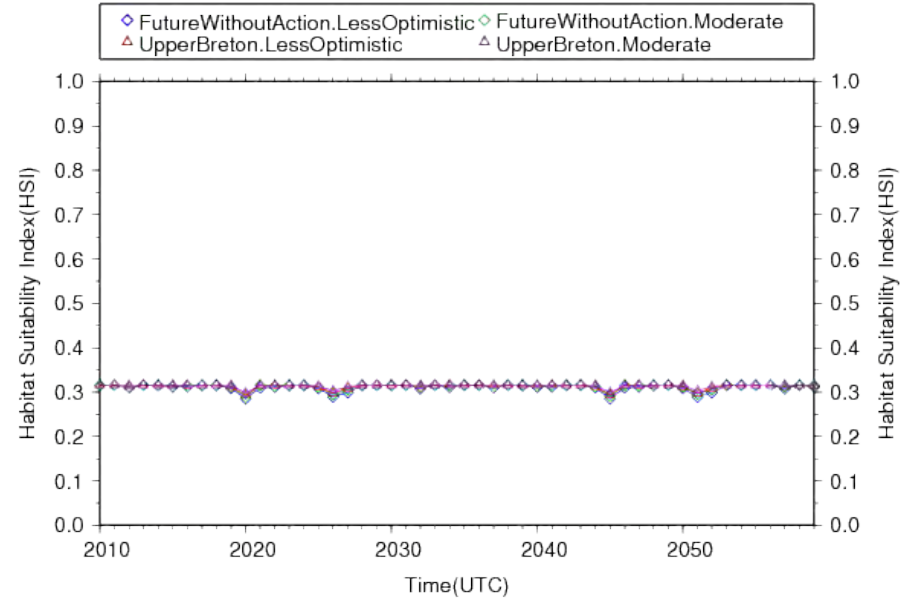




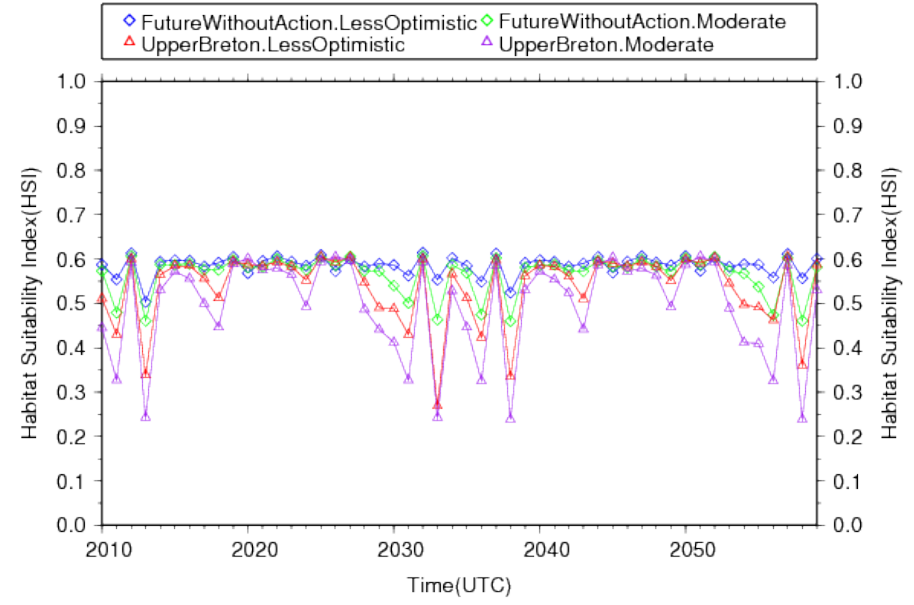
SpottedSeatroutHSI Changes At Bay\_Eloi

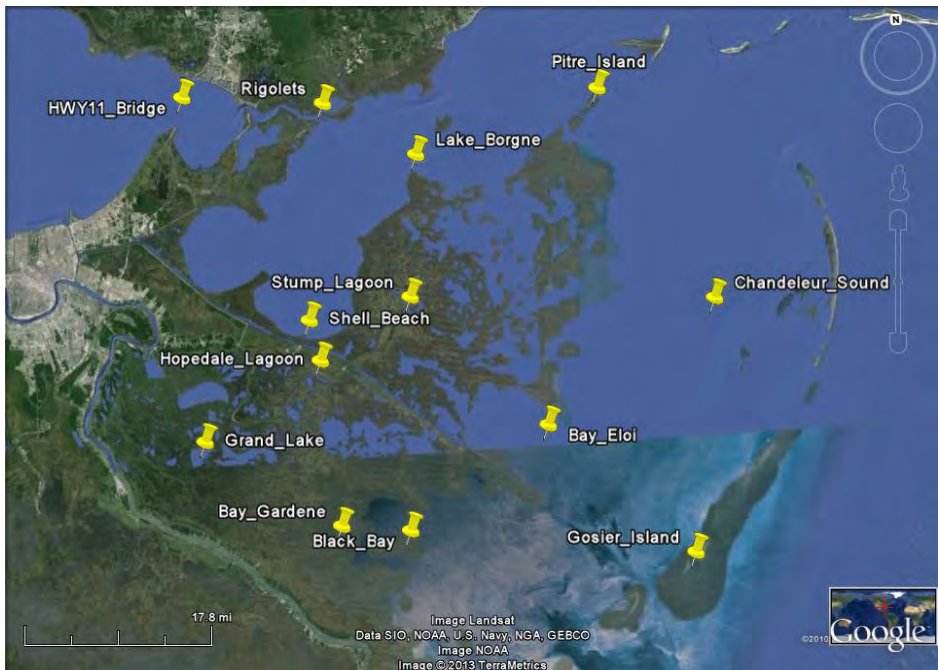


ShrimpHSI Changes At Bay\_Eloi

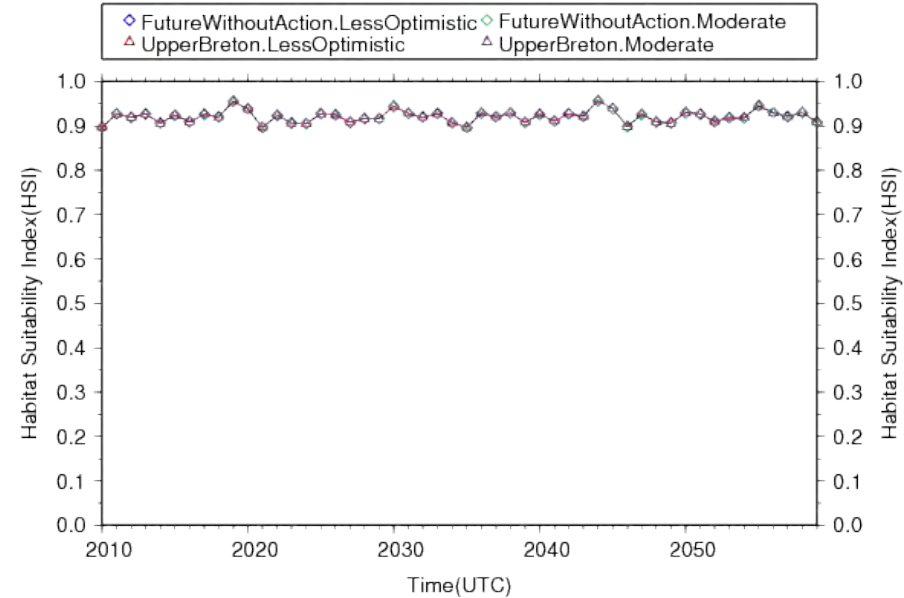


OysterHSI Changes At Bay\_Eloi

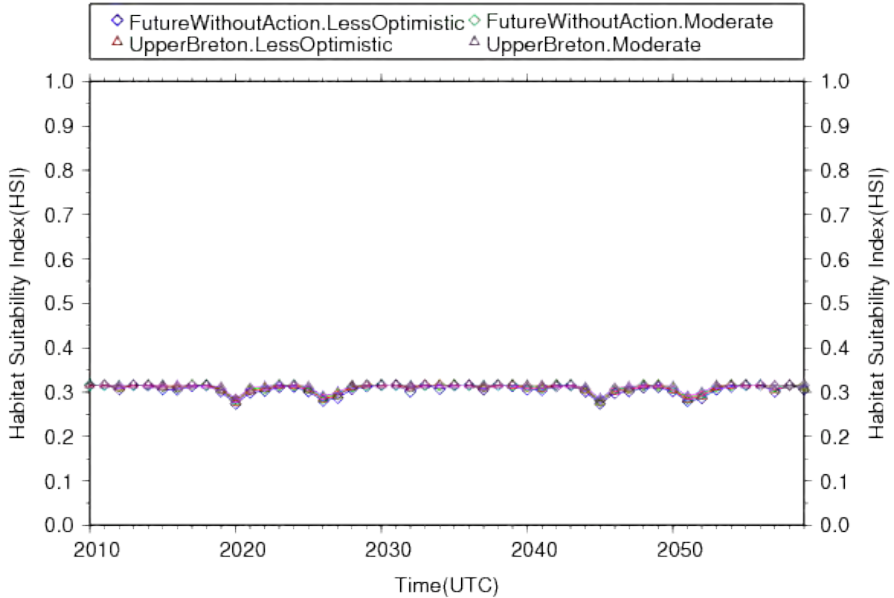




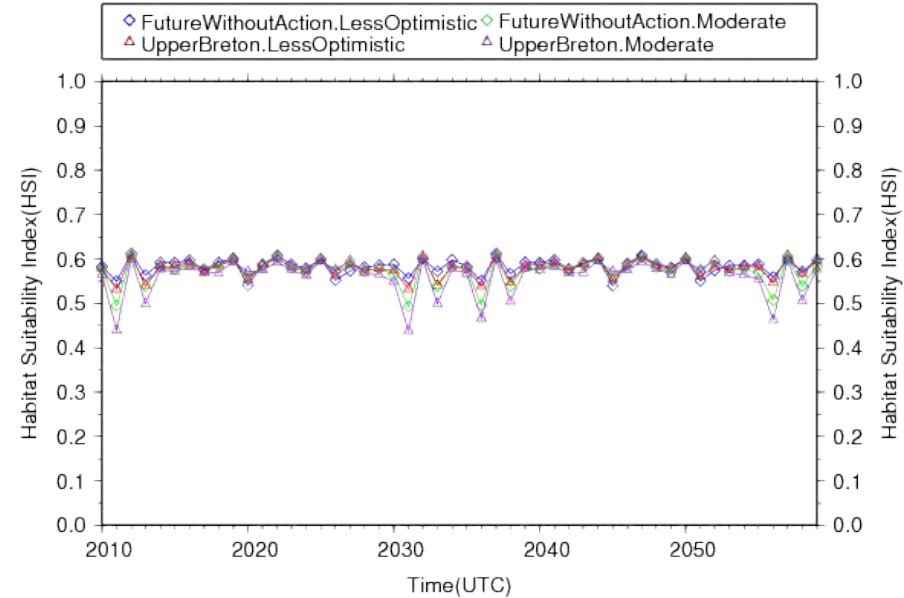
SpottedSeatroutHSI Changes At Chandeleur\_Sound

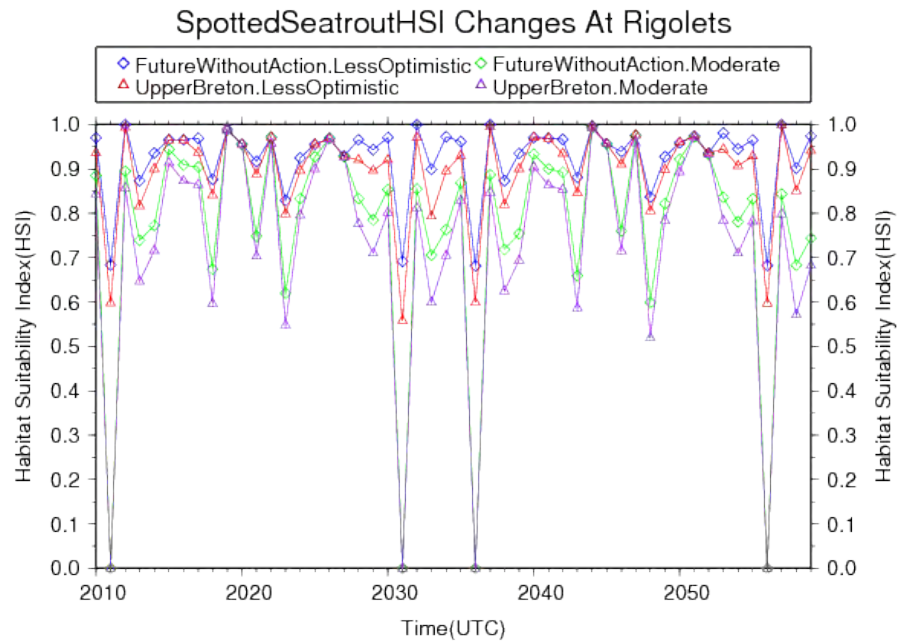
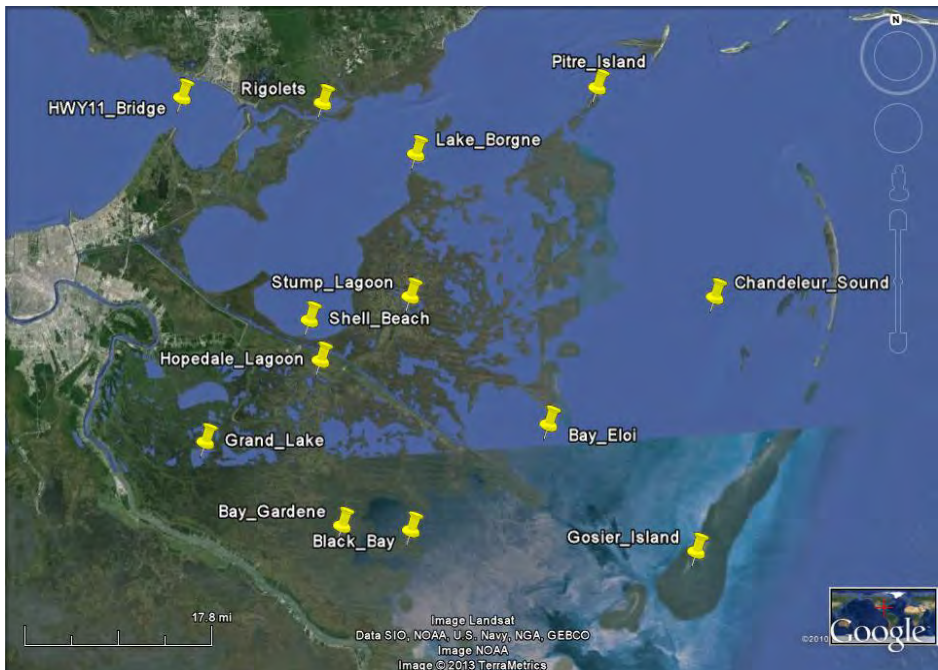


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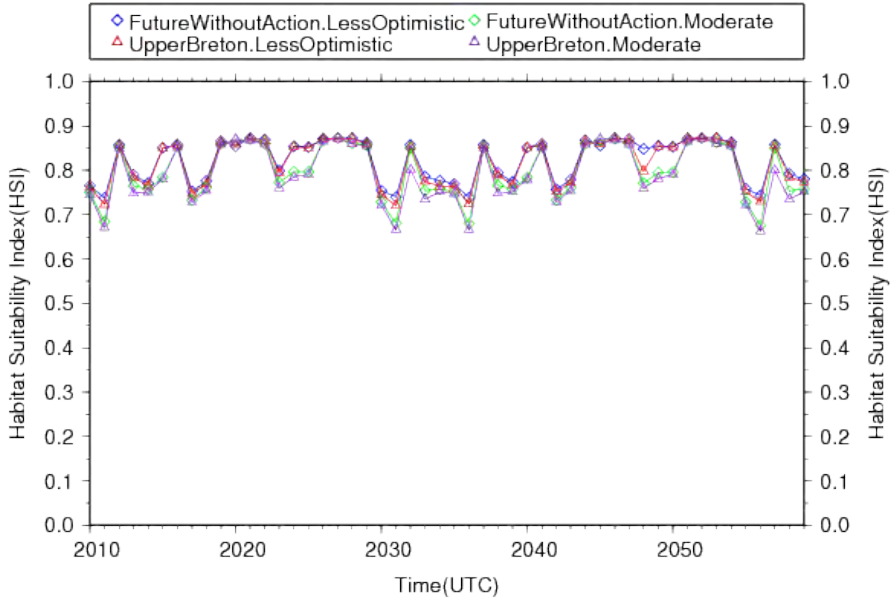


OysterHSI Changes At Chandeleur\_Sound

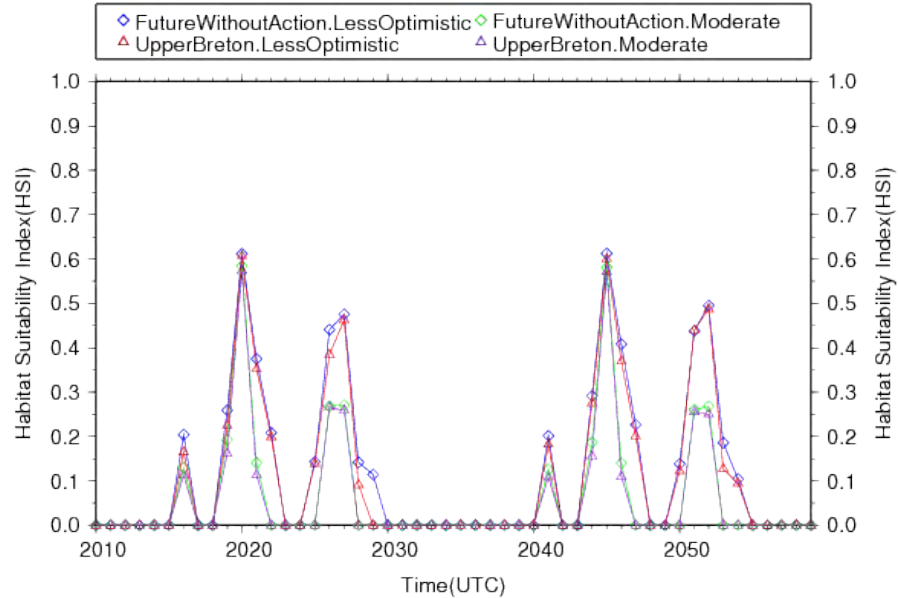




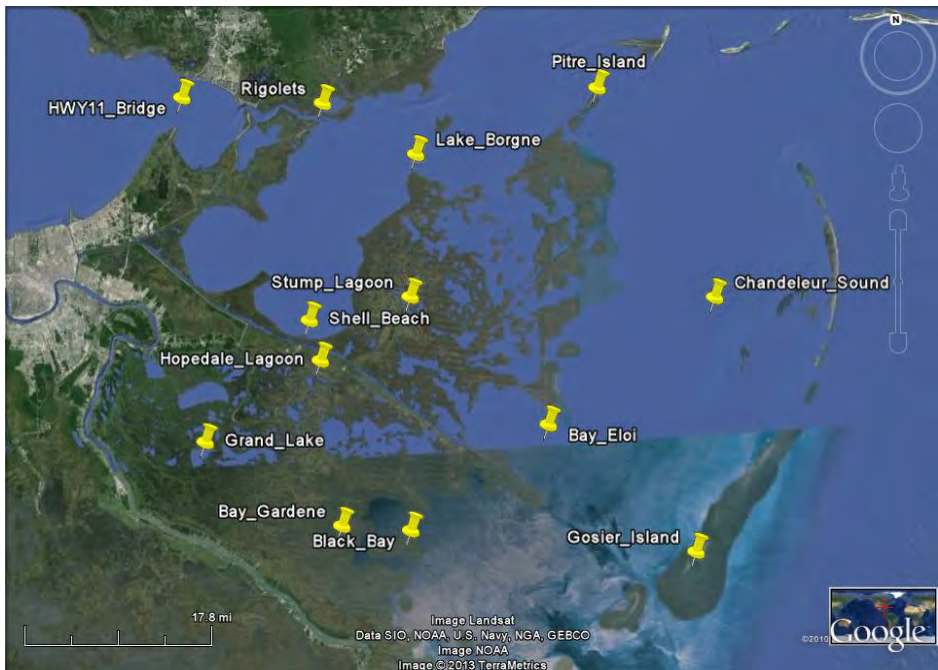
### ShrimpHSI Changes At Rigolets



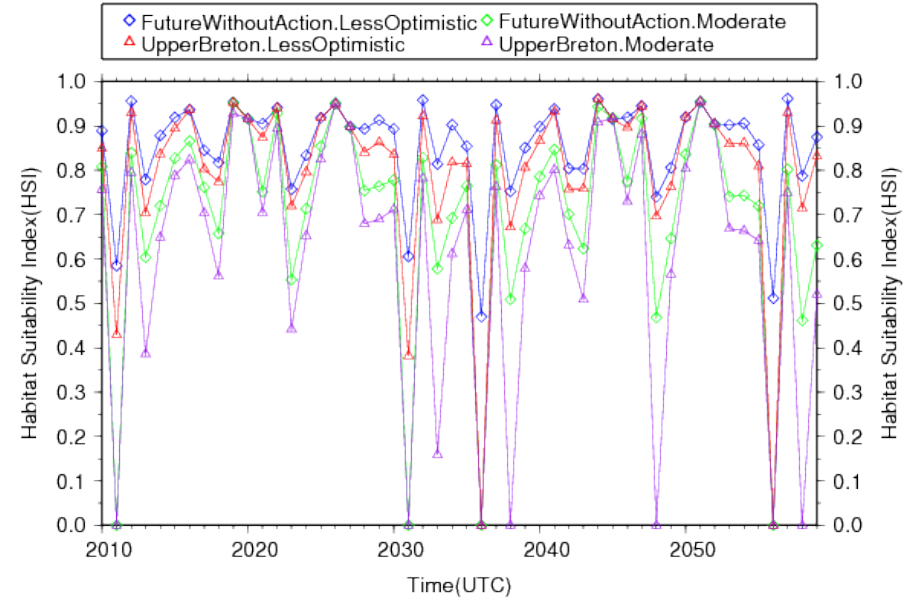
### OysterHSI Changes At Rigolets





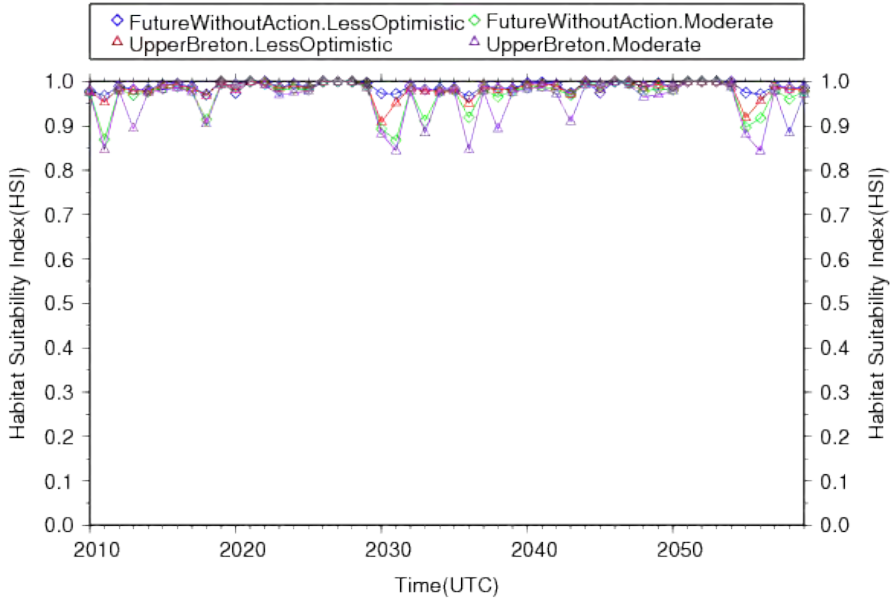


SpottedSeatroutHSI Changes At Shell\_Beach

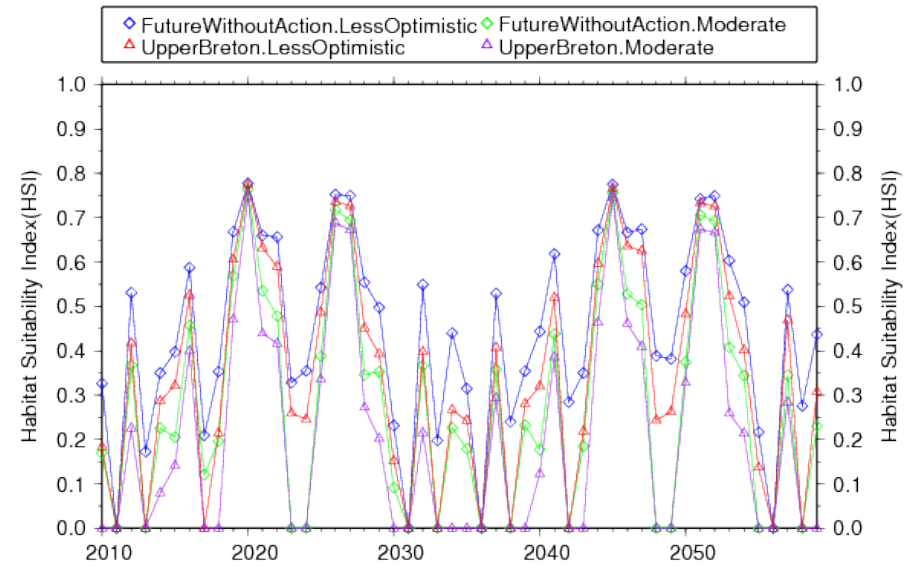


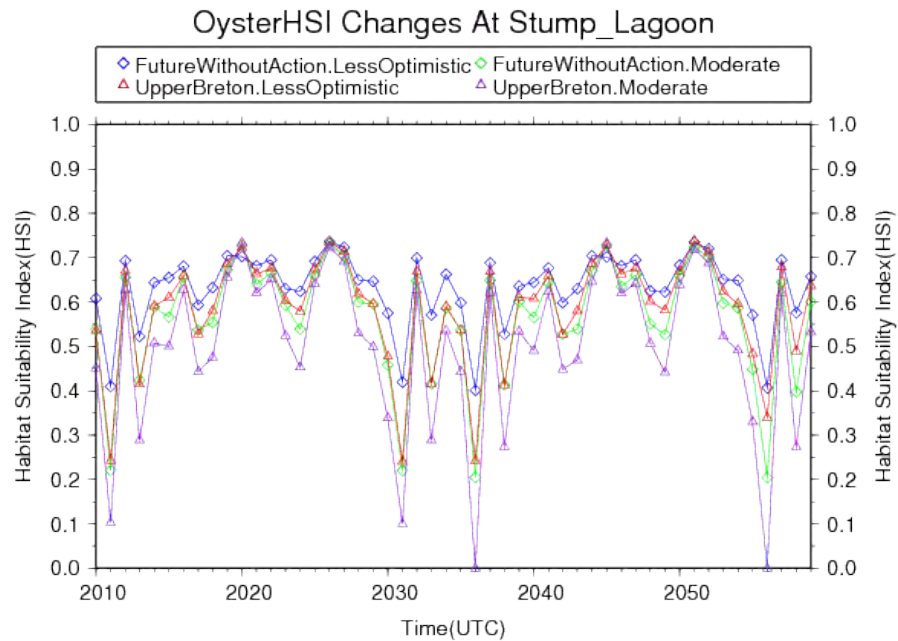
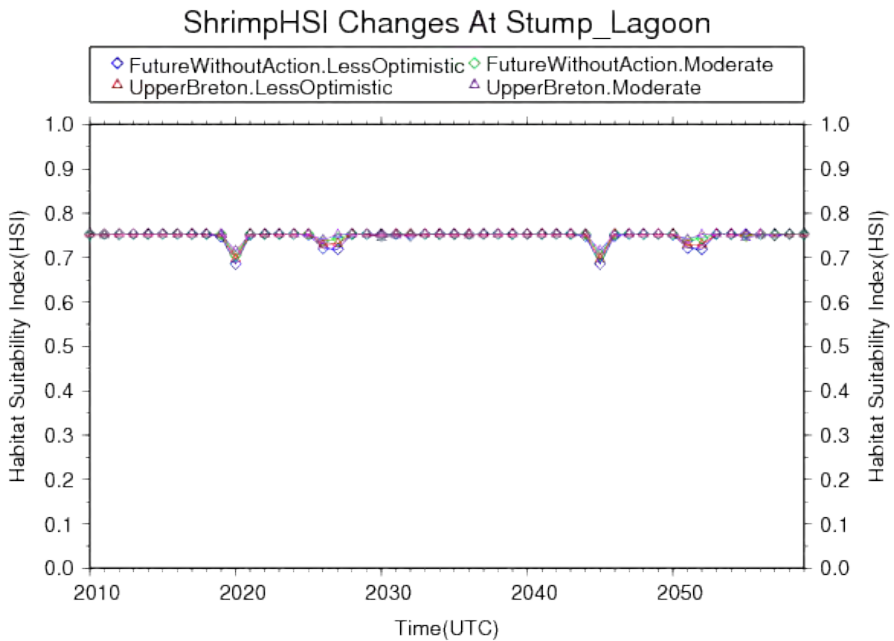
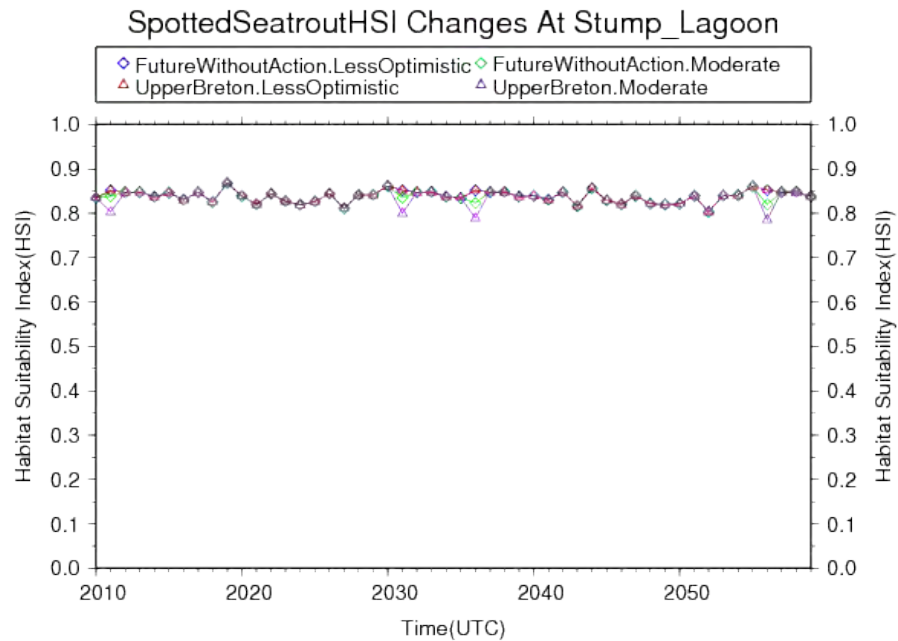
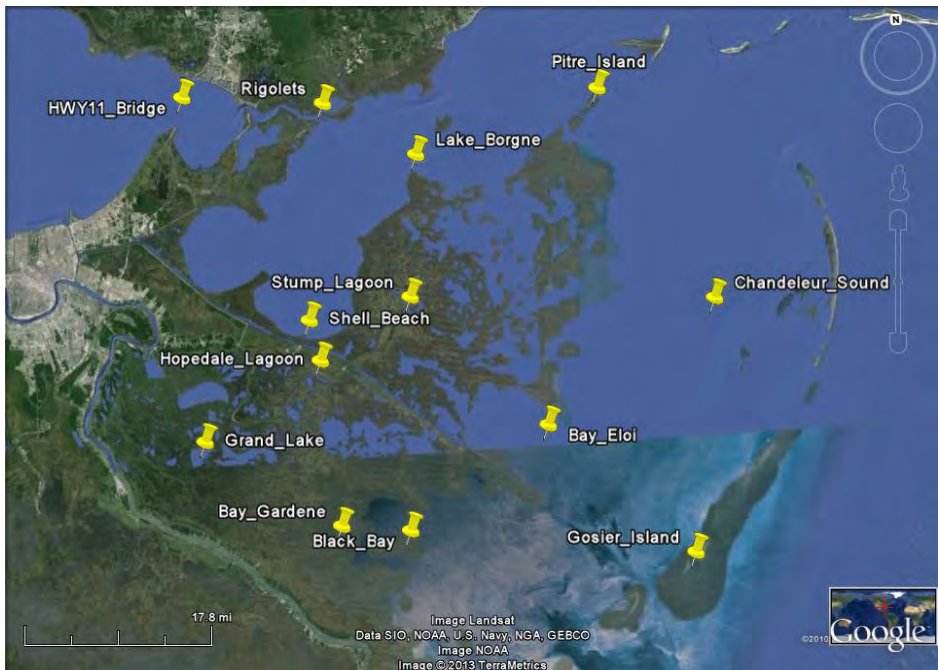
*Note: Oyster HSI does not consider 3 years for oyster to reach marketable size  
Result at Shell Beach and other places may be too optimistic*

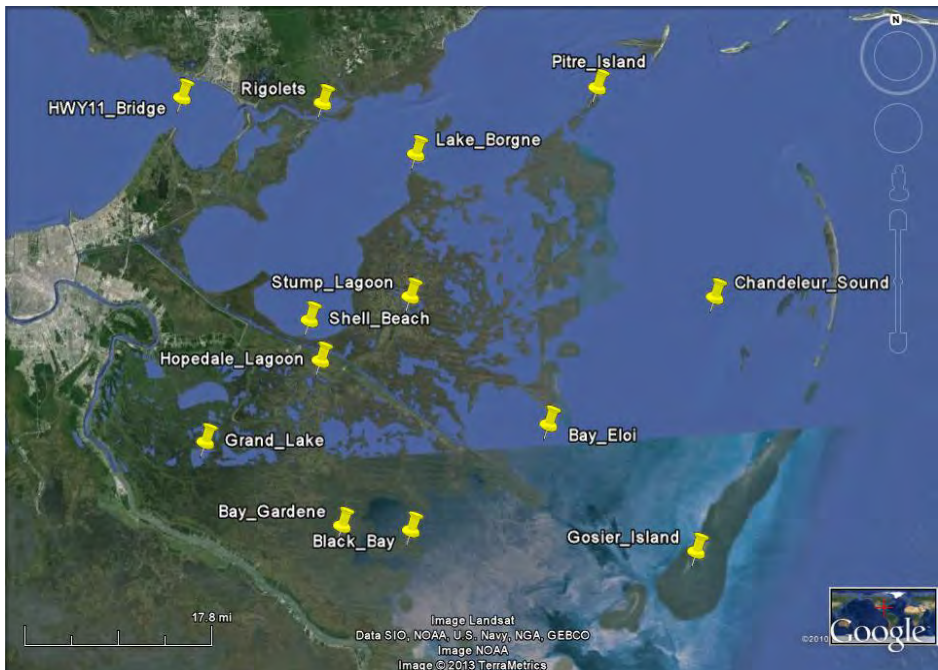
ShrimpHSI Changes At Shell\_Beach



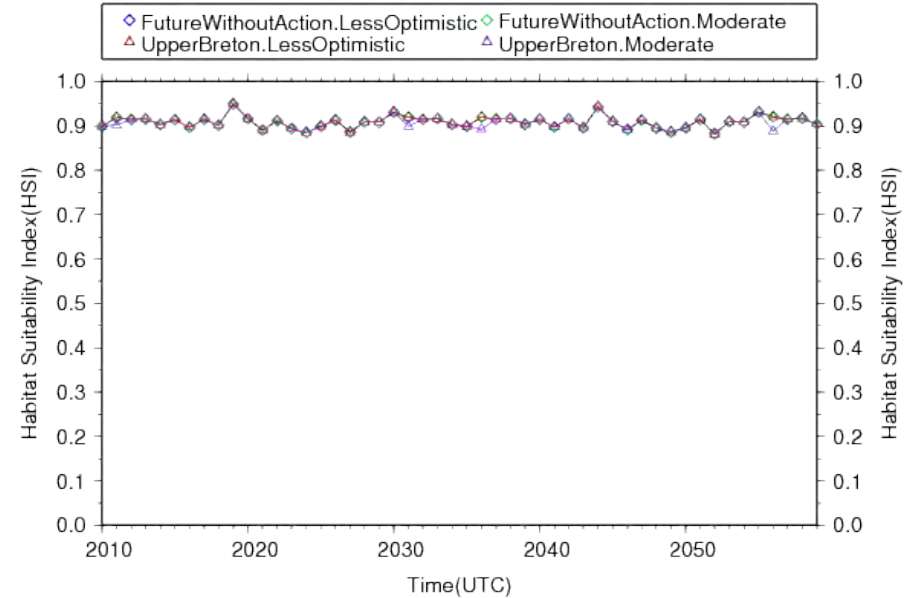
OysterHSI Changes At Shell\_Beach



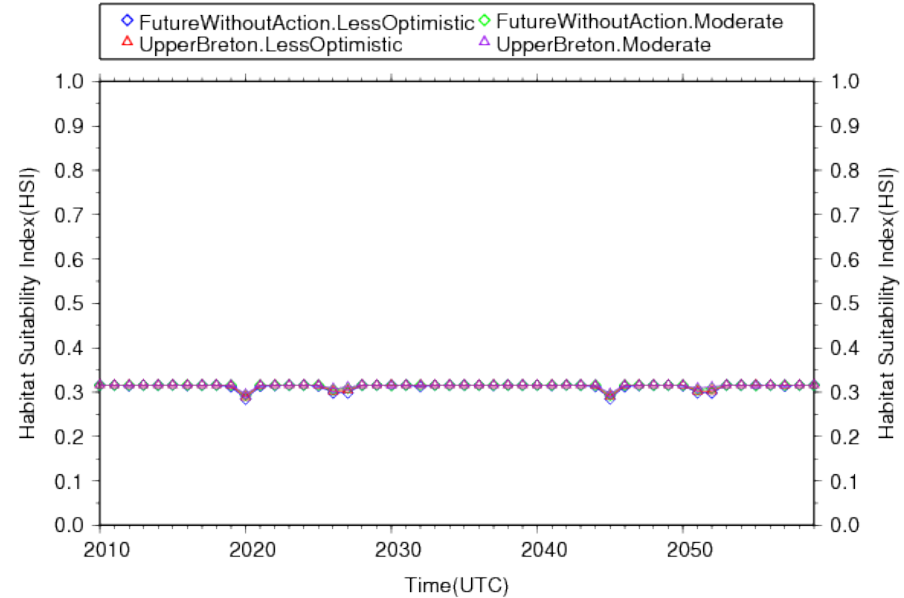




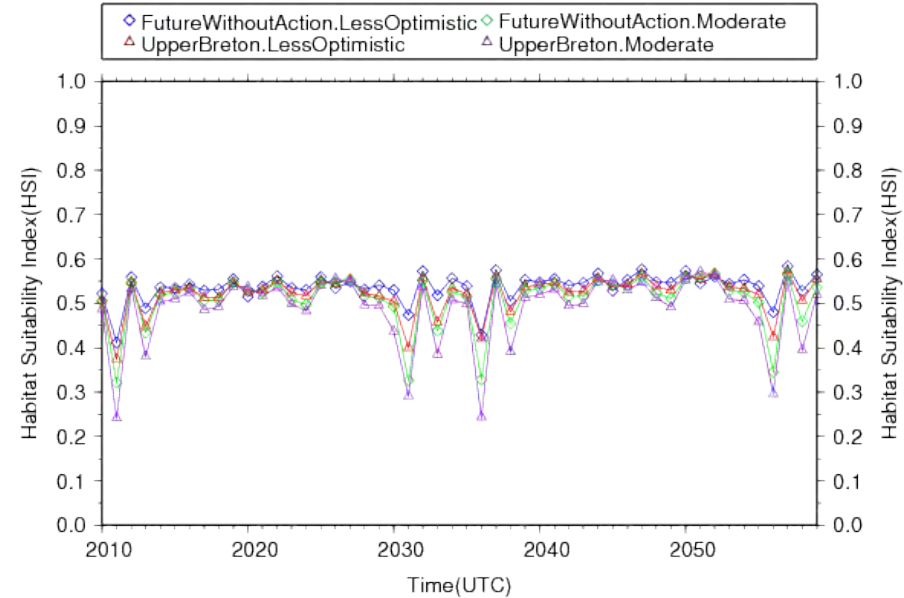
SpottedSeatroutHSI Changes At Pitre\_Island



ShrimpHSI Changes At Pitre\_Island



OysterHSI Changes At Pitre\_Island

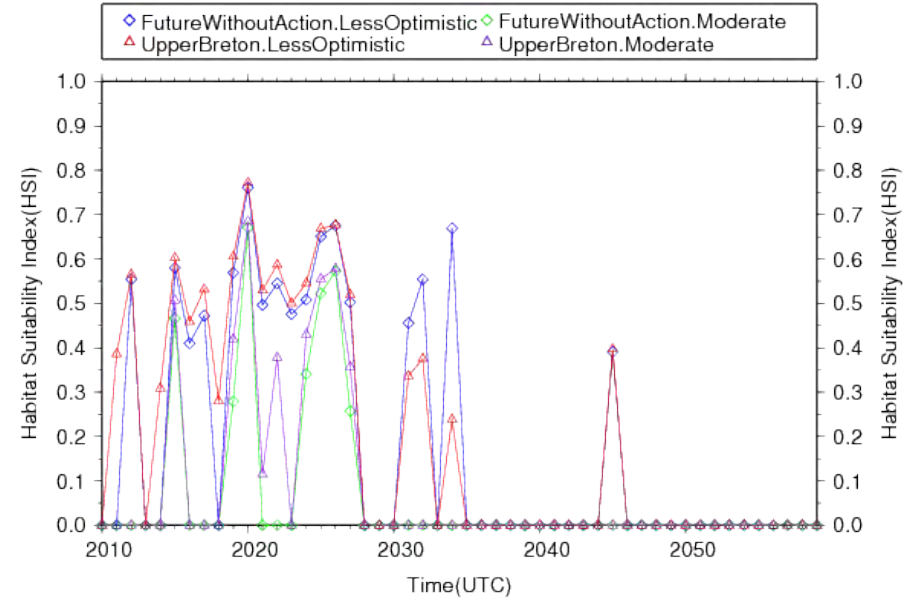


# HSI results, West Bank

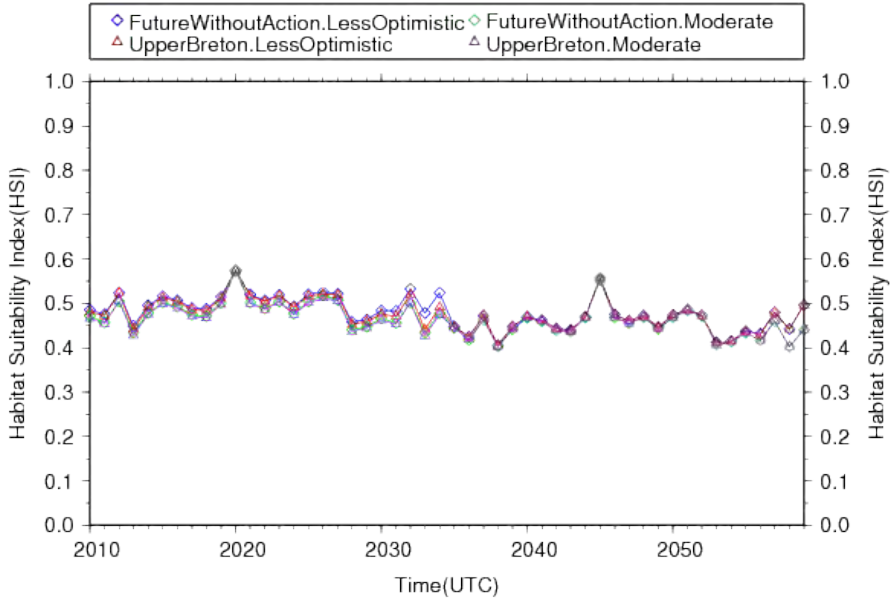




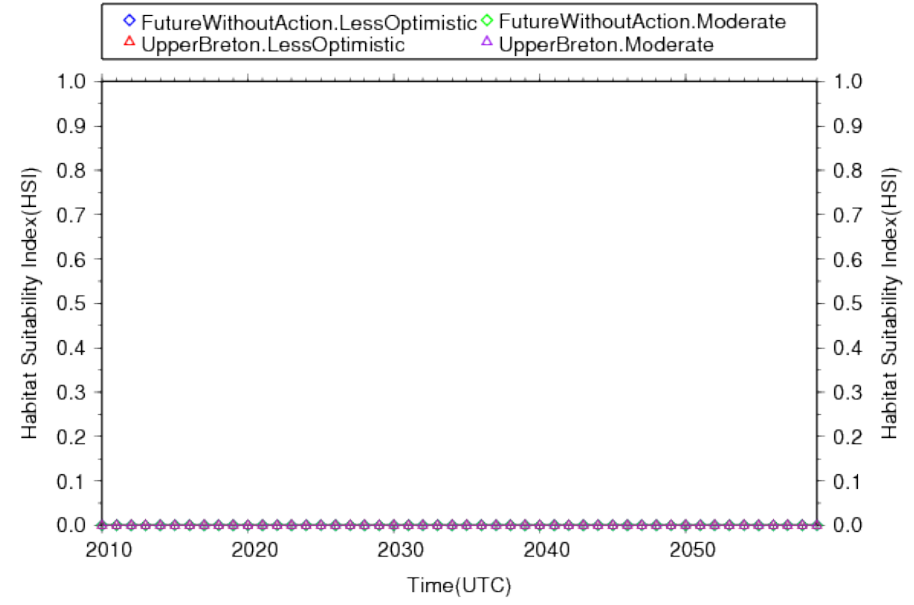
SpottedSeatroutHSI Changes At Texaco\_Canals

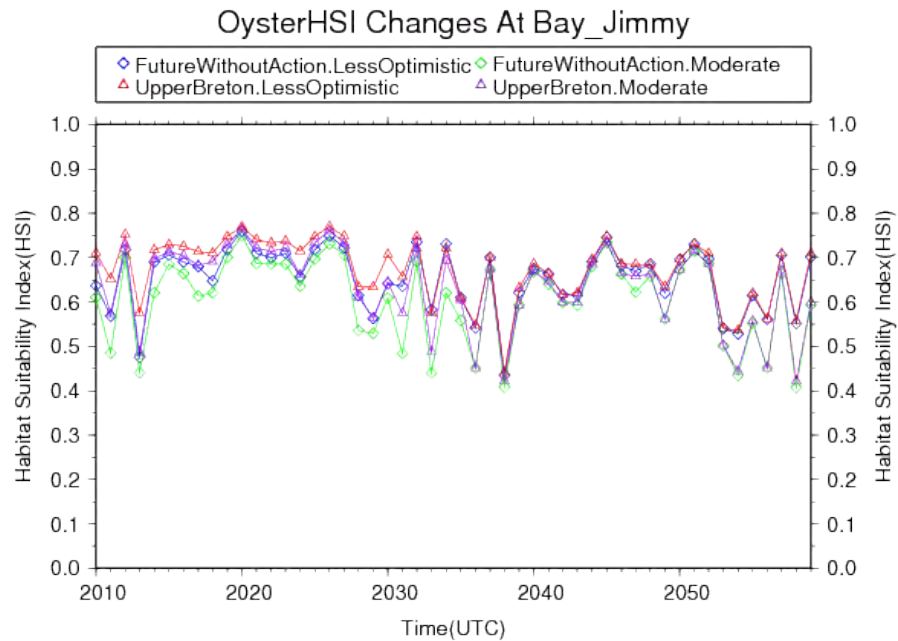
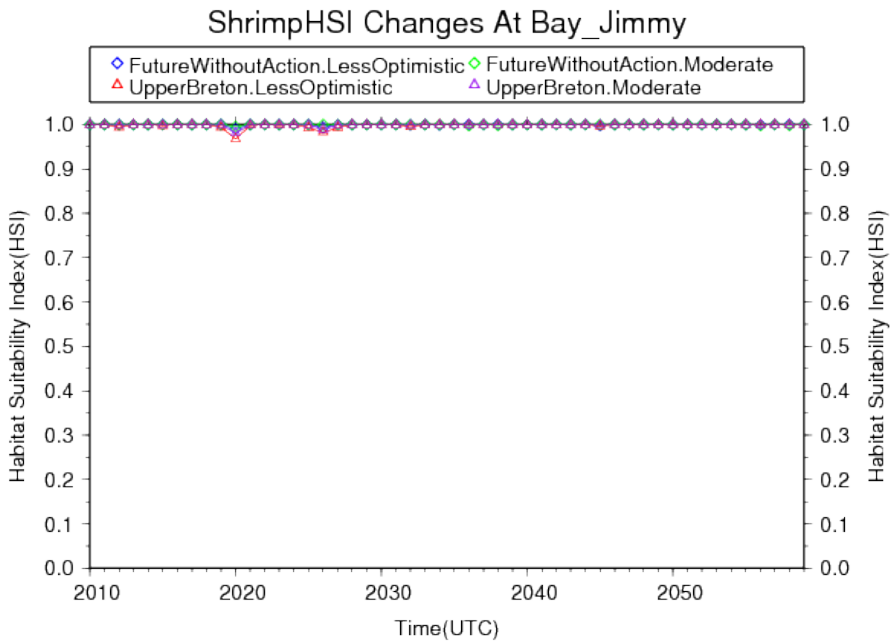
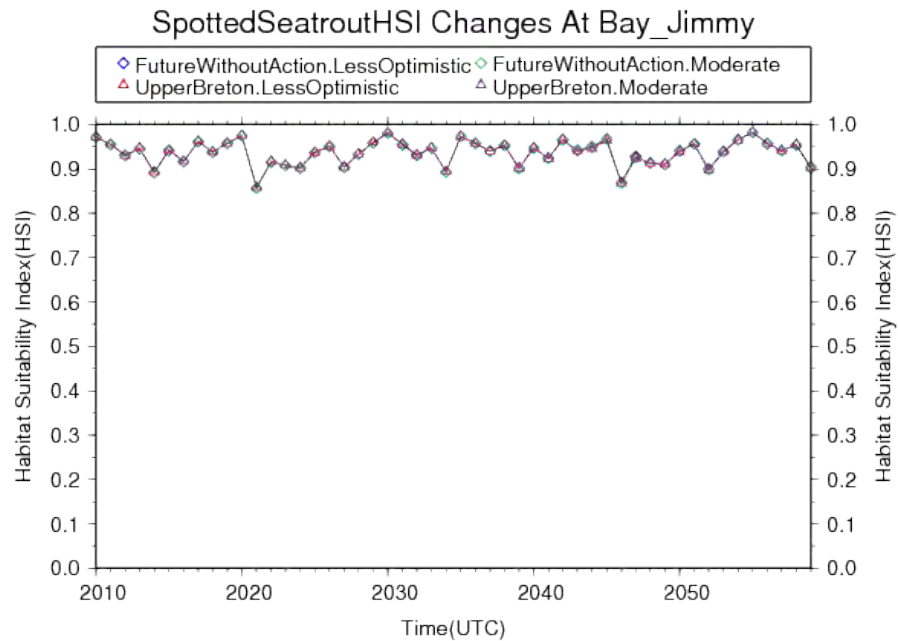


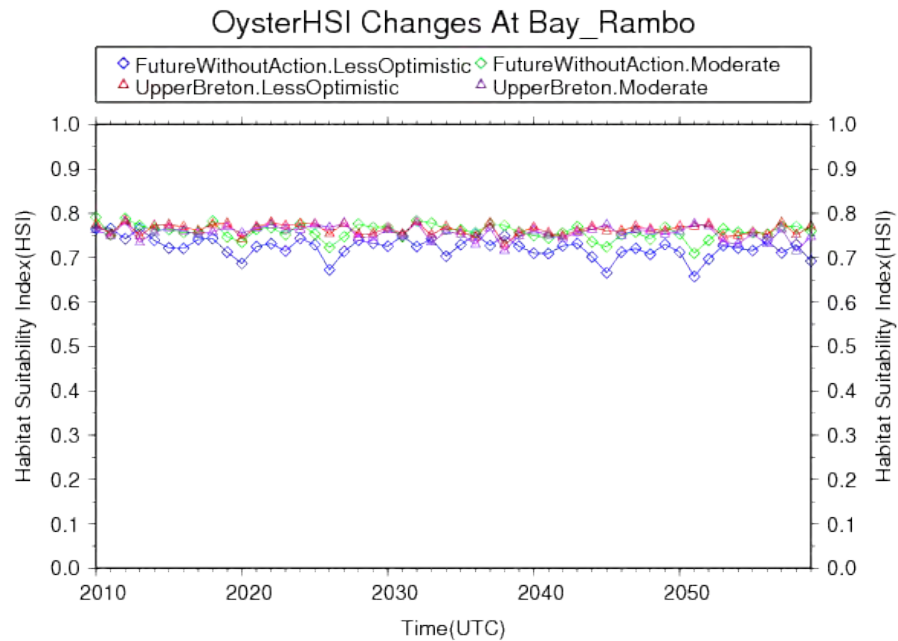
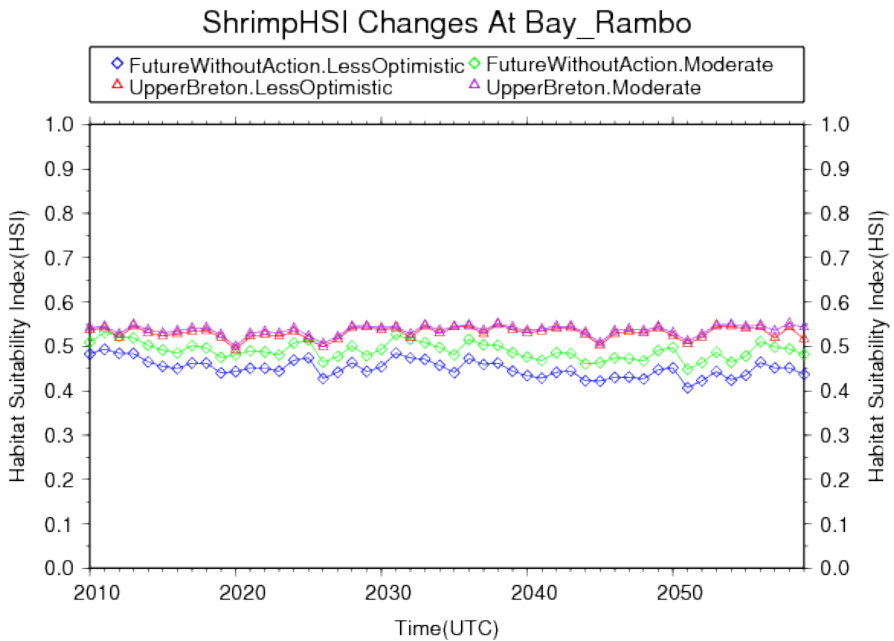
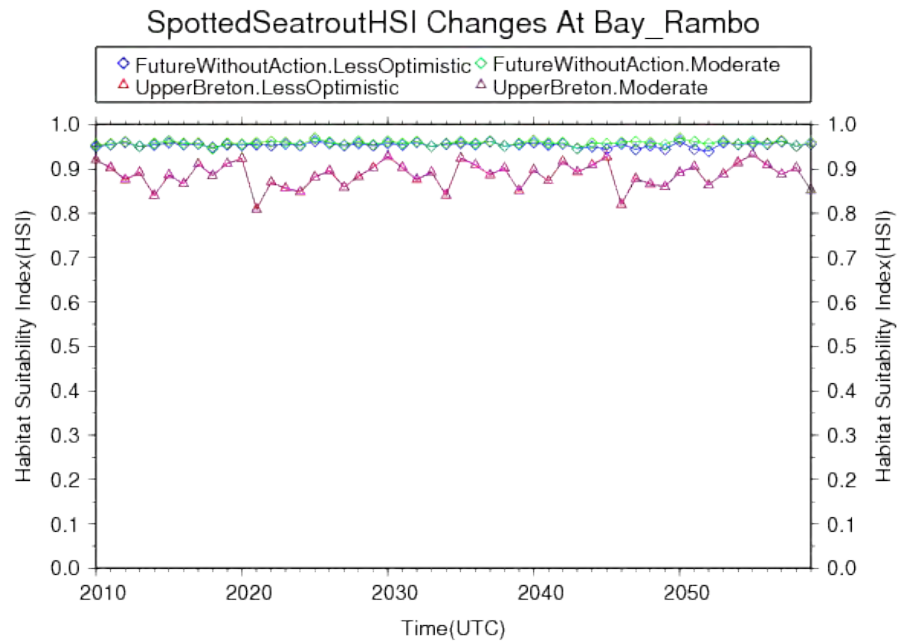
ShrimpHSI Changes At Texaco\_Canals



OysterHSI Changes At Texaco\_Canals



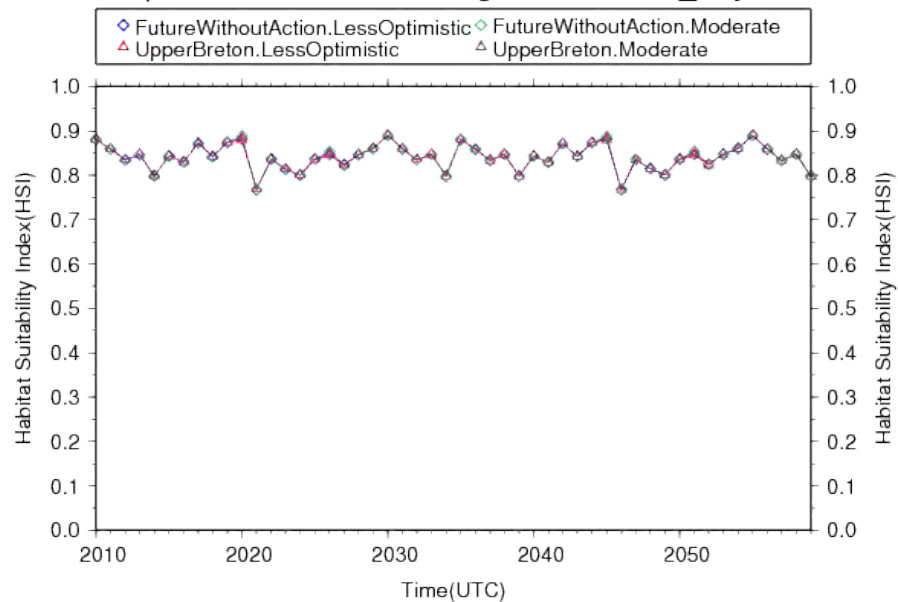




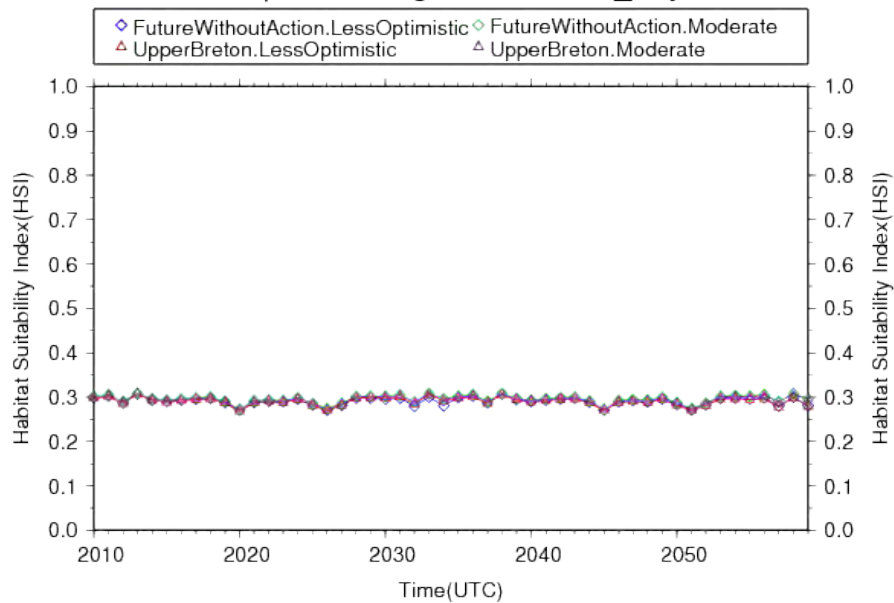




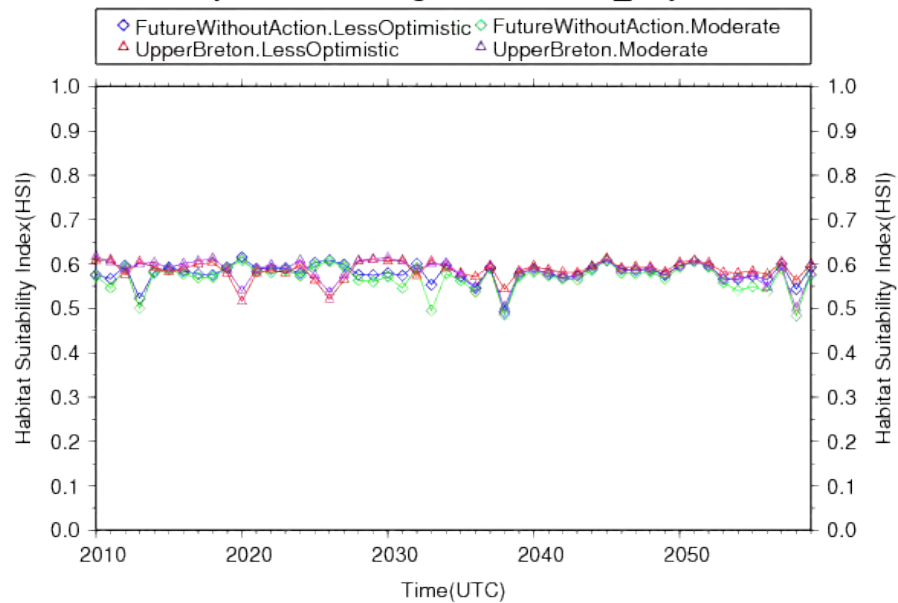
SpottedSeatroutHSI Changes At Scofield\_Bayou



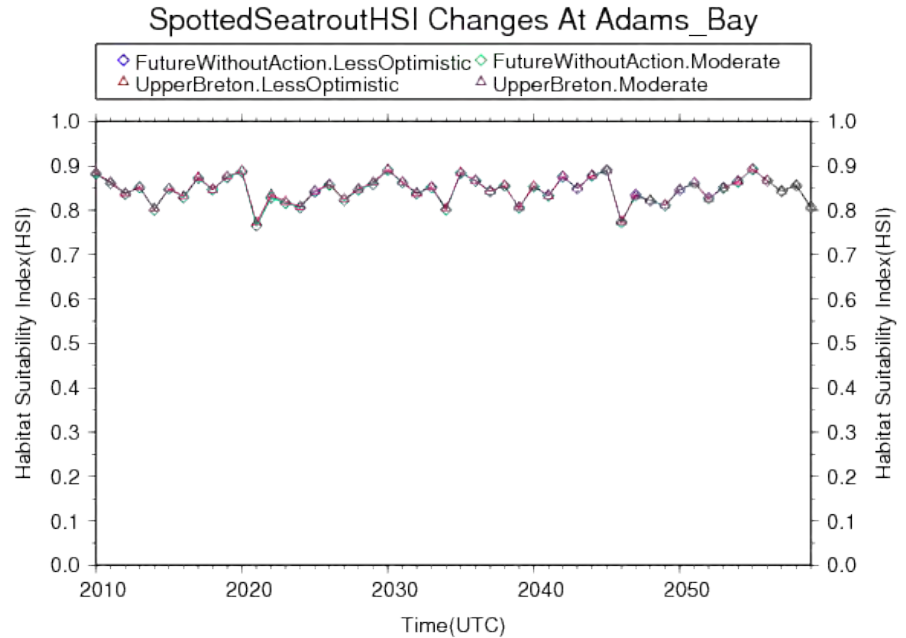
ShrimpHSI Changes At Scofield\_Bayou



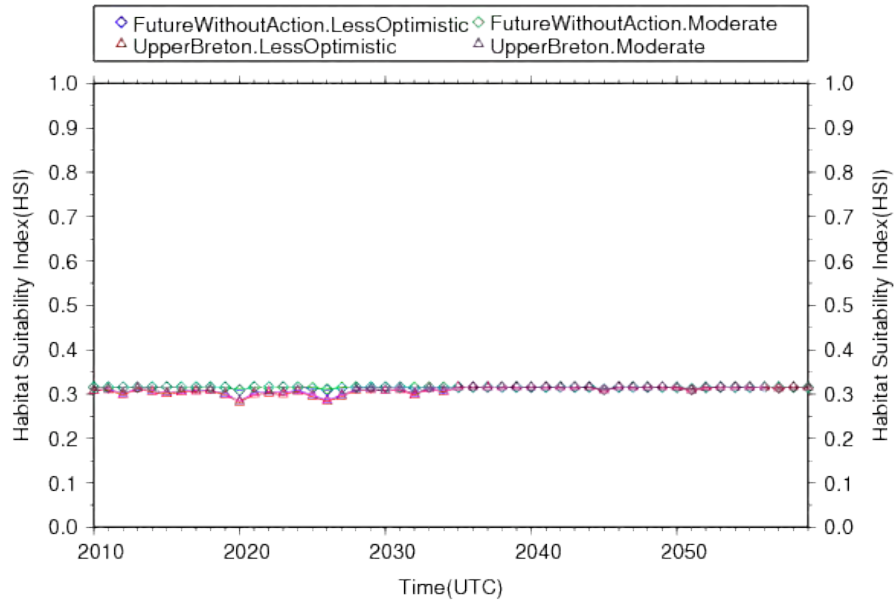
OysterHSI Changes At Scofield\_Bayou



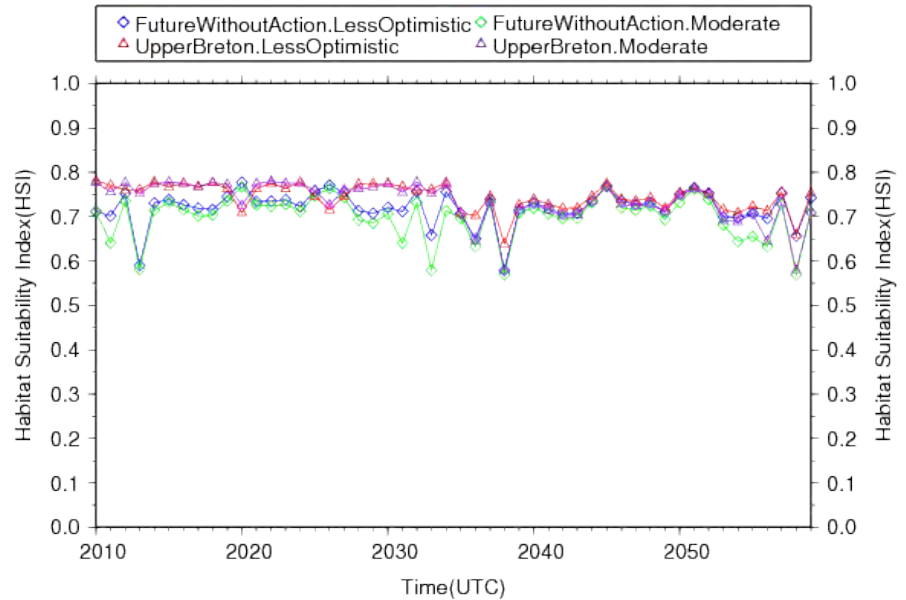


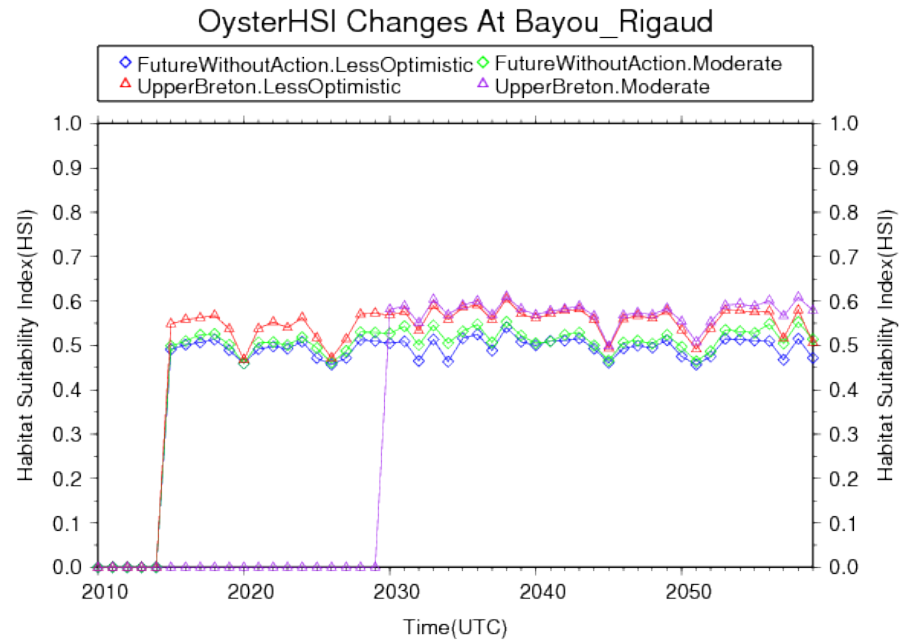
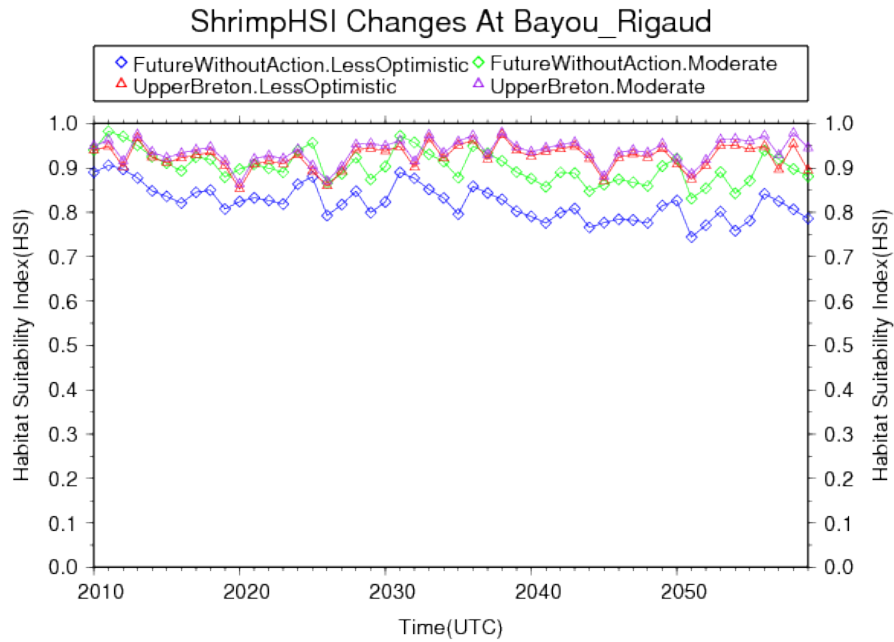
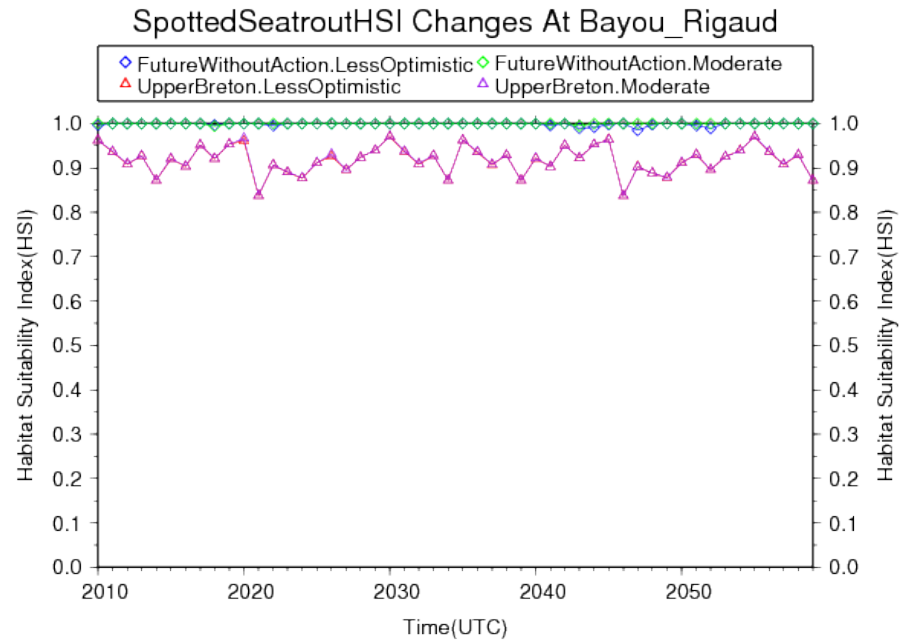


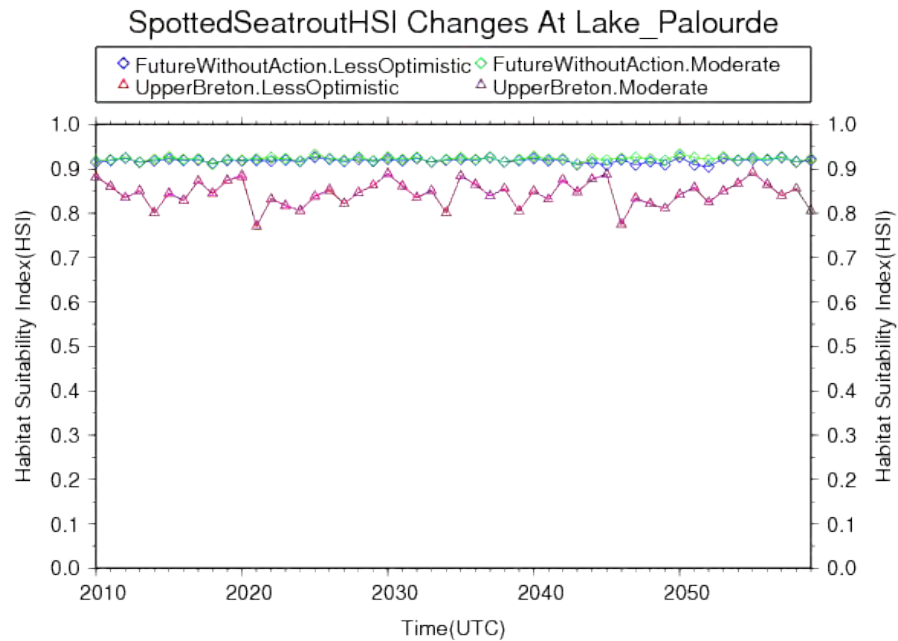
### ShrimpHSI Changes At Adams\_Bay



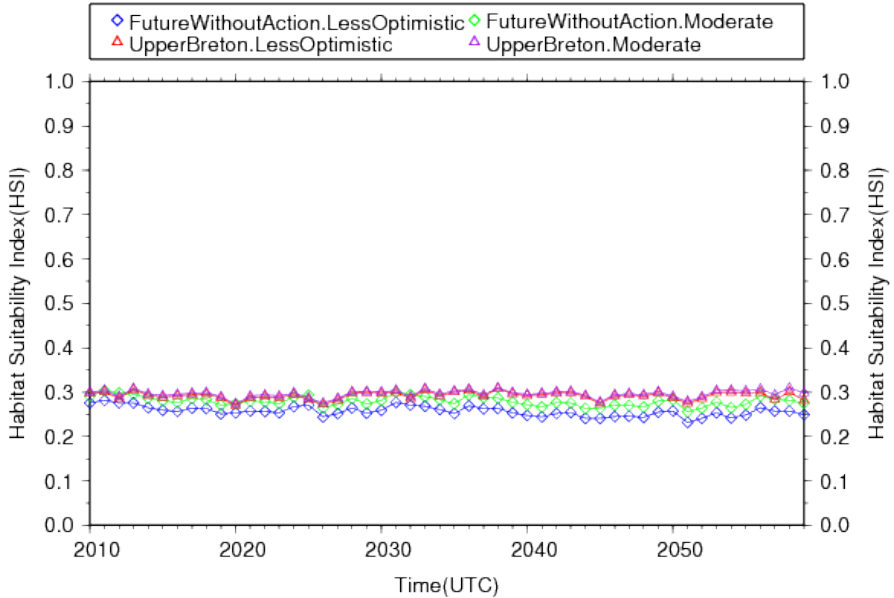
### OysterHSI Changes At Adams\_Bay



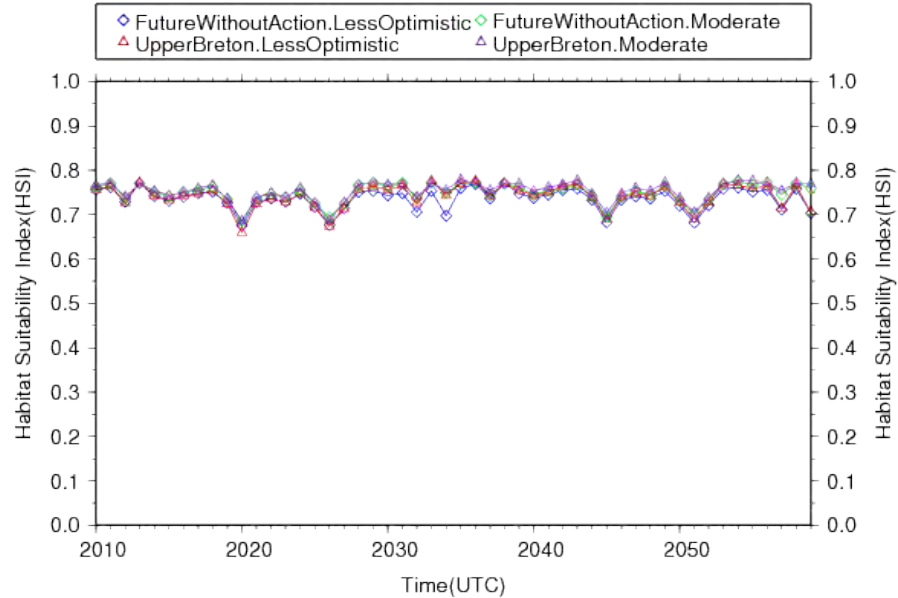




### ShrimpHSI Changes At Lake\_Palourde

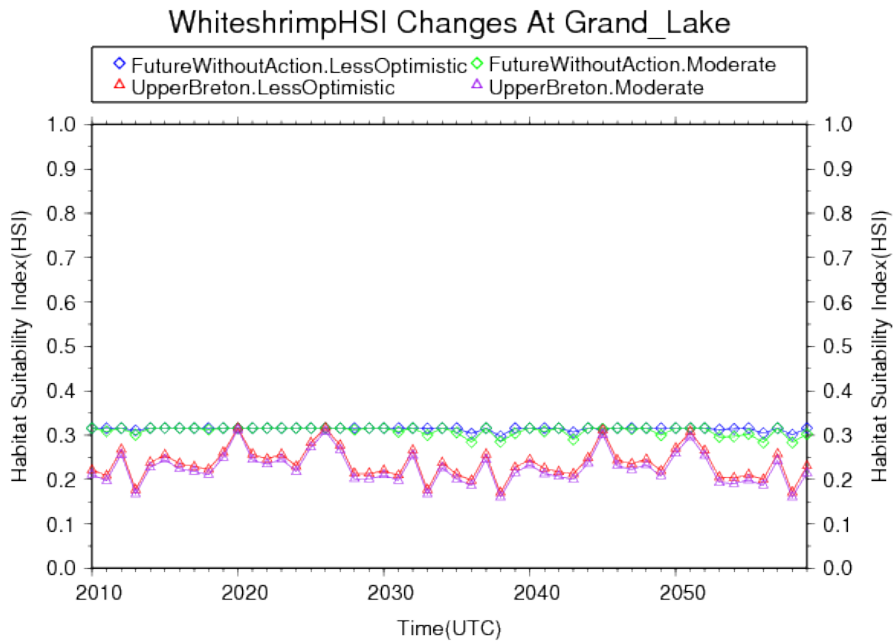
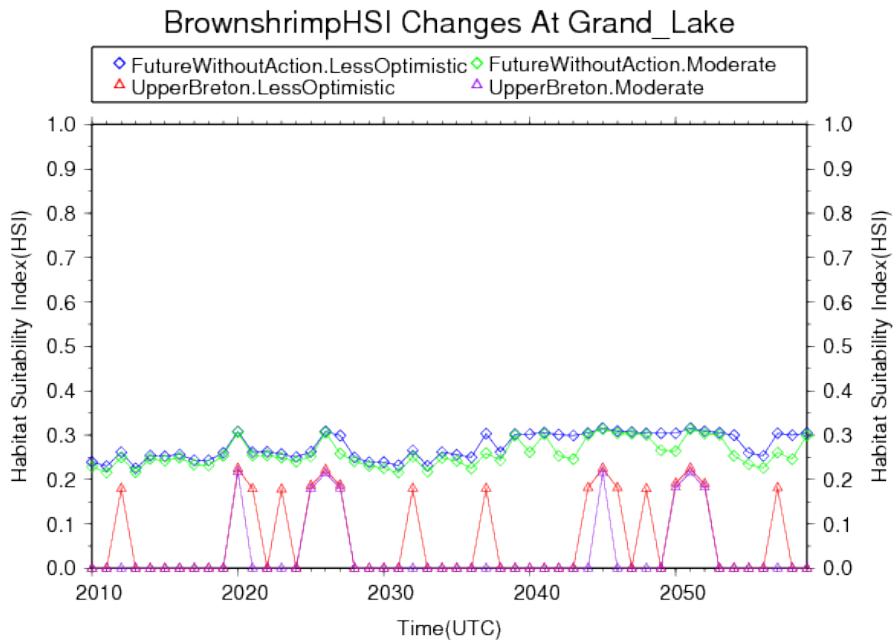
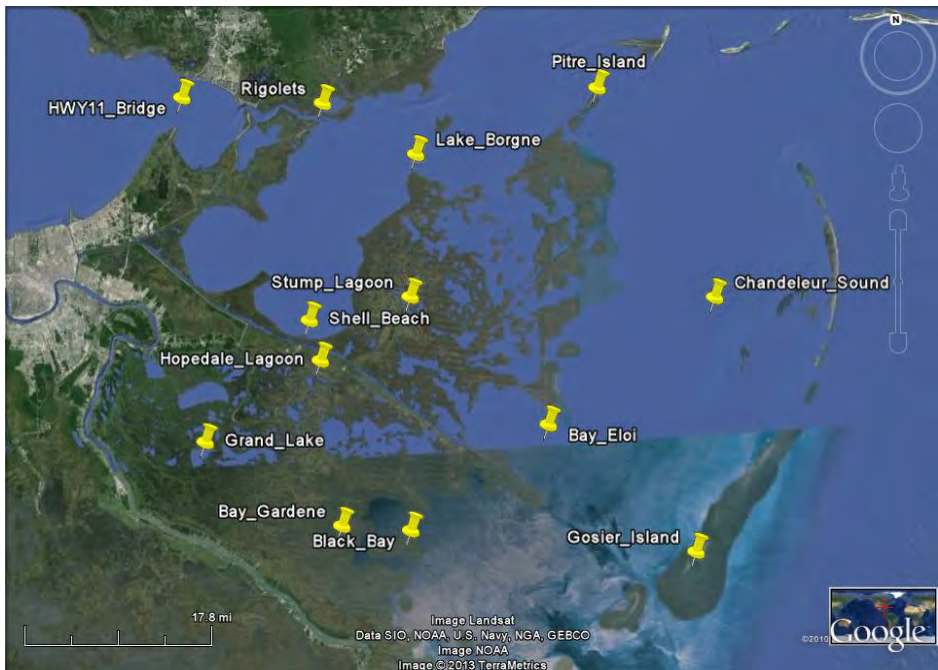


### OysterHSI Changes At Lake\_Palourde

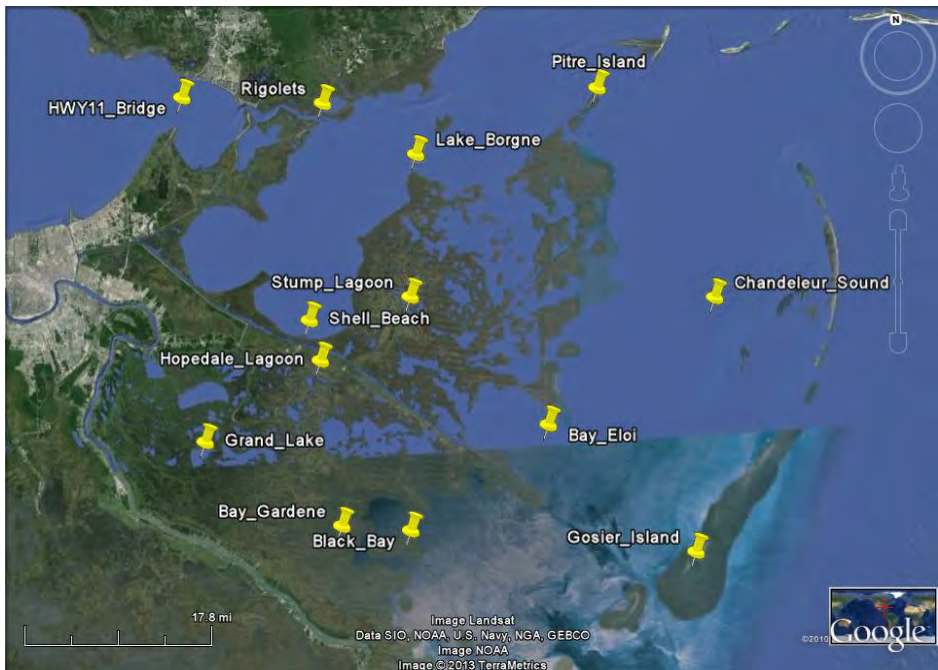


Locations with brown and white shrimp  
HSI differences

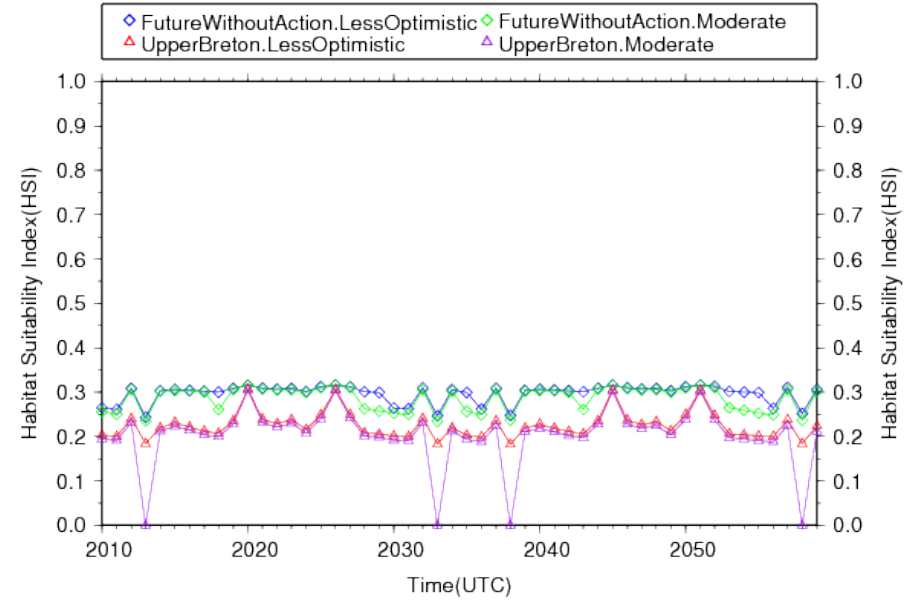




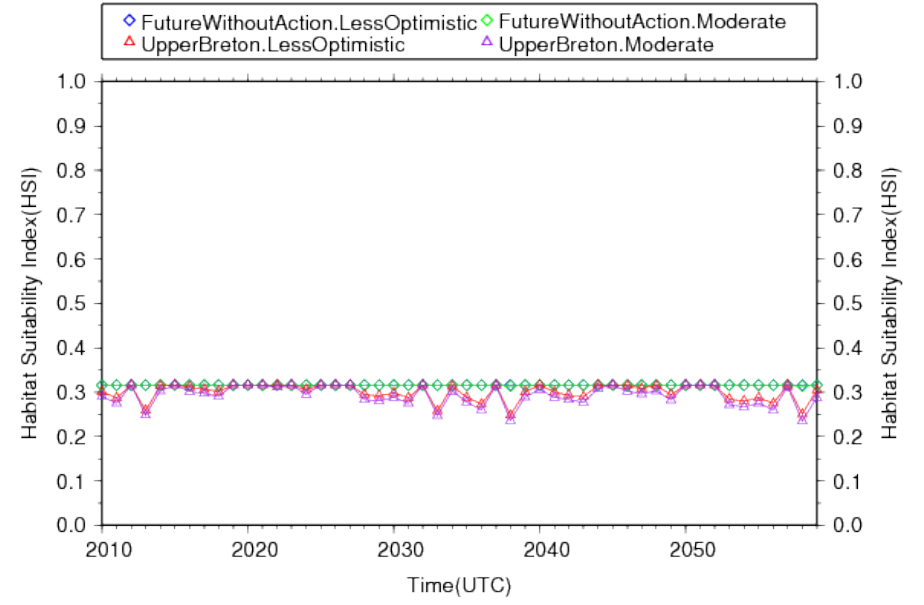


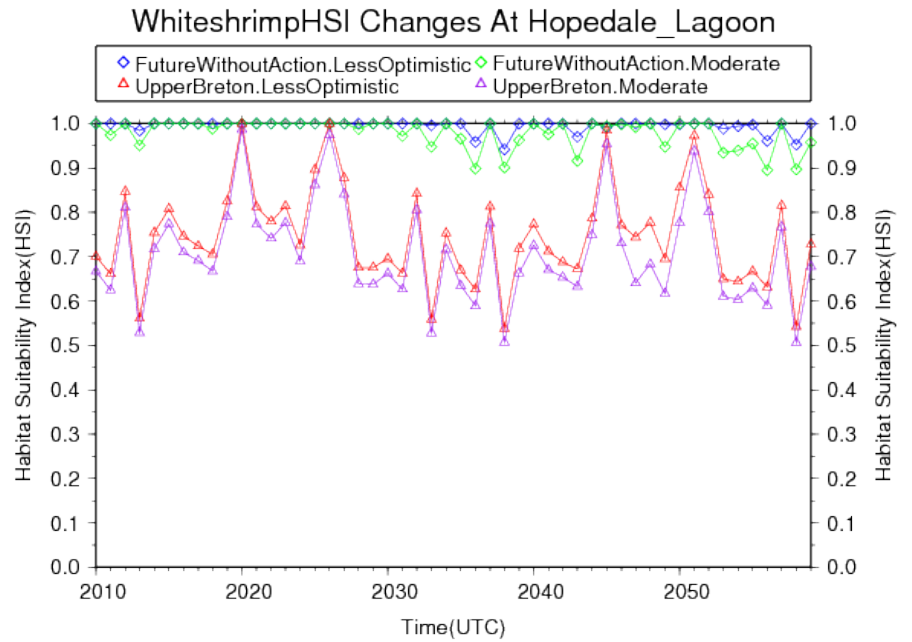
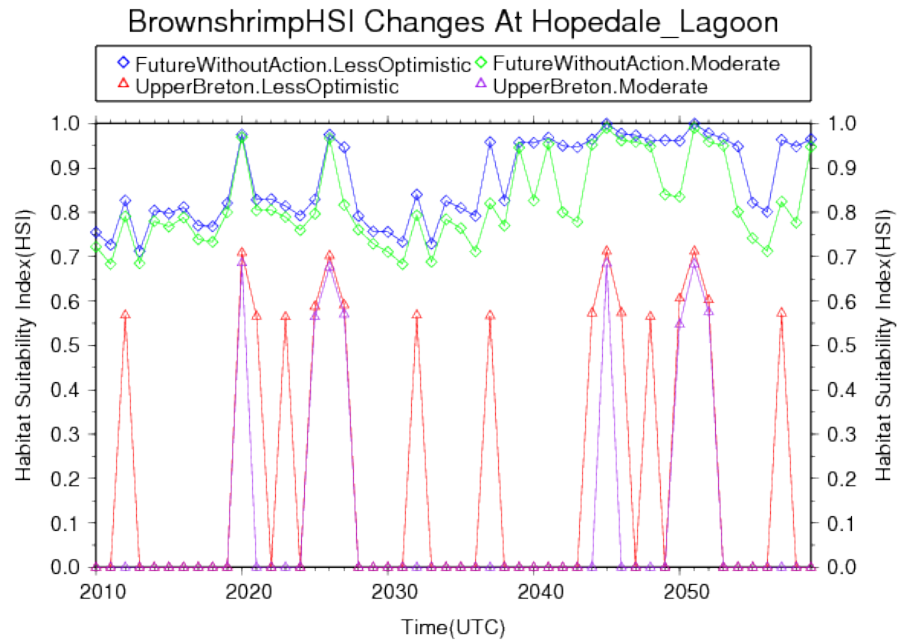
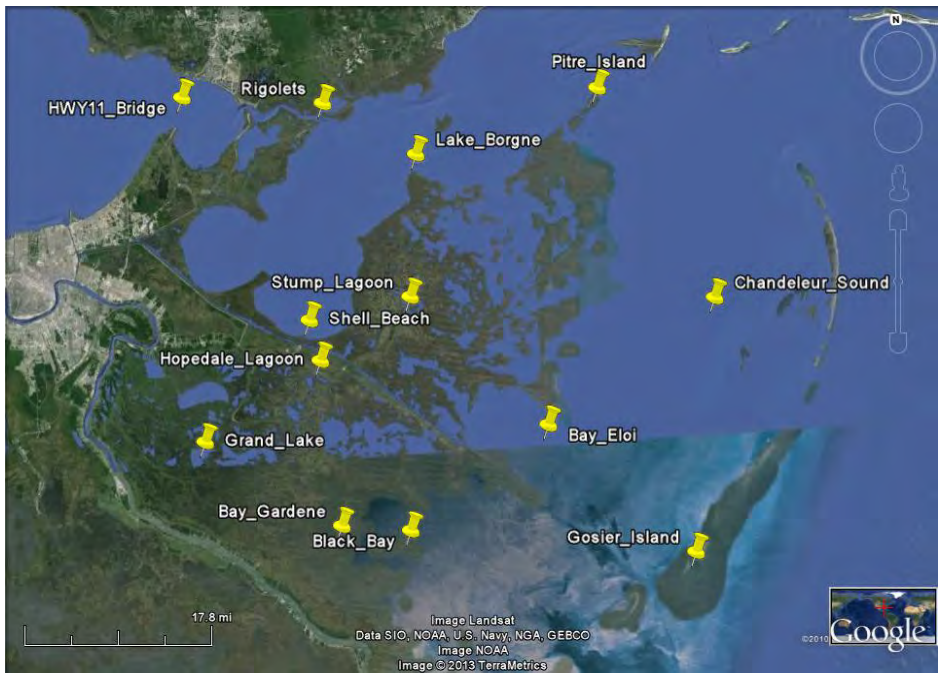


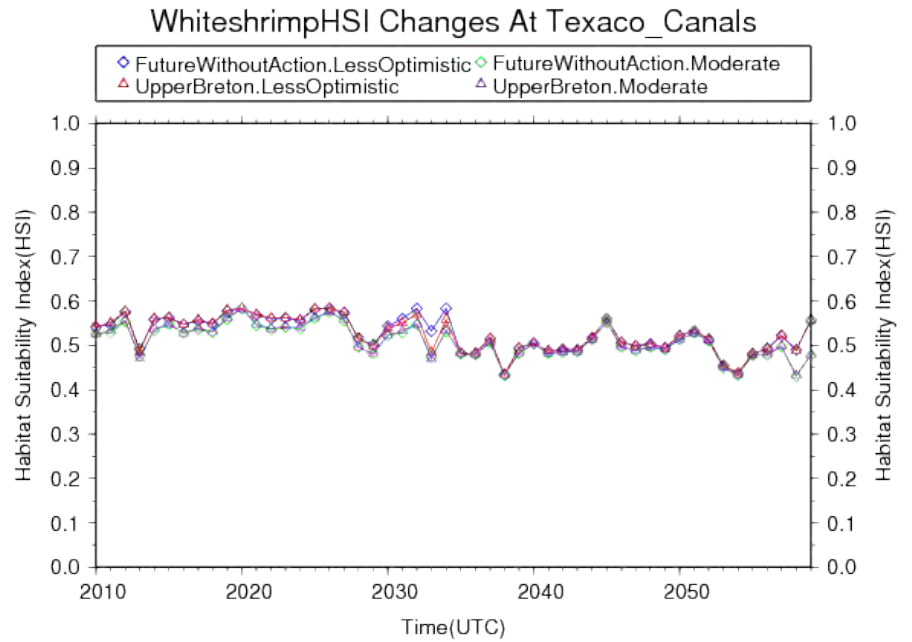
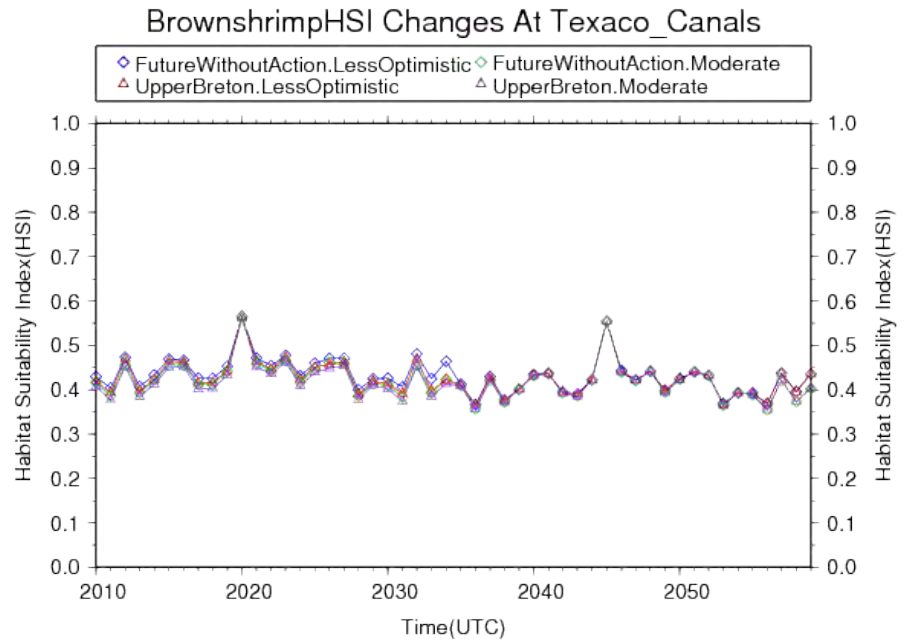
### Brownshrimp HSI Changes At Black\_Bay



### Whiteshrimp HSI Changes At Black\_Bay



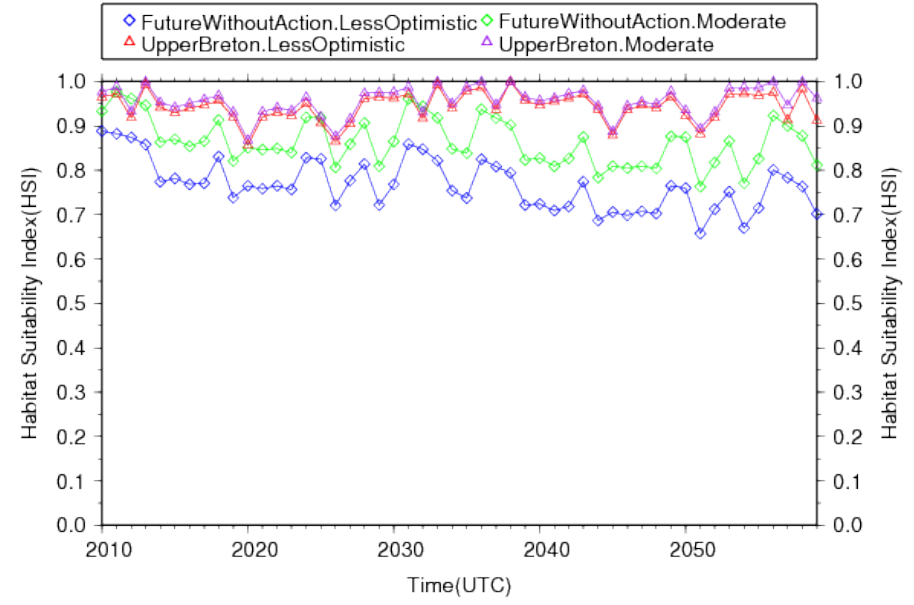




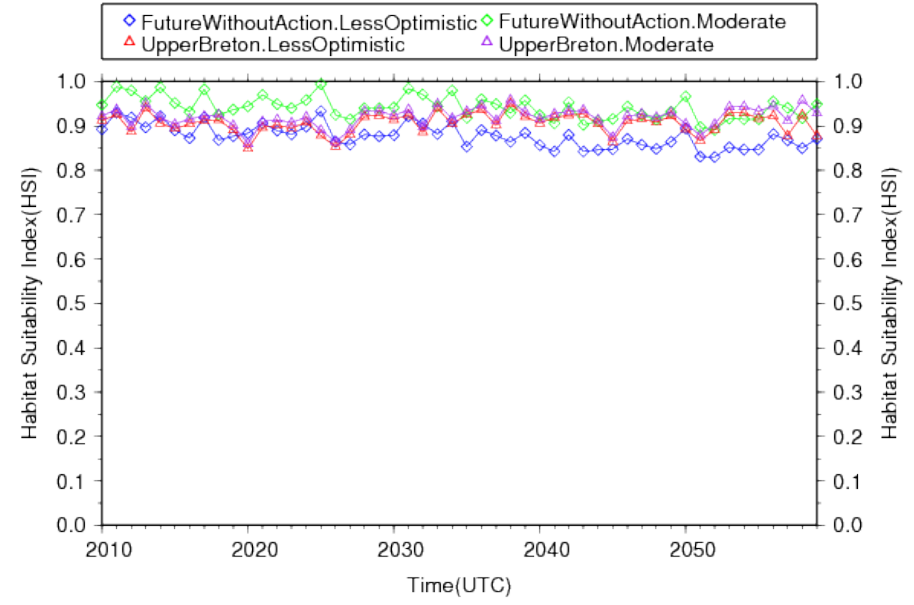




Brownshrimp HSI Changes At Bayou\_Rigaud



Whiteshrimp HSI Changes At Bayou\_Rigaud



# Assessment

- Should not be seen as final result, but starting point for fishery impact discussions.
- Caveat: this is for one diversion on each bank, and does not include the combination of multiple diversions or levee openings.
- The HSIs generally show unsuitable conditions for trout, brown shrimp, and oysters near diversions where salinity < 5 ppt. White shrimp may fair okay, with a tolerance for salinity > 3 ppt.
- On East Bank, Black Bay area will see fishery changes.
- On East Bank, north of MRGO will see fishery changes but it diminishes north and northeast.
- West bank has same general patterns. They suggest fishing productivity concentrated near the coast.
- Generally, fishery productivity is not enhanced by diversions for trout, shrimp, or oysters. Furthermore, at least slight overall productivity declines in shrimp and trout seem likely. However, some areas will retain a fishery as long as the 5 ppt line does not reach the location. Strict monitoring of the 5 ppt line will be needed.
- One exception where productivity may increase is behind Grand Isle for oysters and brown shrimp.

# Suggested next steps

- Obviously, the results are sensitive to the accuracy of the diversion simulations. The validity and resolution of the salinity values in particular require further study with regard to fishery impact.
- The Oyster HSI's may not consider three years for market size to be reached. If so, this should be added in the HSI equation.
- Spawning and larva impact for trout need to be addressed.
- Fishery experts should consider additional metrics for fishery impact. Commercial fishermen should provide feedback as well.
- Seasonal patterns have not been examined. Results suggest, for example, spawning trout on East Bank will move deep into the sounds or NE of Biloxi Marsh, but data is needed to clarify.



Extra material, oysters

## 2. Technical Quality

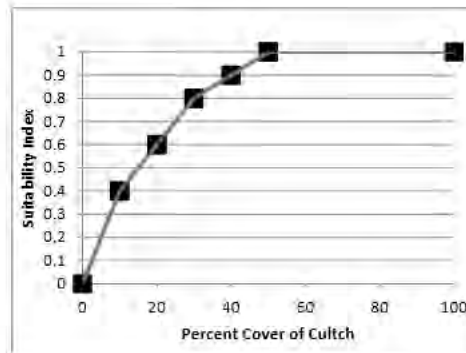
### a. Theory

Oyster larvae require a hard substrate (cultch) upon which to settle and metamorphose. Suitable substrates are hard bottoms such as natural oyster reefs or shell plants. Shell plants are constructed hard bottoms of natural substrate such as oyster shell or alternative substrate such as limestone. The first step in model development is the determination of variables to be included. The following variables were chosen to represent the minimal requirements of an Oyster HSI. Variable 1 ( $V_1$ ) is the percent of bottom covered with cultch. A high-quality bottom (grid) is considered to be one in which  $\geq 50\%$  is hard substrate (Cake 1983), whereas no hard substrate implies no suitable habitat. Cake (1983) considered the relationship between  $V_1$  and  $SI_1$  to be linear from 0 to 50% cultch. In the present construction, SI values for 10%, 20%, 30% and 40% were explicitly assigned, producing a hyperbolic appearance to the relationship between  $V_1$  and  $SI_1$ . The relationship between  $V_1$  and  $SI_1$  is somewhat arbitrary and arguably spatially dependent. At the extremes the relationship is certain – no substrate is unsuitable and 100% coverage is ideal. It is in the intermediate range of PC that the uncertainty arises. Furthermore, the relationship of  $V_1$  to  $SI_1$  *should* be scaled to the explicitly-stated areal unit to which it is applied. For example, requiring 100% PC for an SI of 1.0 in areas of the size of Eco-Hydrology polygons is out of scale, since PC in such large units is never 100% and certainly  $<10\%$ . Cake (1988) does not explicitly state the areal unit for the determination of percent coverage. Soniat and Brody (1988) field tested the Cake model on 0.1 ha sites. In the present model, the areal unit is a 500 x 500m grid. At such, a relatively small scale requiring 100% PC for an SI of 1.0 is within a reasonable spatial scale; in fact, some of the grids did achieve this standard. Since no complete data set exists from which PC values could be generated, an approach based upon a hierarchy of data quality and surrogates of percent coverage was used (see 1.d. above). Unlike the salinity values that change with each model run (i.e., each year), grid percent coverage with cultch is typically the same for all model runs (and years). Changes in the static cultch file are, however, allowed in three special conditions. (1) Reef projects that add cultch to the bottom. Grids can be modified to reflect the new conditions. Grids are assigned PC values according to project specifications or outcomes. This exception allows for the inclusion of

#### APPENDIX D-13 EASTERN OYSTER HABITAT SUITABILITY INDEX TECHNICAL REPORT

restoration projects such as reef building to enhance oyster habitat. (2) Manipulations of the cultch grid to allow for identification of potential for oyster habitat if salinity is suitable. Artificially setting a PC value in selected grids (in addition to the static PC file) and calculating the HSI value provides a tool for locating areas for reef projects such as those described in (1) above. (Potential oyster habitat can also be identified by a four variable model which excludes PC, as discussed below.) (3) Allowances for land loss (newly created open water areas) to become suitable oyster habitat, by implementing model code changes that incorporate percent land. The default PC for newly created open water is 0%, but can be adjusted for scenarios incorporating proposed reef construction (as in 1 above) or for selecting locations for reef construction (as in 2 above).

$S_{I_1} =$	0.0	for $V_1 = 0$
	0.4	for $V_1 = 10$
	0.6	for $V_1 = 20$
	0.8	for $V_1 = 30$
	0.9	for $V_1 = 40$
	1.0	for $V_1 = 50$
	1.0	for $V_1 = 100$

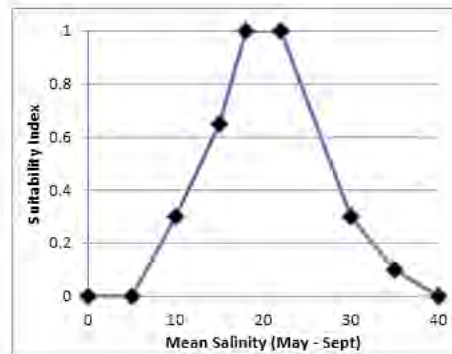


Three salinity-based variables, which describe different aspects of the oyster's dependency on salinity, are defined. Oysters require a higher salinity for spawning than for survival of adults. An annual mean salinity designates an expected range over which oysters exist and an optimum range over which they thrive, and a minimum salinity describes the potential impacts of floods. Salinity values are derived from the spatially-referenced data in polygons provided by the Eco-Hydrology model. See 1.d. above for the method by which monthly salinity values were interpolated for this model. These interpolated monthly values for each 500 x 500m grid were used to derive values for each of the following salinity-based variables.

Variable 2 ( $V_2$ ) is the mean salinity during the spawning season. The value applied is the mean of the monthly May through September salinities for each 500 x 500m grid. This variable reflects the higher optimal salinities required for spawning as opposed to the optimum salinity requirements of adults (Butler 1954, Cake 1983).

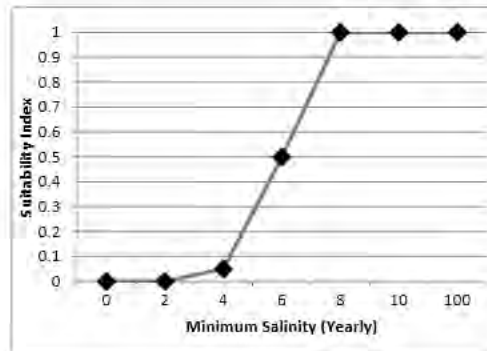
APPENDIX D-13 EASTERN OYSTER HABITAT SUITABILITY INDEX TECHNICAL REPORT

$SI_2 =$	0	for $V_2 = 0$
	0	for $V_2 = 5$
	0.3	for $V_2 = 10$
	0.65	for $V_2 = 15$
	1.0	for $V_2 = 18$
	1.0	for $V_2 = 22$
	0.3	for $V_2 = 30$
	0.1	for $V_2 = 35$
	0	for $V_2 = 40$



Variable 3 ( $V_3$ ) is the minimum salinity, i.e. the minimum value of the 12 monthly mean salinities for each 500 x 500m grid. Minimum salinity values were derived from the spatially-referenced data in polygons provided by the Eco-Hydrology model after linear interpolations were made across salinity gradients, and each grid was populated with a monthly salinity value. The lowest value of monthly salinity was used as the minimum salinity. Minimum salinity is a surrogate for frequency of floods in the models of Cake (1983) and Sniat and Brody (1988), which require long-term historical salinity data sets for parameterization. This variable is essential to describe impacts of freshwater diversions or hydrological alterations. Low salinity has a greater negative impact in the summer than in the winter; however, the model does not include a temperature effect. Furthermore, the relationship between minimum salinity and SI does not describe any potential positive benefits of floods, such as reducing predators and disease (Butler 1953, Gunter 1979, Mackin 1962, LaPeyre et al. 2009).

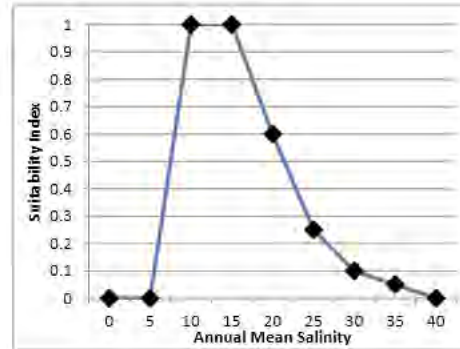
$SI_3 =$	0.0	for $V_3 = 0$
	0.0	for $V_3 = 2$
	0.05	for $V_3 = 4$
	0.5	for $V_3 = 6$
	1.0	for $V_3 = 8$
	1.0	for $V_3 = 10$



APPENDIX D-13 EASTERN OYSTER HABITAT SUITABILITY INDEX TECHNICAL REPORT

Variable 4 ( $V_4$ ) is annual mean salinity. The value for  $V_4$  is the grand mean of the 12 monthly mean salinities for each 500 x 500m grid. Annual mean salinity defines the range over which adult oysters survive and thrive (Gunter 1955, Calabrese and Davis 1970, Castagna and Chanley 1973, Cake 1983, Chatry et al. 1983). The relationship between  $V_4$  and  $SI_4$  follows that of Soniat and Brody (1988), with the exception that the optimum annual mean salinity in the present HSI is a range (10 to 15 ppt) and not a discrete point (12.5 ppt).

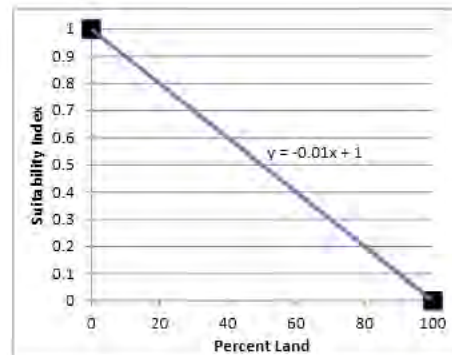
$SI_4 =$	0.0	for $V_4 = 0$
	0.0	for $V_4 = 5$
	1.0	for $V_4 = 10$
	1.0	for $V_4 = 15$
	0.6	for $V_4 = 20$
	0.25	for $V_4 = 25$
	0.1	for $V_4 = 30$
	0.05	for $V_4 = 35$
	0.0	for $V_4 = 40$



Variable 5 ( $V_5$ ) is percent land. It restricts oysters to aquatic habitats by excluding terrestrial habitats. This variable is used to scale all of the others since they are based on a full 500 X 500m grid cell, but water may not cover the entire cell. NOTE: Use Percent Land as a percentage in the equation, but  $V_5$  is reported as a value between 0 and 1. This is an output from the Wetland Morphology model (see Appendix D-2).

$$V_5 = (-0.01 \times \%Land) + 1$$

$$SI_5 = V_5$$





Extra material, trout

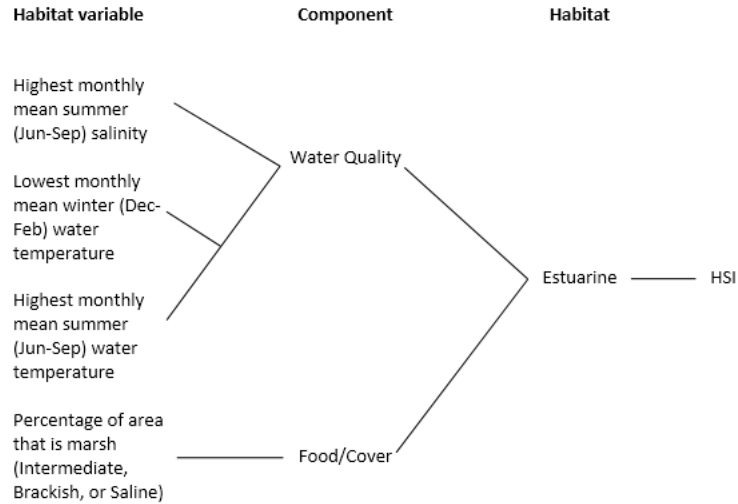
## **2. *Technical Quality***

### **a. Theory**

The spotted seatrout HSI model predicts the suitability of habitat for the juvenile life stage and is based on food/cover and water quality environmental variables. Juvenile spotted seatrout are sensitive to environmental variation and are assumed to be important in contributing to population size (Kostecki 1984).

APPENDIX D-18 SPOTTED SEATROUT (JUVENILE) HABITAT SUITABILITY INDEX TECHNICAL REPORT

An index value between zero (unsuitable habitat) and one (optimal habitat) is generated by the model.



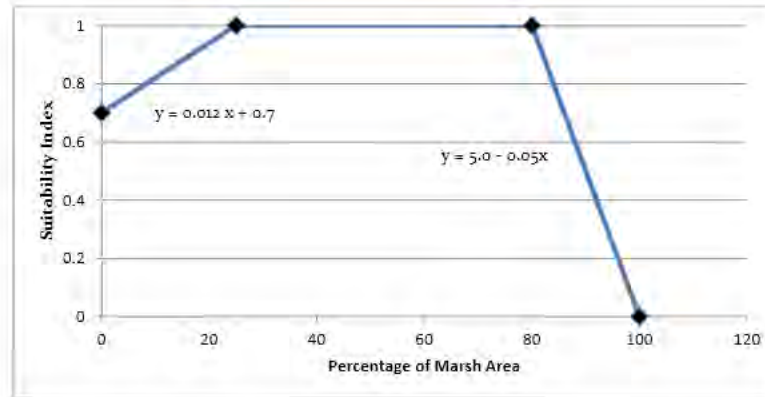
The variables included in this model are: V1 - the percentage of area km<sup>2</sup> that is covered by marsh vegetation, V2 – the highest mean summer (Jun-Sep) salinity, V3 - the highest monthly mean summer (Jun-Sep) temperature, and V4 – the mean lowest mean winter (Dec-Feb) water temperature. The model outputs on a yearly time step for a period of 50 years.

*Variable 1: Percentage of area that is marsh (Intermediate, Brackish, or Saline)*

Suitability function for V1

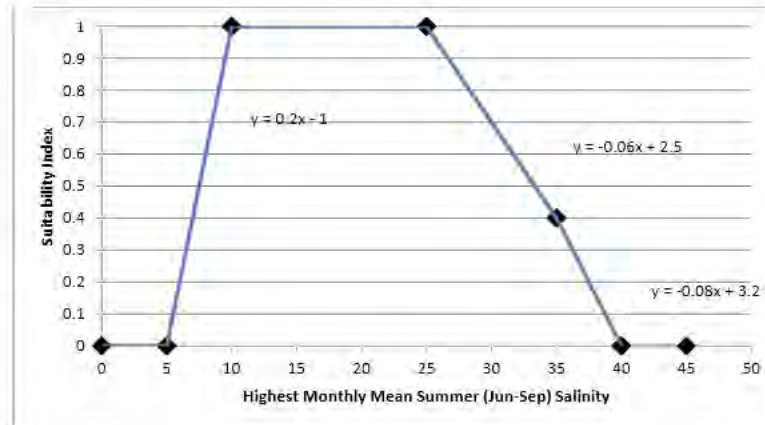
$Sl_1 = 0.012 * V1 + 0.7$	for $0 \leq V1 \leq 25$
1.0	for $25 < V1 \leq 80$
$5.0 - 0.05 * V1$	for $80 < V1 \leq 100$

APPENDIX D-18 SPOTTED SEATROUT (JUVENILE) HABITAT SUITABILITY INDEX TECHNICAL REPORT



Variable 2: Highest monthly mean summer (Jun-Sep) salinity  
Suitability function for V2

$S_{I2} = 0$	for $V2 \leq 5$
$0.2 * V2 - 1.0$	for $5 < V2 \leq 10$
$1.0$	for $10 < V2 \leq 25$
$-0.06 * V2 + 2.5$	for $25 < V2 \leq 35$
$-0.08 * V2 + 3.2$	for $35 < V2 \leq 40$
$0$	for $V2 > 40$

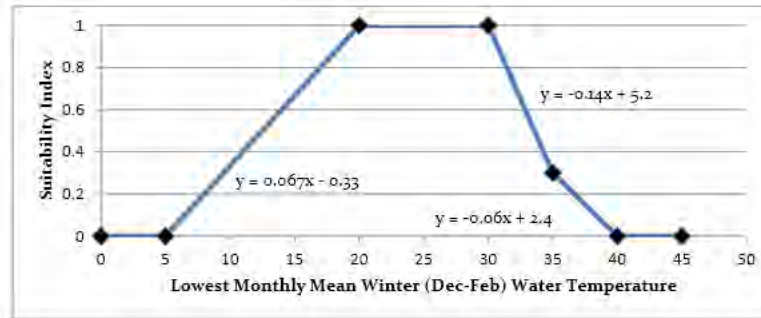


APPENDIX D-18 SPOTTED SEATROUT (JUVENILE) HABITAT SUITABILITY INDEX TECHNICAL REPORT

Variable 3: Lowest monthly mean winter (Dec-Feb) water temperature

Suitability function for V3

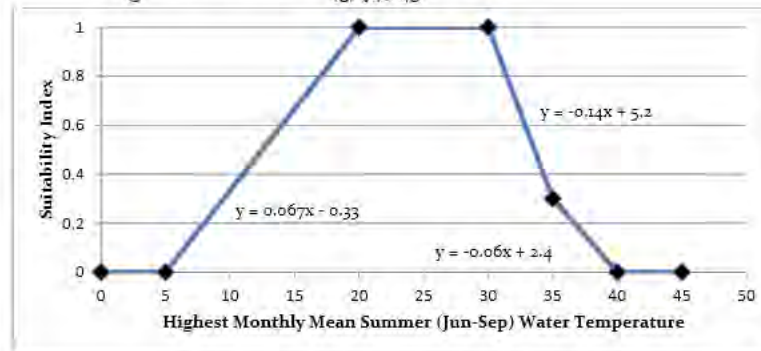
$$SI_3 = \begin{cases} 0 & \text{for } V3 \leq 5 \\ 0.067 * V3 - 0.33 & \text{for } 5 < V3 \leq 20 \\ 1 & \text{for } 20 < V3 \leq 30 \\ -0.14 * V3 + 5.2 & \text{for } 30 < V3 \leq 35 \\ -0.06 * V3 + 2.4 & \text{for } 35 < V3 \leq 40 \\ 0 & \text{for } V3 > 40 \end{cases}$$



Variable 4: Highest monthly mean summer (Jun-Sep) water temperature

Suitability function for V4

$$SI_4 = \begin{cases} 0 & \text{for } V4 \leq 5 \\ 0.067 * V4 - 0.33 & \text{for } 5 < V4 \leq 20 \\ 1 & \text{for } 20 < V4 \leq 30 \\ -0.14 * V4 + 5.2 & \text{for } 30 < V4 \leq 35 \\ -0.06 * V4 + 2.4 & \text{for } 35 < V4 \leq 40 \\ 0 & \text{for } V4 > 40 \end{cases}$$



Habitat Suitability Index

The formula for combining the variables is:  $HSI = (SI_1 * SI_2 * SI_3 * SI_4)^{1/4}$





Extra material, white shrimp

## 2. *Technical Quality*

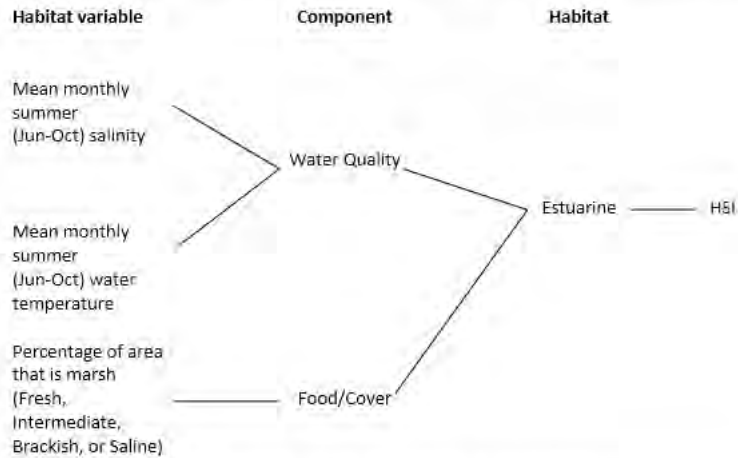
### a. **Theory**

The white shrimp HSI model predicts the suitability of habitat for the juvenile life stage. This stage is sensitive to environmental variation and is assumed to be important in contributing to population size (Turner and Brody 1983). An index between zero (unsuitable habitat) and one (optimal habitat) is generated by this model.

The model is generated by using two primary habitat components: water quality & food/cover.

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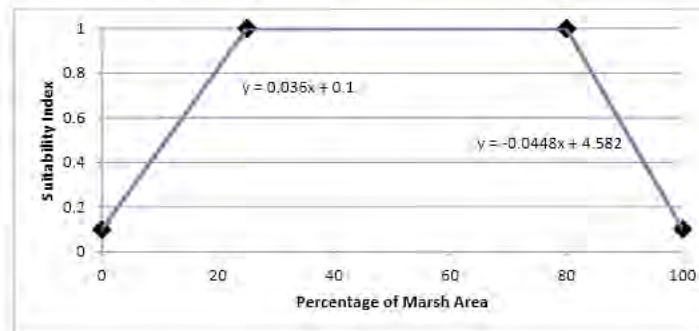
APPENDIX D-17 SHRIMP, WHITE (JUVENILE) HABITAT SUITABILITY INDEX TECHNICAL REPORT



The variables included in this model are: V1 - Percentage of area km<sup>2</sup> that is land, V2 - Mean salinity for summer (June - October), and V3 - Mean water temperature for summer (June - October). The model outputs on a yearly time step for a period of 50 years.

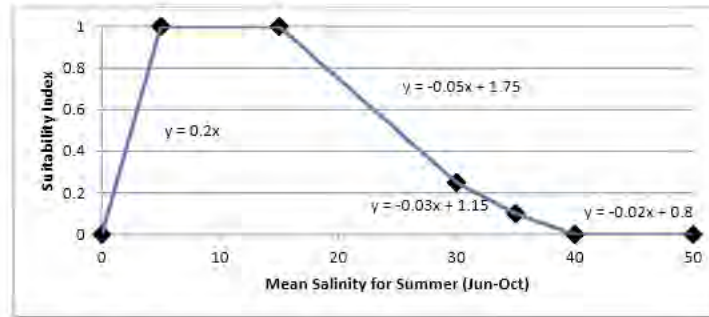
Variable 1: Percentage of Area (km<sup>2</sup>) Covered by Marsh Vegetation

$$SI_1 = \begin{cases} 0.036 * V1 + 0.1 & \text{for } 0 \leq V1 \leq 25 \\ 1.0 & \text{for } 25 < V1 \leq 80 \\ 4.582 - 0.0448 * V1 & \text{for } 80 < V1 \leq 100 \end{cases}$$



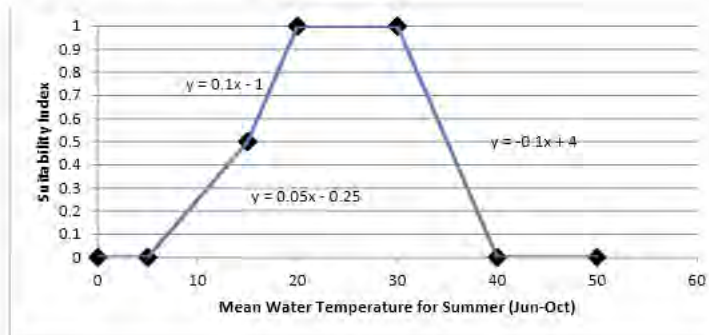
Variable 2: Mean Salinity for Summer (June-October)

$$SI_2 = \begin{cases} 0.2 * V_2 & \text{for } V_2 \leq 5 \\ 1.0 & \text{for } 5 < V_2 \leq 15 \\ -0.05 * V_2 + 1.75 & \text{for } 15 < V_2 \leq 30 \\ -0.03 * V_2 + 1.15 & \text{for } 30 < V_2 \leq 35 \\ -0.02 * V_2 + 0.8 & \text{for } 35 < V_2 \leq 40 \\ 0.0 & \text{for } V_2 > 40 \end{cases}$$



Variable 3: Mean Water Temperature for Summer (June-October)

$$SI_3 = \begin{cases} 0.0 & \text{for } V_3 \leq 5 \\ 0.05 * V_3 - 0.25 & \text{for } 5 < V_3 \leq 15 \\ 0.1 * V_3 - 1.0 & \text{for } 15 < V_3 \leq 20 \\ 1.0 & \text{for } 20 < V_3 \leq 30 \\ -0.1 * V_3 + 4.0 & \text{for } 30 < V_3 \leq 40 \\ 0.0 & \text{for } V_3 > 40 \end{cases}$$



Habitat Suitability Index

The formula for combining the variables is:  $HSI = (SI_1^2 \times SI_2 \times SI_3)^{1/4}$



Extra material, brown shrimp

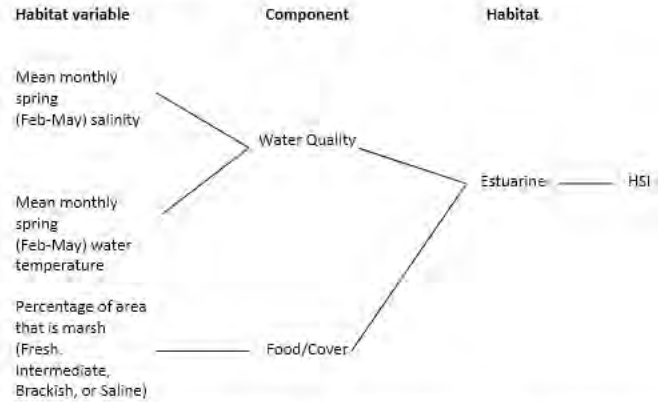
## 2. *Technical Quality*

### a. **Theory**

The brown shrimp HSI model predicts the suitability of habitat for the juvenile life stage. This stage is sensitive to environmental variation and is assumed to be important in contributing to population size (Turner and Brody 1983). An index between zero (unsuitable habitat) and one (optimal habitat) is generated by this model.

The model is generated by using two primary habitat components: water quality & food/cover.

APPENDIX D-16 SHRIMP, BROWN (JUVENILE) HABITAT SUITABILITY INDEX TECHNICAL REPORT

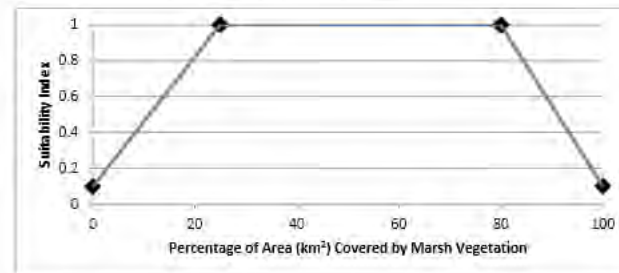


The variables included in this model are: V1 - Percentage of area km<sup>2</sup> that is covered by marsh vegetation, V2 - Mean salinity for spring (February-May), and V3 - Mean water temperature for spring (February-May). The model outputs on a yearly time step for a period of 50 years.

*Variable 1: Percentage of Area (km<sup>2</sup>) Covered by Marsh Vegetation*

The decision rules for variable one are:

$$S_1 = \begin{cases} 0.036 * V_1 + 0.1 & \text{for } 0 < V_1 \leq 25 \\ 1.0 & \text{for } 25 < V_1 \leq 80 \\ 4.582 - 0.0448 * V_1 & \text{for } 80 < V_1 \leq 100 \end{cases}$$

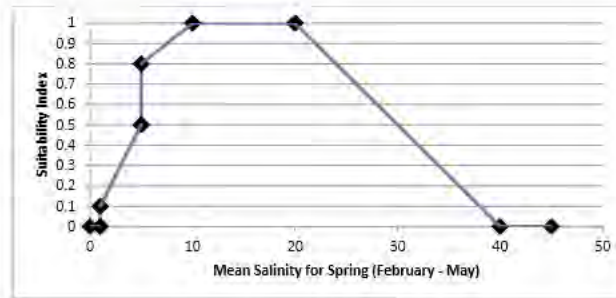


*Variable 2: Mean Salinity for Spring (February-May)*

The decision rules for variable two are:

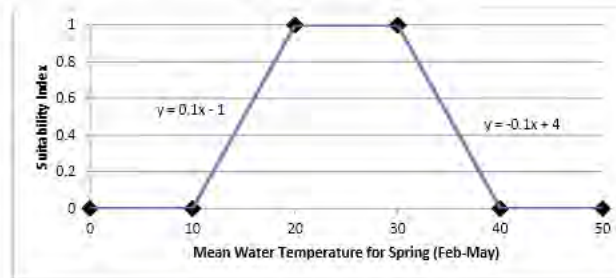
$$S_2 = \begin{cases} 0.0 & \text{for } V_2 < 1 \end{cases}$$

$0.1 * V2$	for $1 \leq V2 \leq 5$
$0.04 * V2 + 0.6$	for $5 < V2 \leq 10$
1.0	for $10 < V2 \leq 20$
$-0.05 * V2 + 2.0$	for $20 < V2 \leq 40$
0.0	for $V2 > 40$



Variable 3: Mean Water Temperature for Spring (February-May)  
 The decision rules for variable three are:

$S_3 = 0.0$	for $V3 \leq 10$
$0.1 * V3 - 1.0$	for $10 < V3 \leq 20$
1.0	for $20 < V3 \leq 30$
$-0.1 * V3 + 4.0$	for $30 < V3 \leq 40$
0.0	for $V3 > 40$



Habitat Suitability Index

The formula for combining the variables is:  $HSI = (S_1^2 \times S_2 \times S_3)^{1/4}$













