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

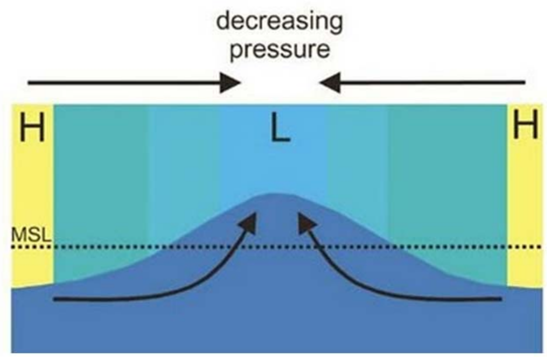
Inundation impacts from diversion activity during weather events

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.

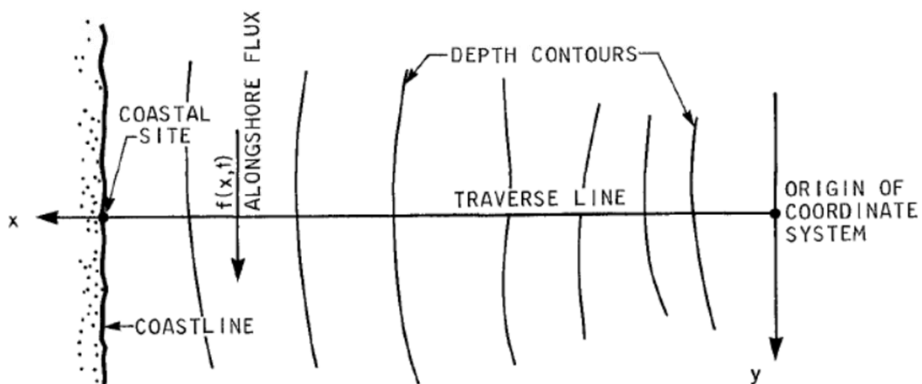
Pressure effect

(peaks at landfall)



Surge forerunner

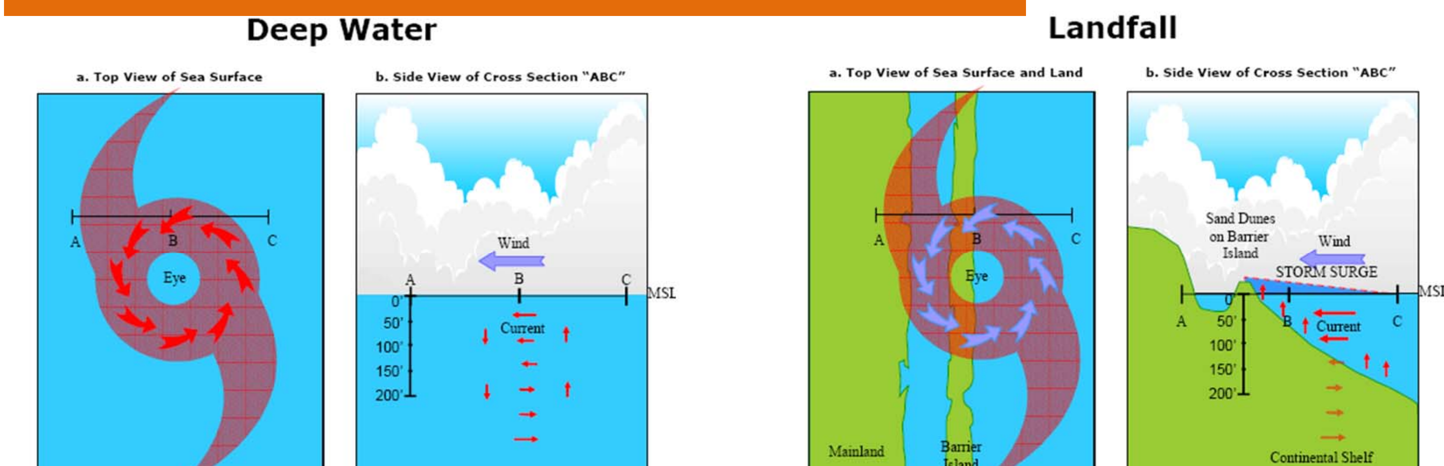
*(peaks before landfall, still
Important at landfall)*



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

Wind effect

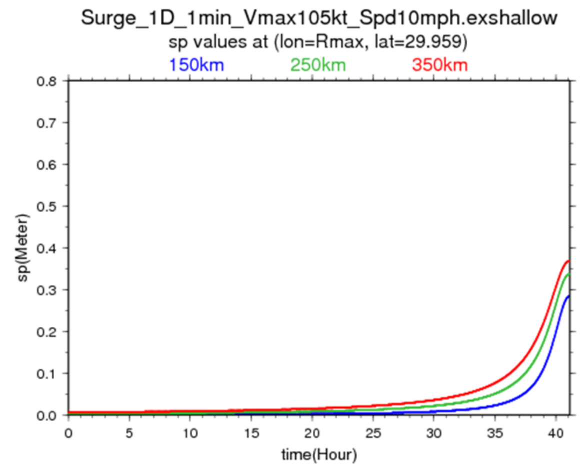
(peaks at landfall)



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

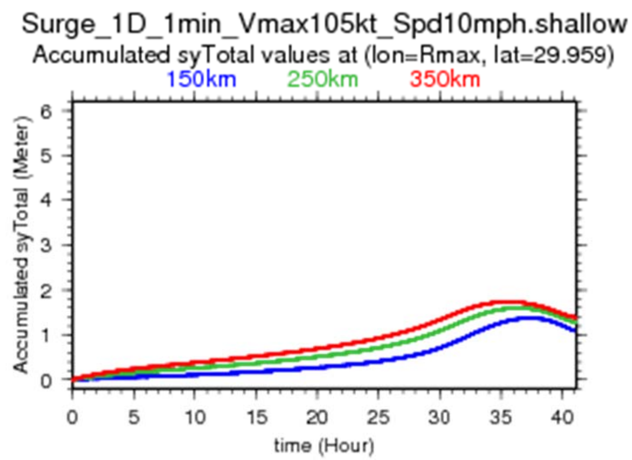
Pressure effect

(peaks at landfall)



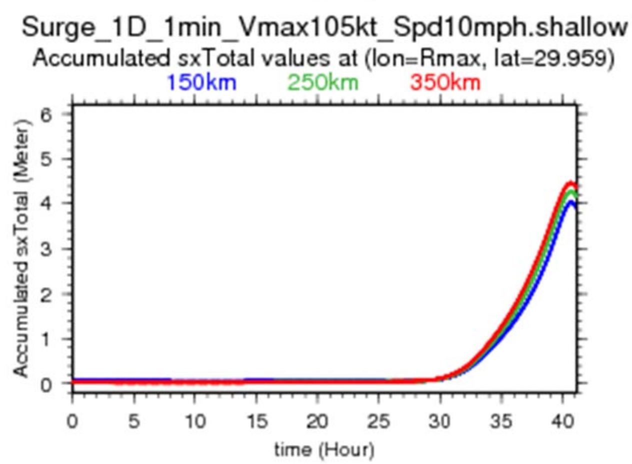
Surge forerunner

(peaks before landfall)



Wind effect

(peaks at landfall)



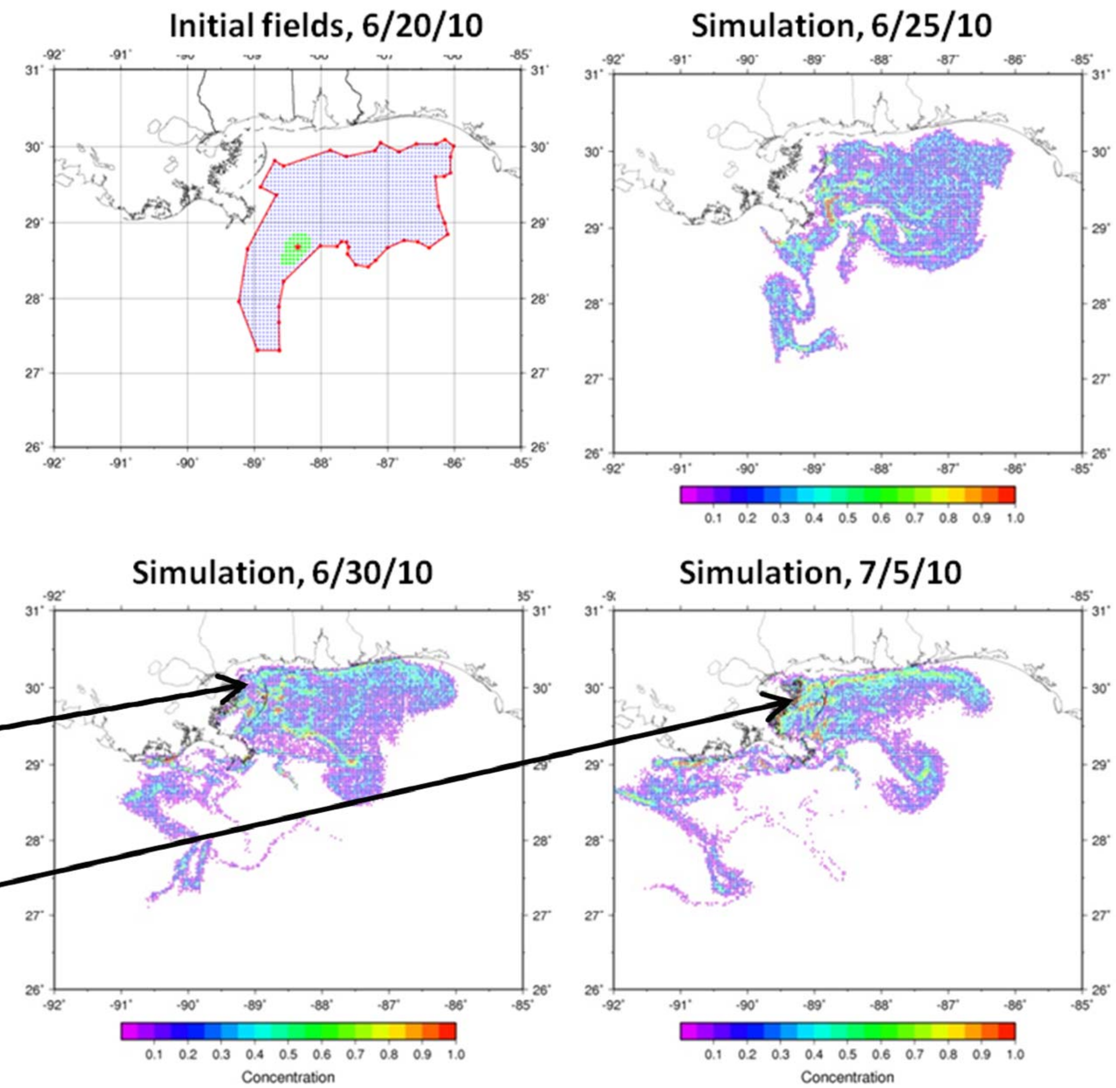
Time series example for Cat 3 in shallow bathymetry for small, average, and large hurricane moving 10 mph

Surge on coastline

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

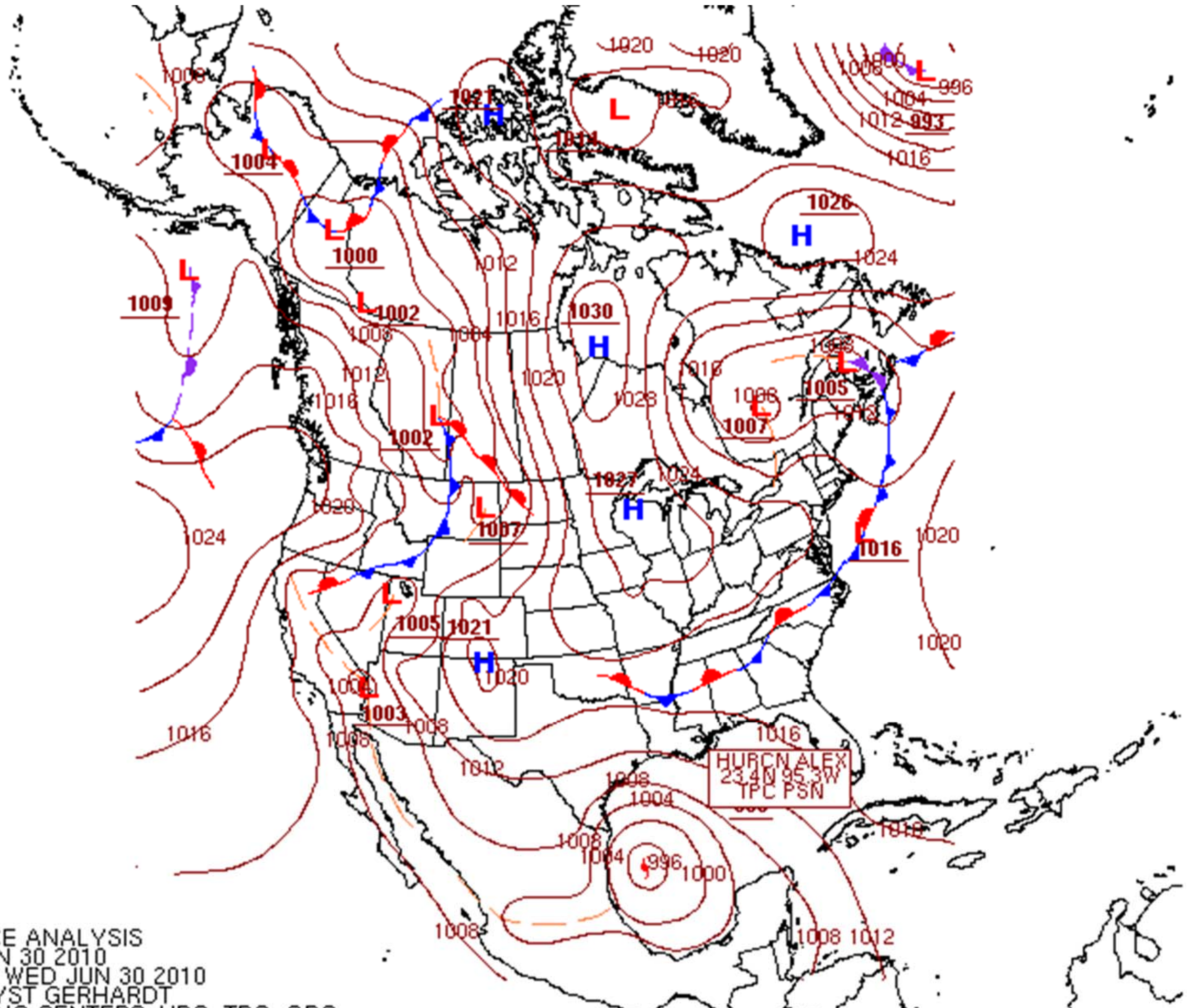
Oil spill simulation from
6/20/10-7/10/10
using AMSEAS NCOM data

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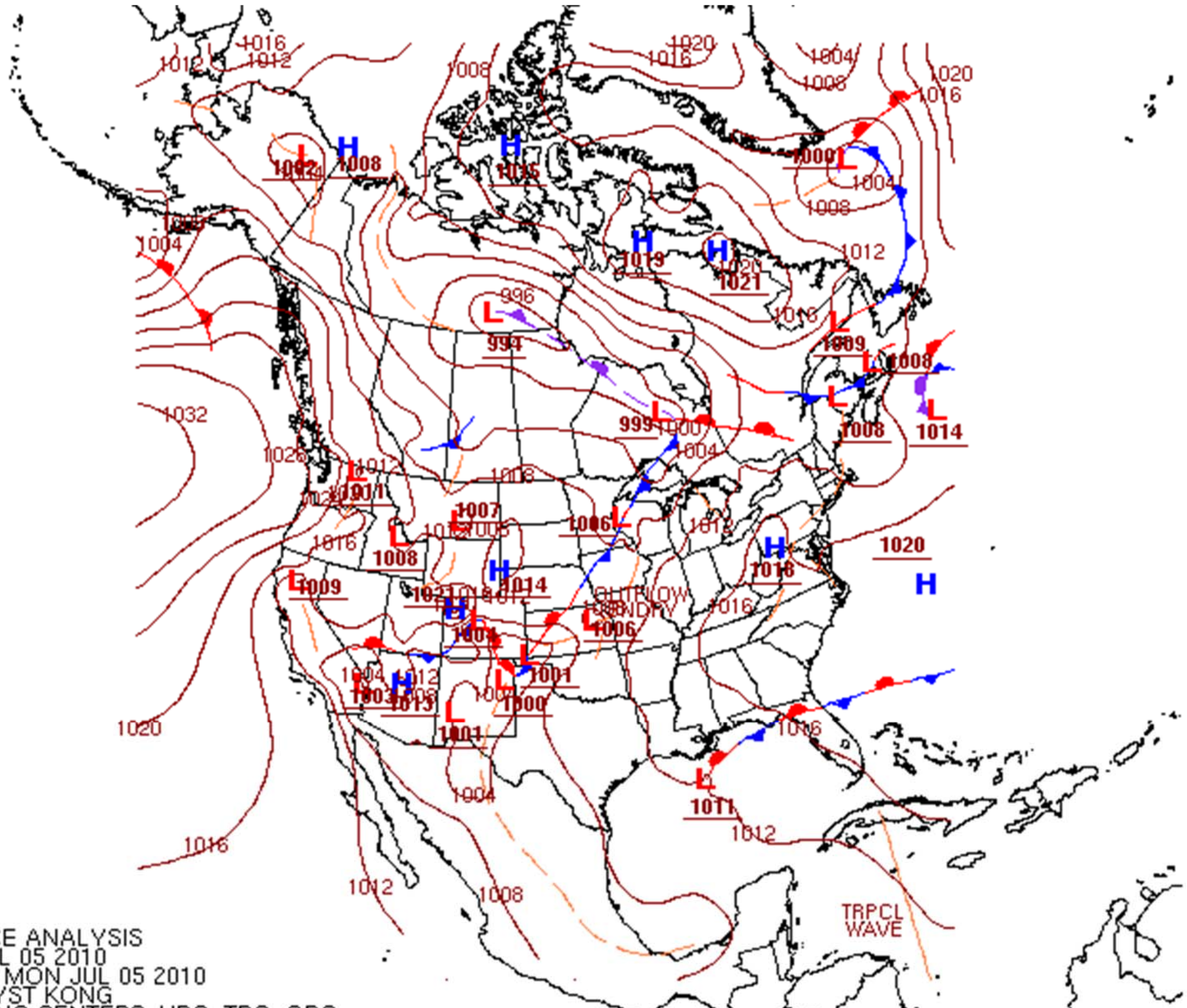
ISSUED: 1335Z WED JUN 30 2010
BY HPC ANALYST GERHARDT
COLLABORATING CENTERS: HPC, TPC, OPC



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BY HPC ANALYST KONG
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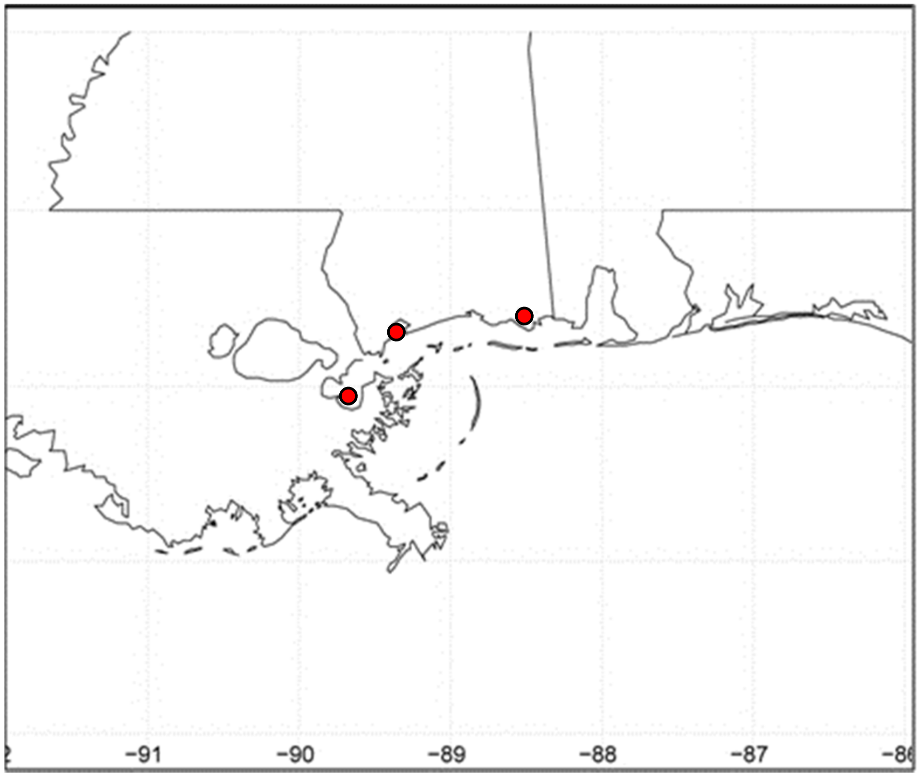
-91
-90
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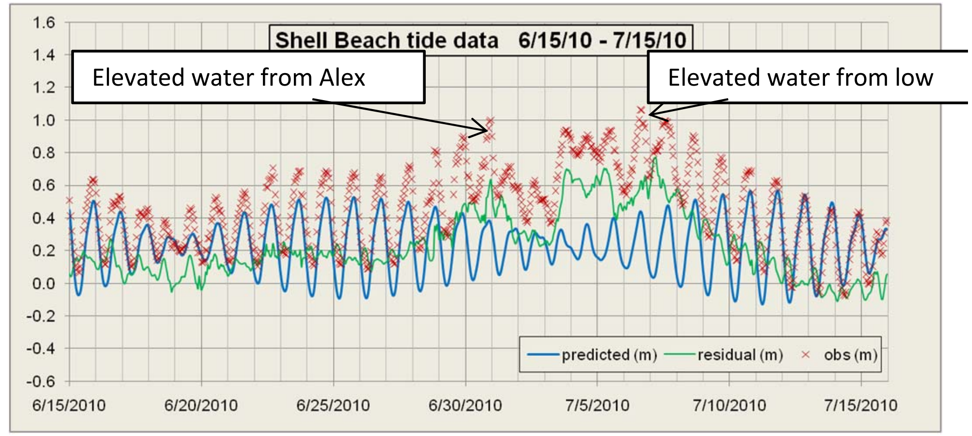
Shell Beach tide data 6/15/10 - 7/15/10
Elevated water from Alex
Elevated water from low
predicted (m)
residual (m)
obs (m)
6/15/2010
6/20/2010
6/25/2010
6/30/2010
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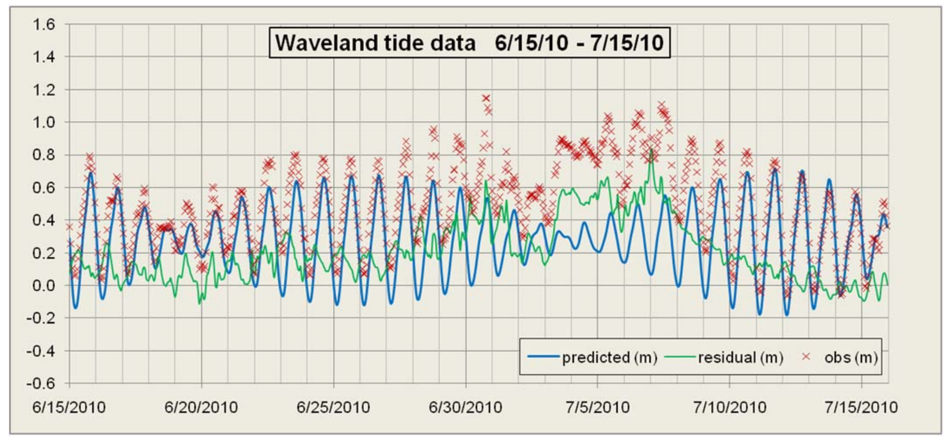
7/10/2010
7/15/2010


Waveland tide data 6/15/10 - 7/15/10
predicted (m)
residual (m)
obs (m)
6/15/2010
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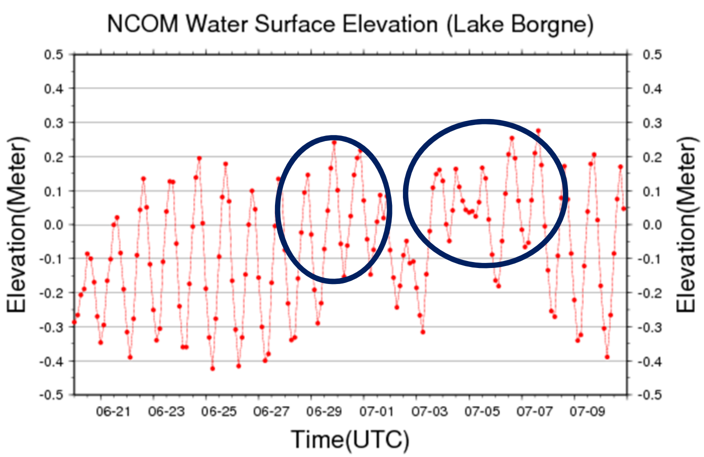
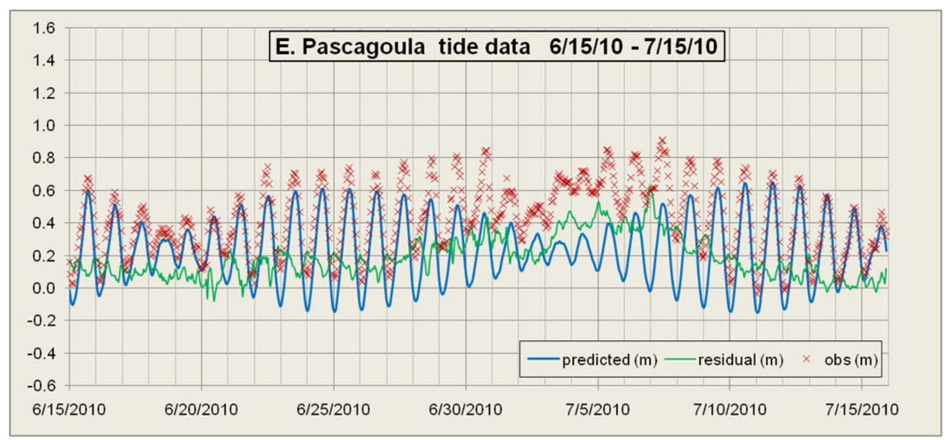
7/15/2010


NCOM Water Surface Elevation (Lake Borgne)
Elevation(Meter)
Time(UTC)
06-21
06-23
06-25
06-27
06-29
07-01
07-03
07-05
07-07
07-09


E. Pascagoula tide data 6/15/10 - 7/15/10
predicted (m)
residual (m)
obs (m)
6/15/2010
6/20/2010
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6/30/2010
7/5/2010
7/10/2010
7/15/2010

Diversion simulation summary

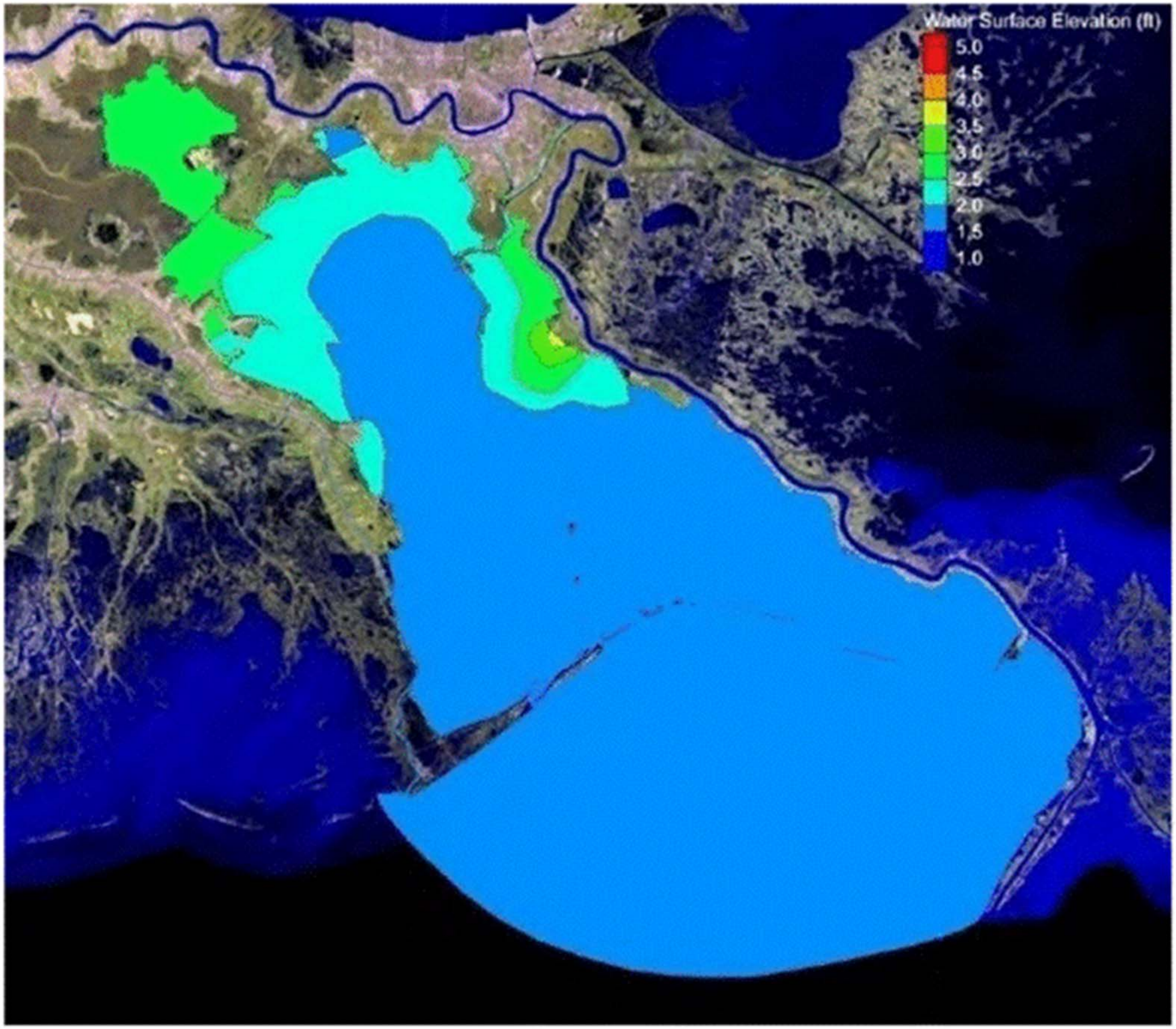


Figure 5-5. Monthly Maximum Water Surface Elevation

Suggested next steps

- The possibility that long-term onshore wind fetches, especially associated with a low pressure, can impede diversion outflow an 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.

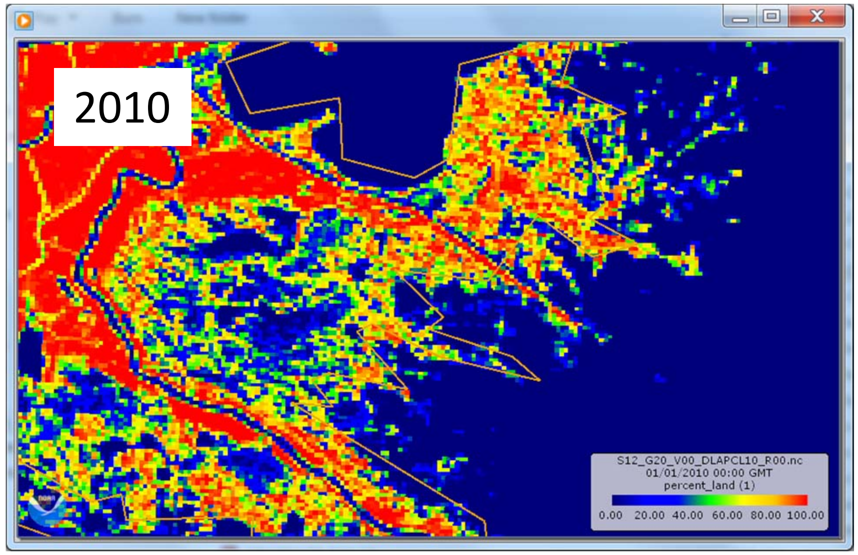
Diversion simulations

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

Next two slides show “moderate” erosion scenarios.

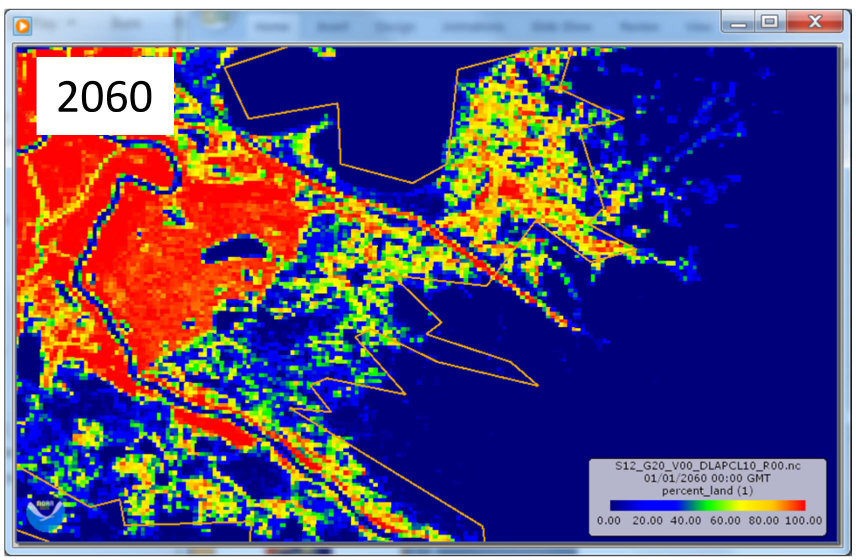
There are also simulations for “less optimistic”, or accelerated erosion (not shown)

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

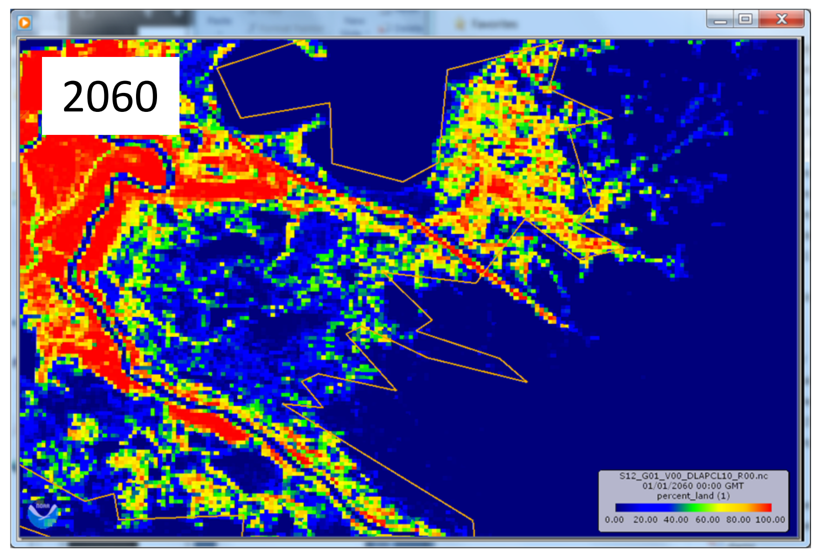


Percent land
Yellow to Red –70-100%
Blues –0-40%

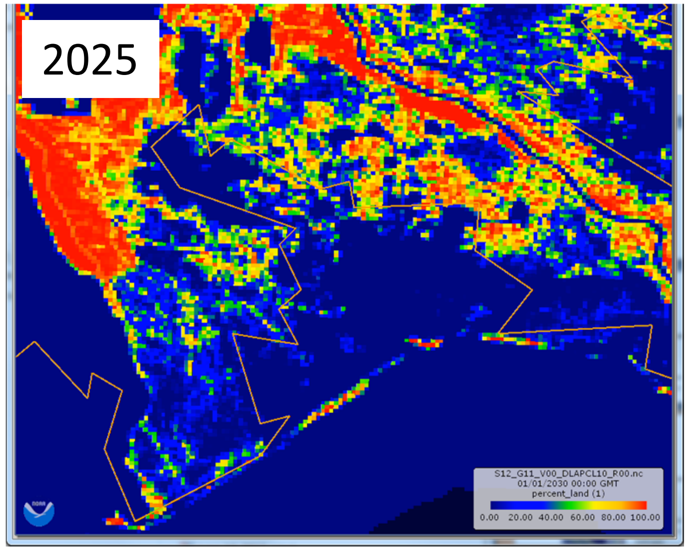
Upper Breton (Braithwaite) diversion
250,000 cfs



No restoration projects



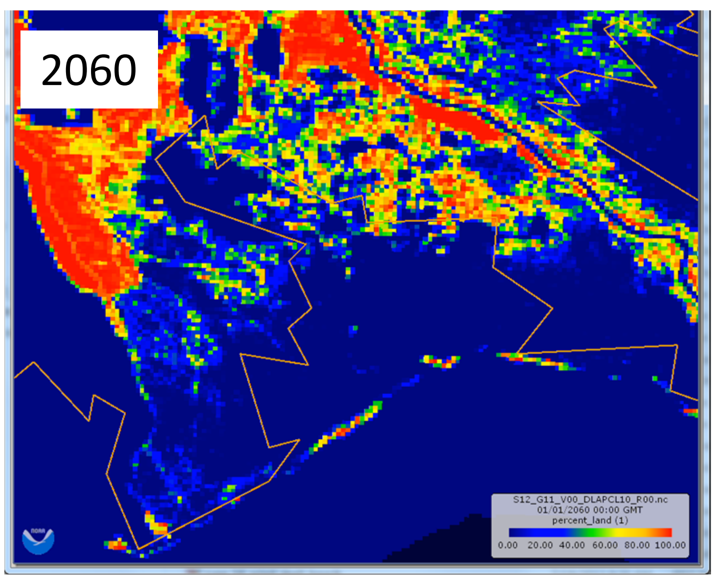
Possible wetland evolution, moderate erosion scenario, West Bank, 2025-2060



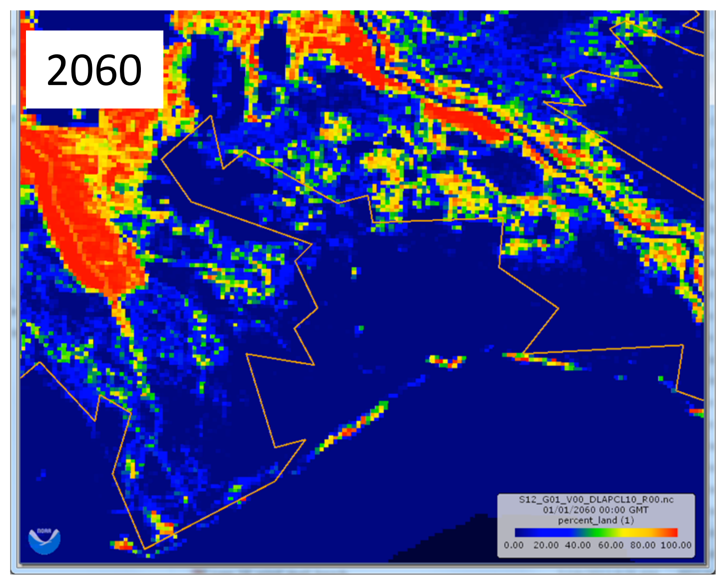
Percent land
Yellow to Red –70-100%
Blues –0-40%

Mid-Barataria (Myrtle Grove) diversion

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

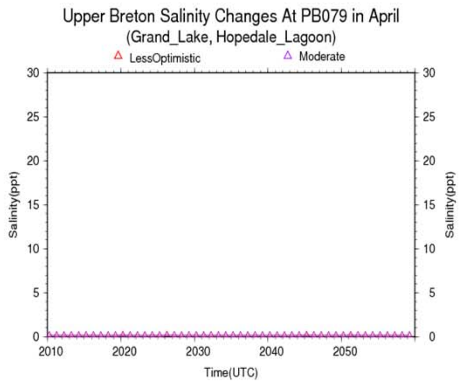


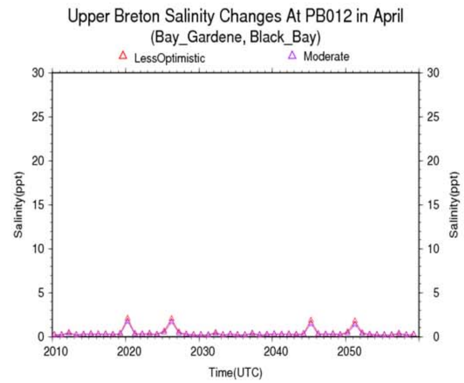
No restoration projects

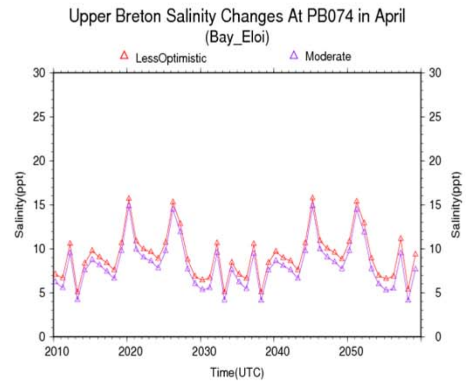


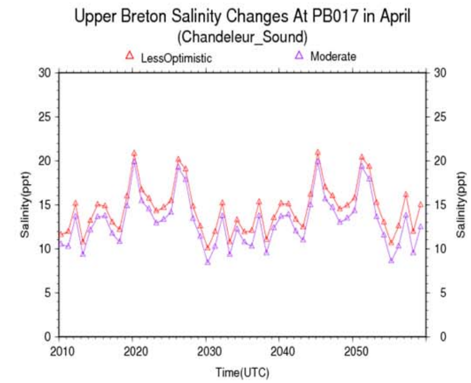
Salinity time series

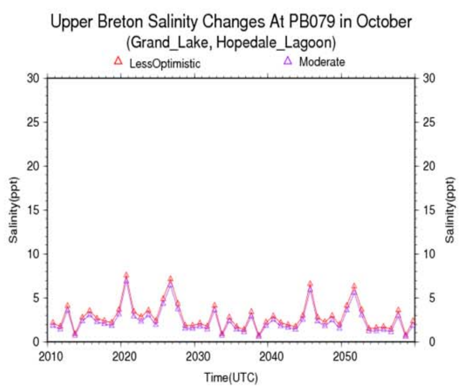
Braithwaite diversion Salinity time series, East Bank, April and October

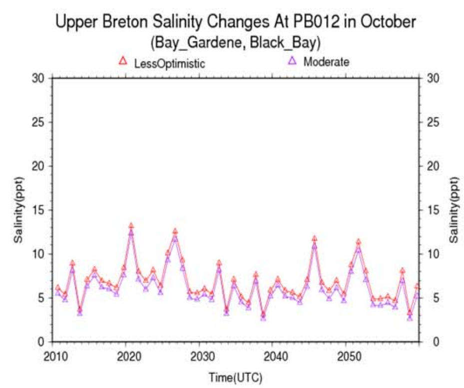


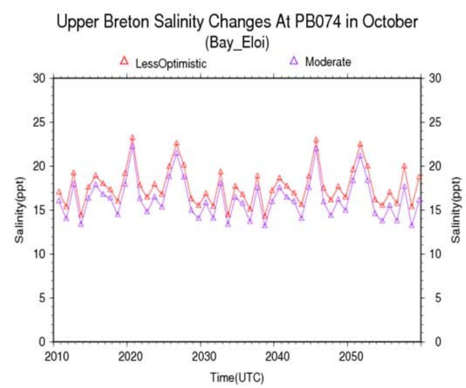


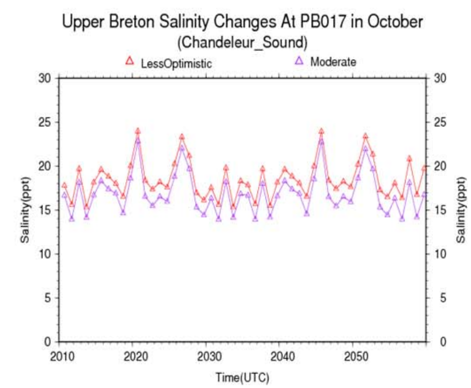




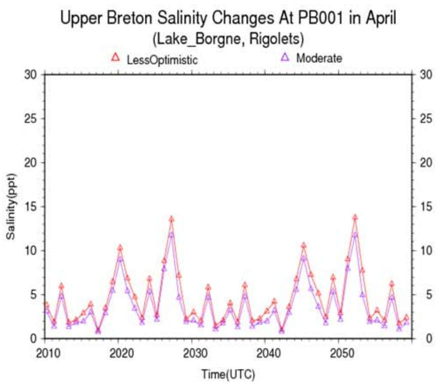


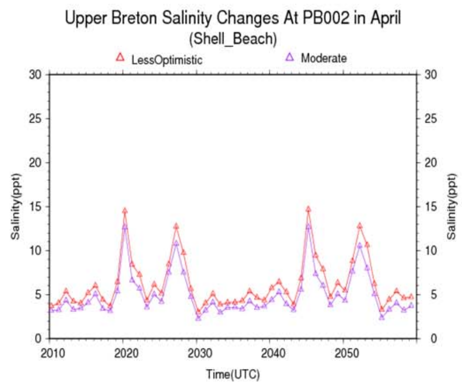


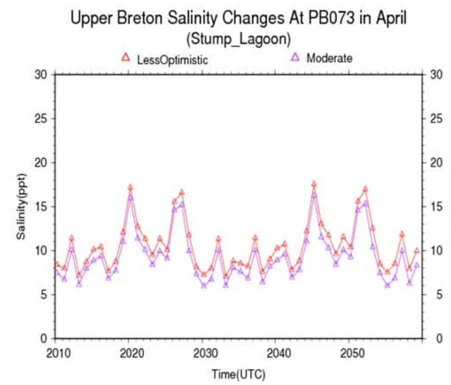


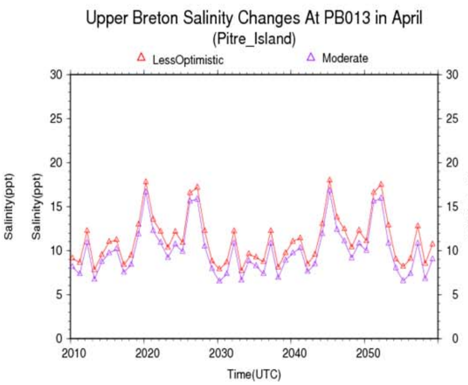


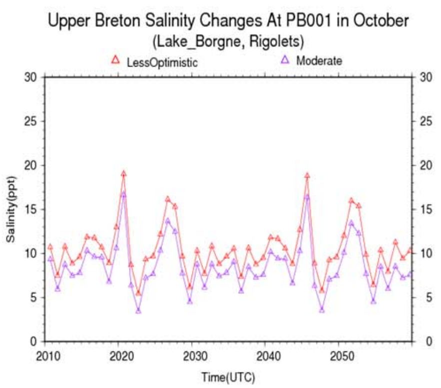
Braithwaite diversion salinity time series, East Bank, April and October

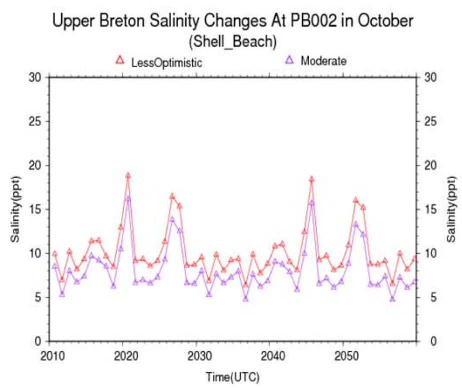


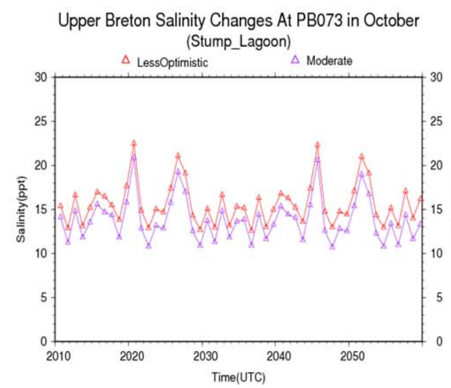


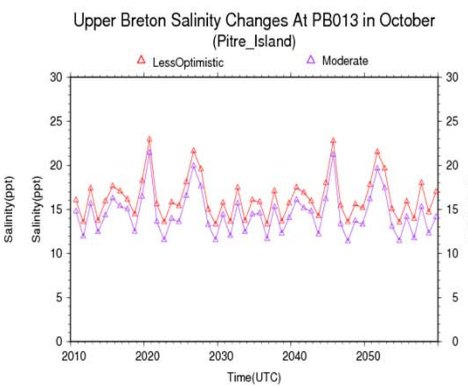






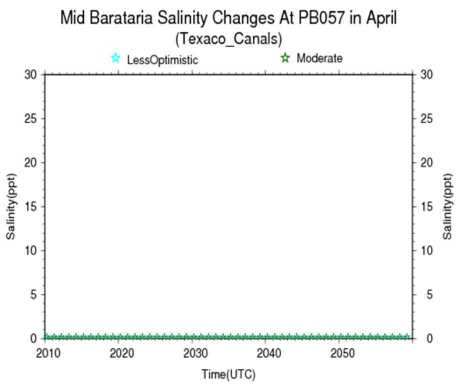


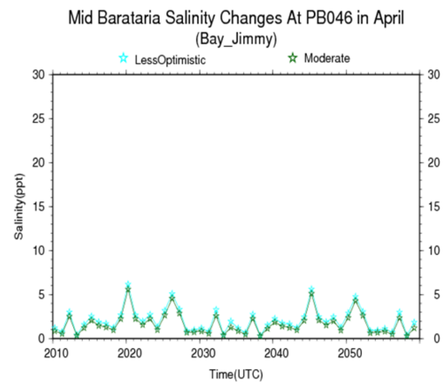


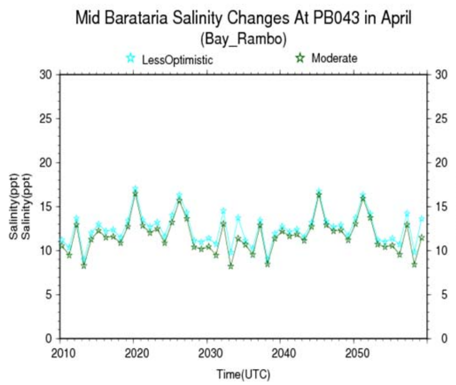


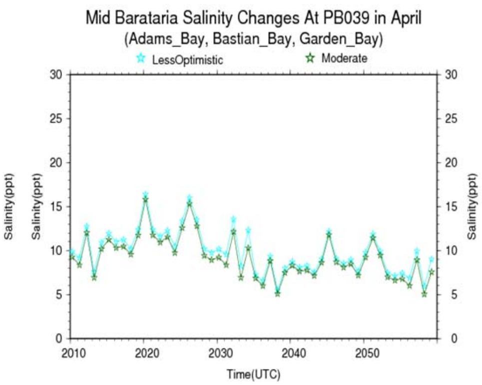
A problem; Pitre Island salinity should be different from Stump Lagoon, probably higher

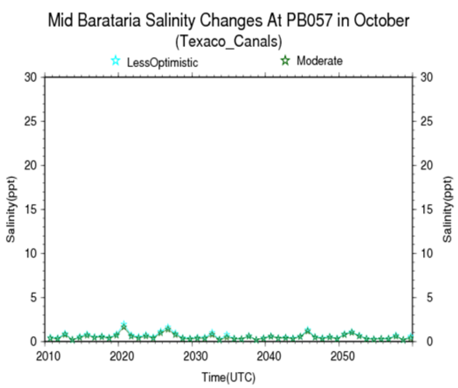
Myrtle Grove diversion salinity time series, West Bank, April and October

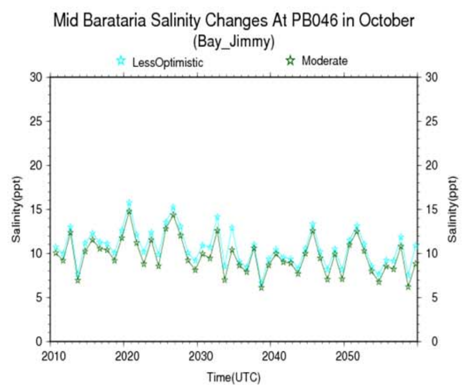


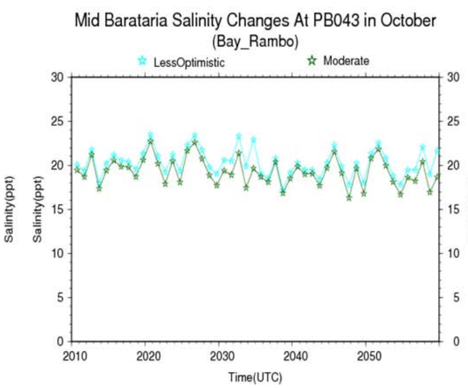


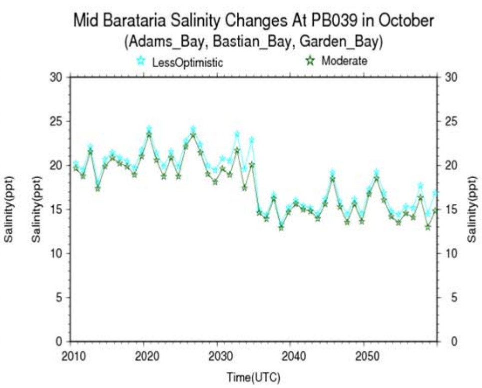




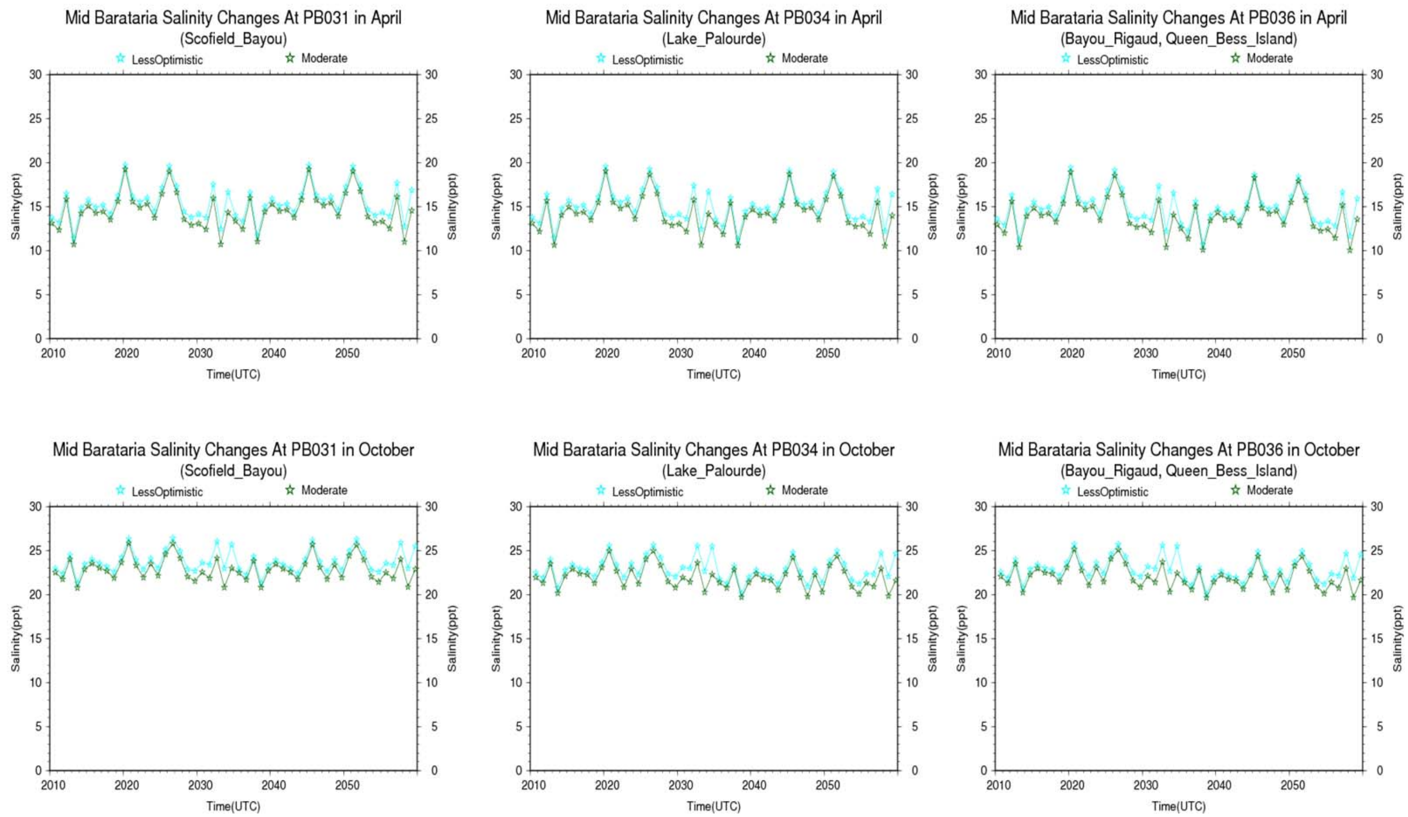








Myrtle Grove diversion salinity time series, West Bank, April and October



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

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

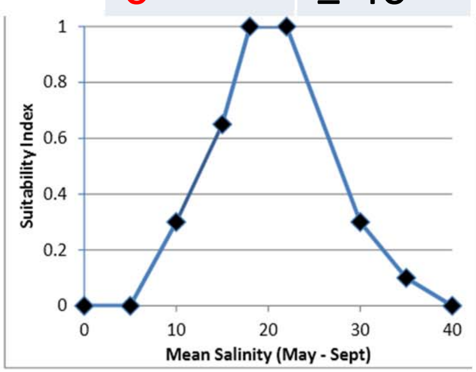
Normalized	Percent Substrate
0	0
0.4	10
0.6	20
0.8	30
0.9	40
1.0	50 to 100

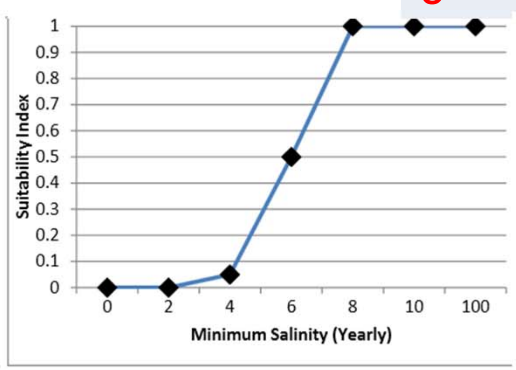
Normalized	Mean Salinity Summer (ppt)
0	≤ 5
0.3	10
0.65	15
1.0	18
1.0	22
0.3	30
0.1	35
0	≥ 40

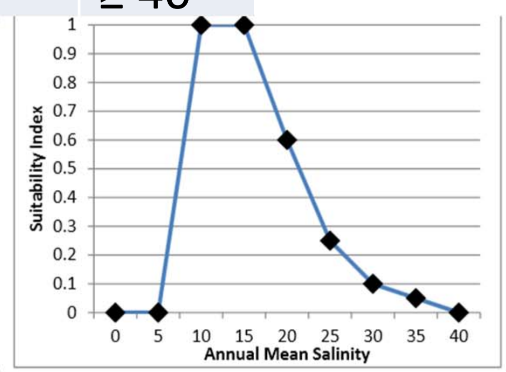
Normalized	Minimal Annual Salinity (ppt)
0	≤ 2
0.05	4
0.5	6
1.0	≥8

Normalized	Annual Mean Salinity (ppt)
0	≤ 5
1.0	10
1.0	15
0.6	20
0.25	25
0.1	30
0.05	35
0	≥ 40

Normalized	Percent Land
1	0
0.8	20
0.6	40
0.4	60
0.2	80
0	100



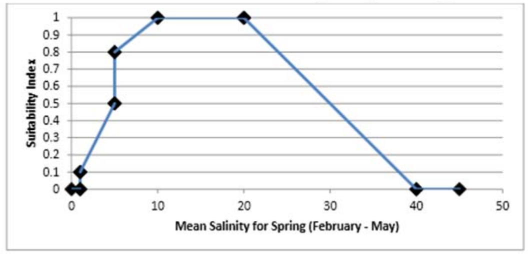




Question for fishery experts: Does not consider 3 years of supportable salinity for oysters to reach marketable size?

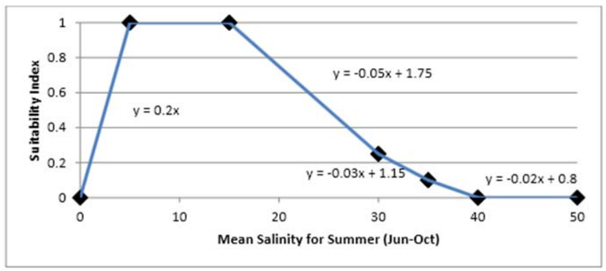
Brown shrimp habitat suitability index equation

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



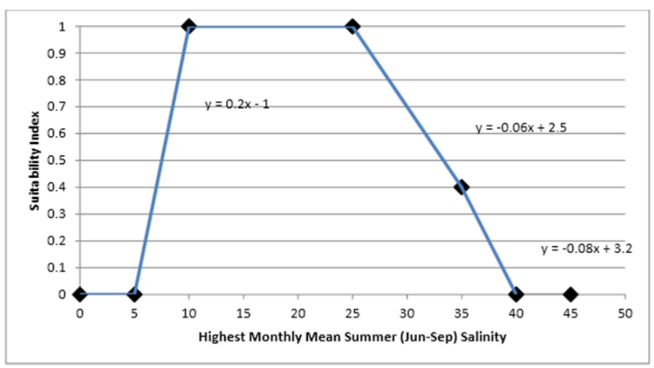
White shrimp habitat suitability index equation

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



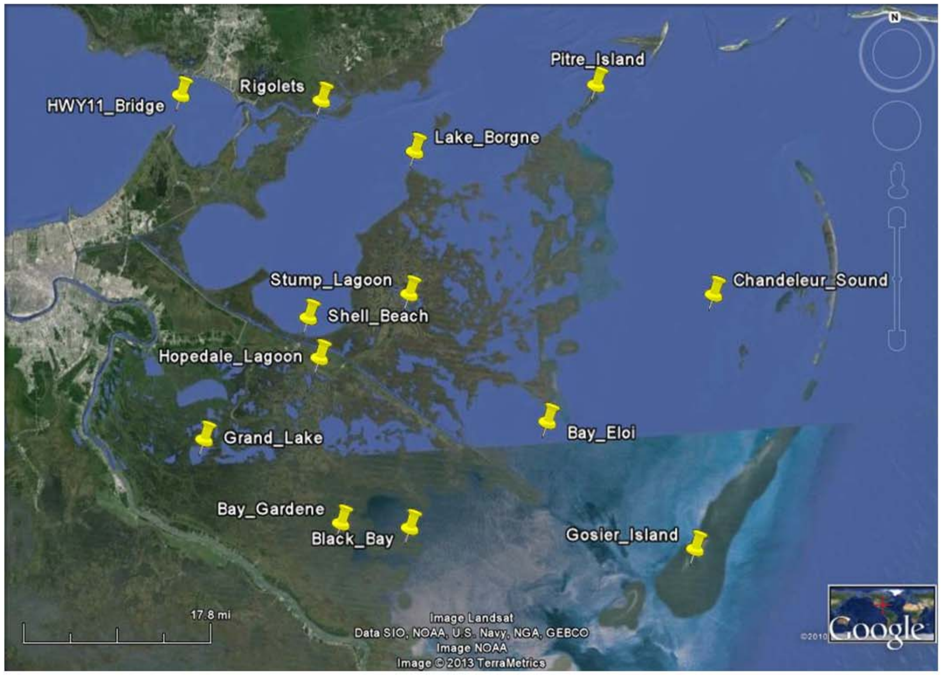
Speckled trout habitat suitability index equation

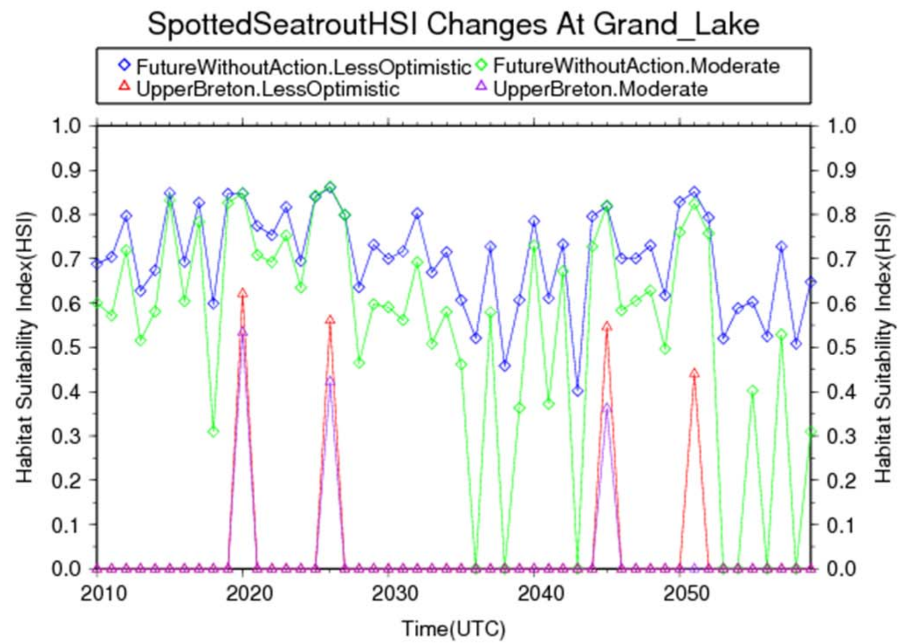
$$HSI = \sqrt[4]{\begin{pmatrix} coverage \\ marsh\ area \end{pmatrix} \times \begin{pmatrix} \max monthly\ mean \\ salinity\ summer \end{pmatrix} \times \begin{pmatrix} \max monthly\ mean \\ summer\ water\ temperature \end{pmatrix} \times \begin{pmatrix} \min monthly\ mean \\ winter\ water\ temperature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

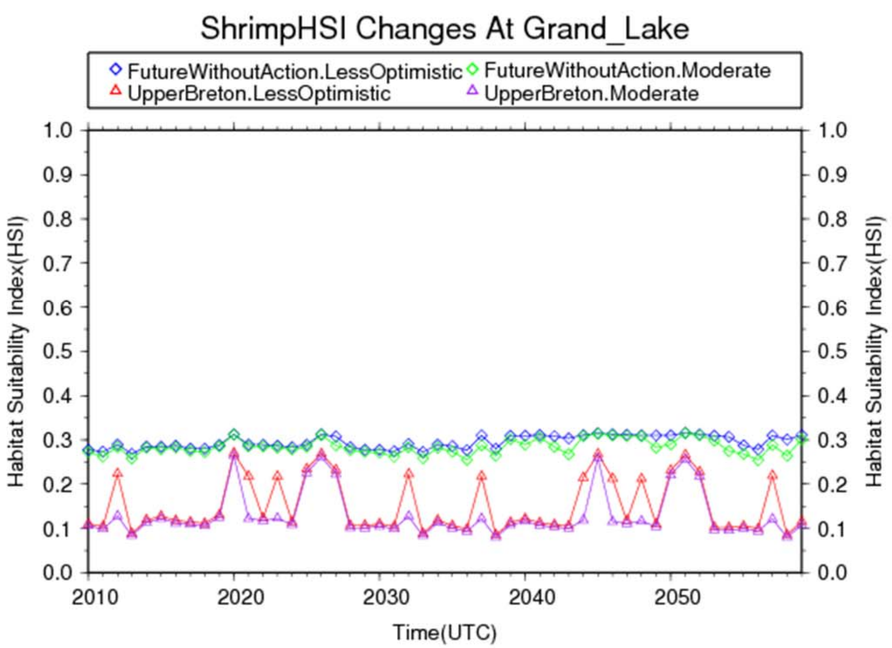


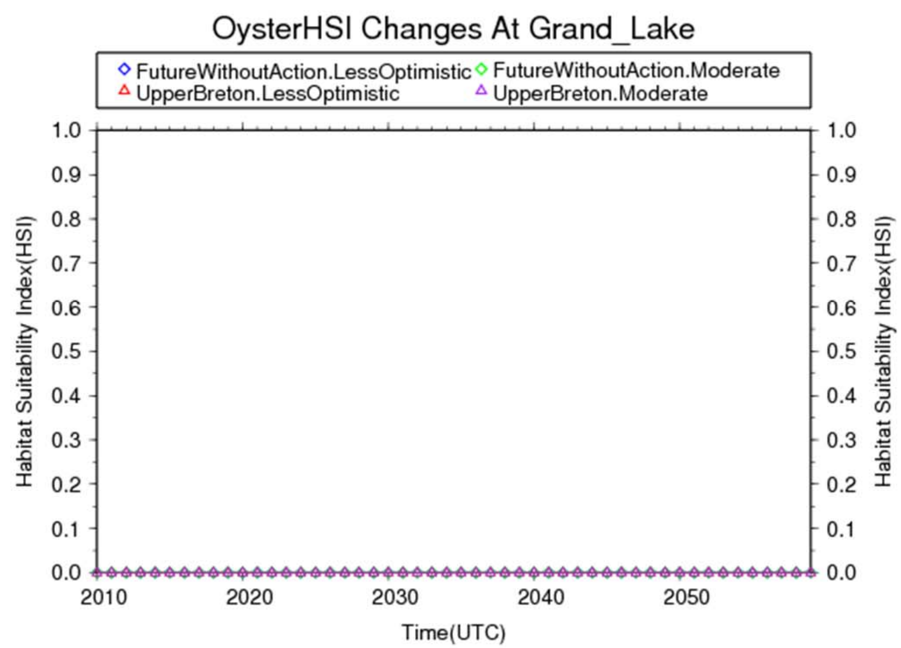
Spawning and larval impact not Considered. Eggs need high salinity to float into marsh.

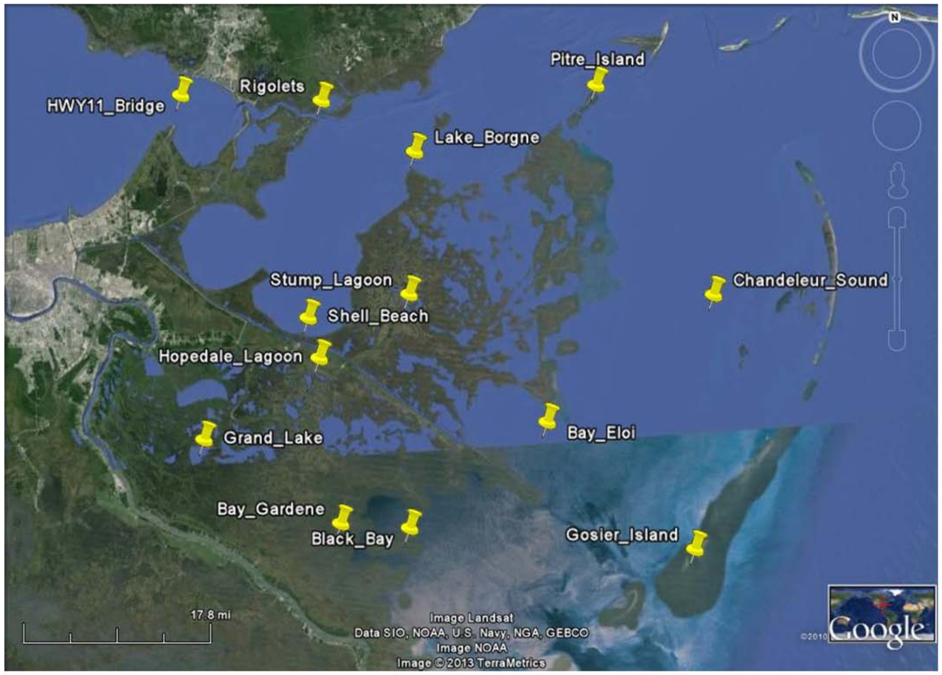
HSI results, East Bank

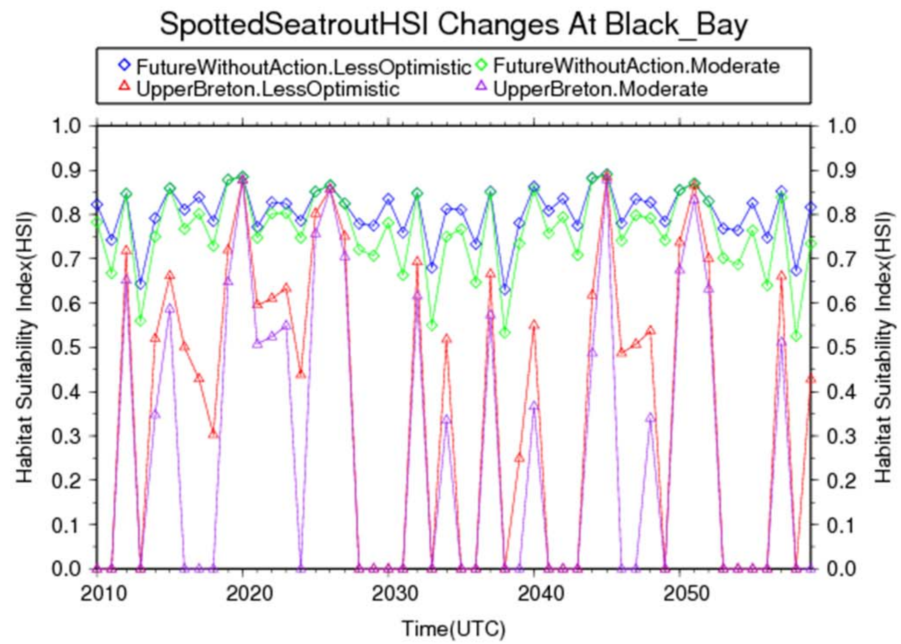

Pitre_Island
Rigolets
HWY11_Bridge
Lake_Borgne
Stump_Lagoon
Chandeleur_Sound
Shell_Beach
Hopedale_Lagoon
Bay_Eloi
Grand_Lake
Bay_Gardene
Black_Bay
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google


SpottedSeatroutHSI Changes At Grand_Lake
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Grand_Lake
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Grand_Lake
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


Pitre_Island
Rigolets
HWY11_Bridge
Lake_Borgne
Stump_Lagoon
Chandeleur_Sound
Shell_Beach
Hopedale_Lagoon
Bay_Eloi
Grand_Lake
Bay_Gardene
Black_Bay
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google


SpottedSeatroutHSI Changes At Black_Bay
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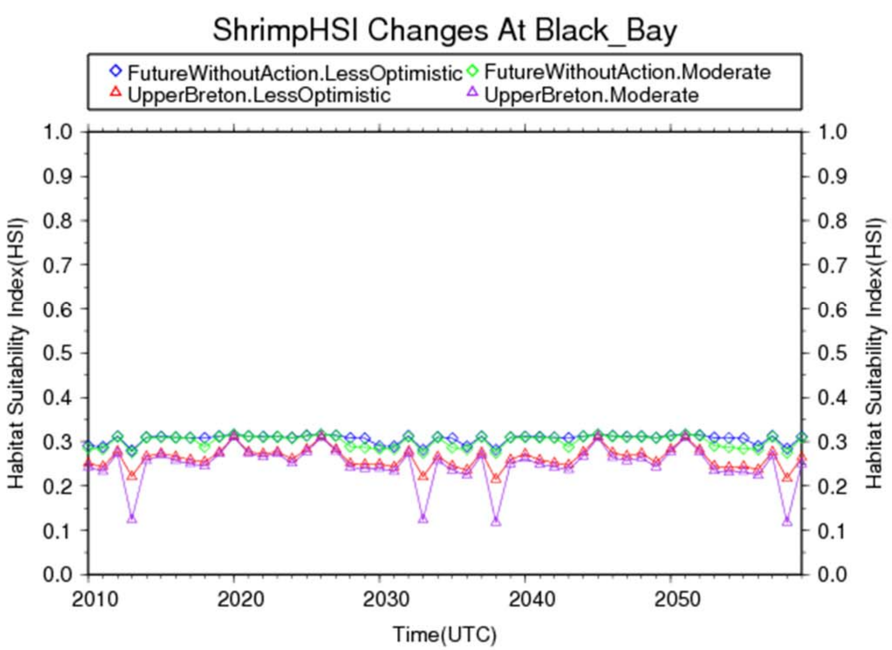
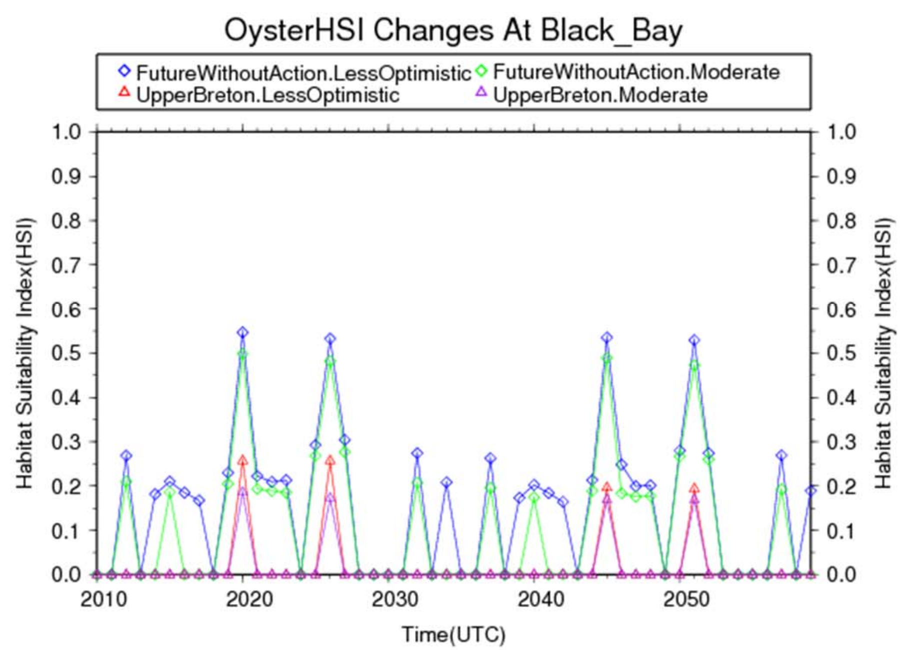
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Black_Bay
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Black_Bay
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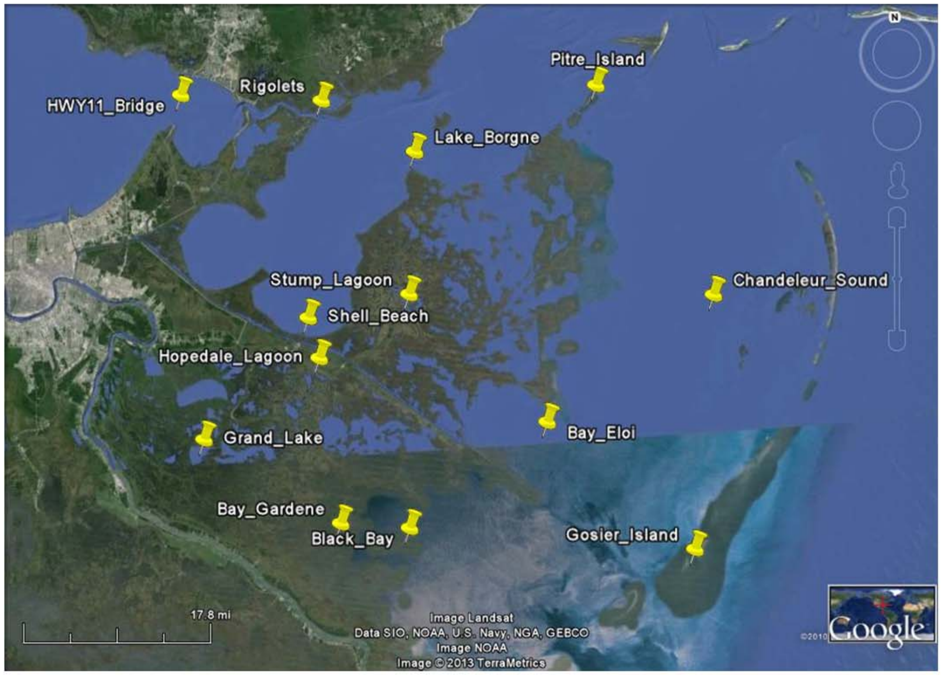
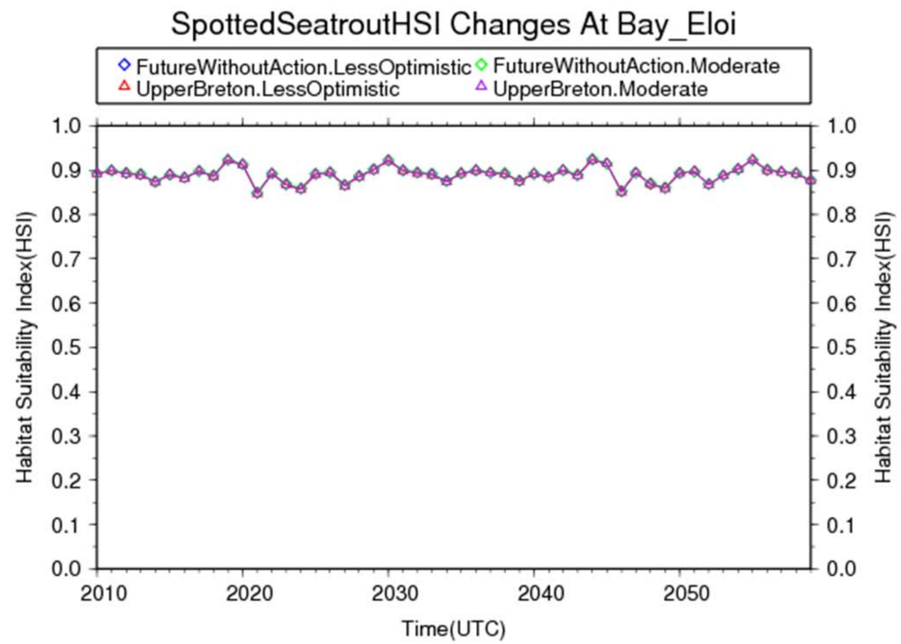
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)



Pitre_Island
Rigolets
HWY11_Bridge
Lake_Borgne
Stump_Lagoon
Chandeleur_Sound
Shell_Beach
Hopedale_Lagoon
Bay_Eloi
Grand_Lake
Bay_Gardene
Black_Bay
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
©2010
Google



SpottedSeatroutHSI Changes At Bay_Eloi
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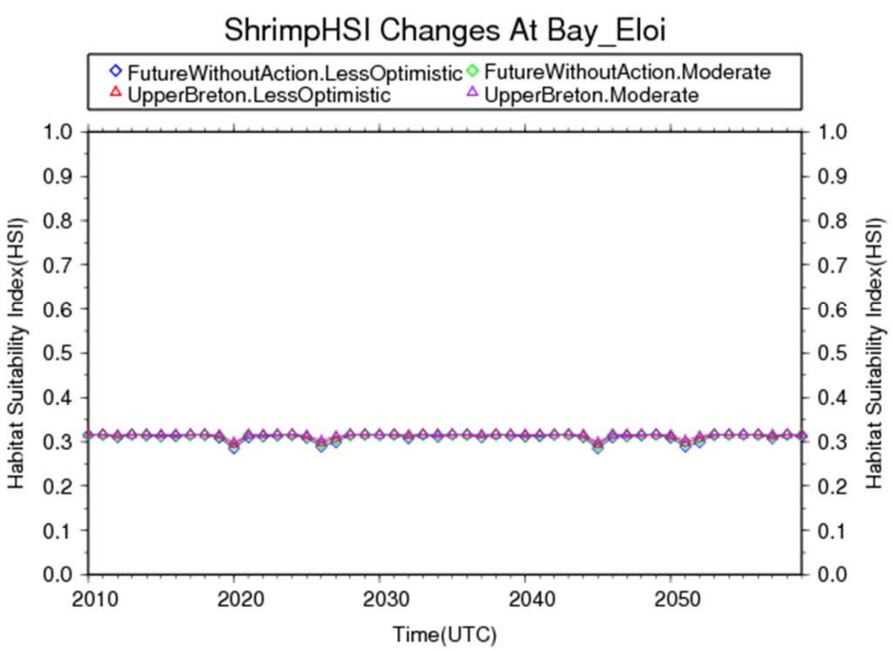
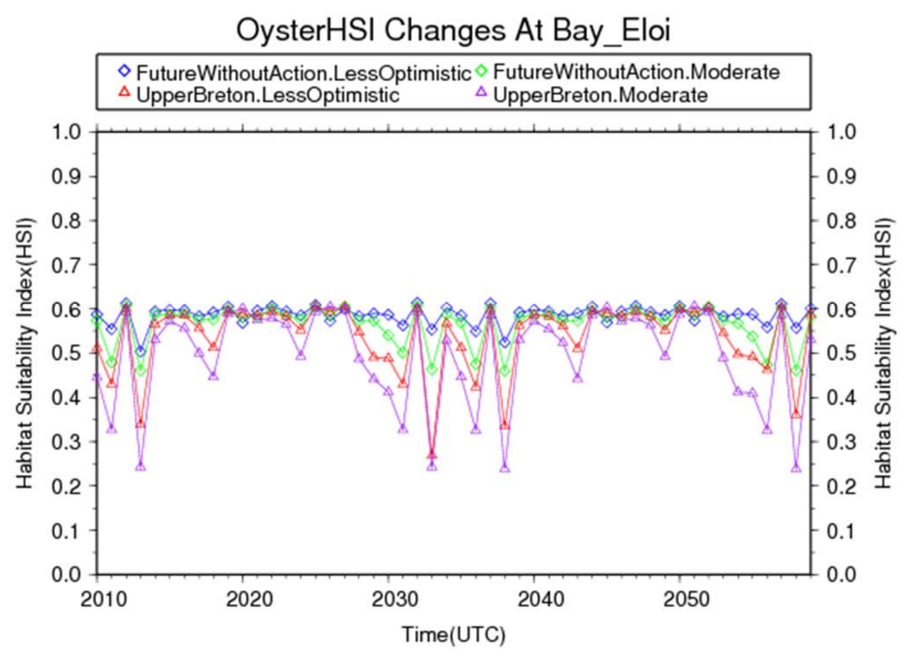
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)



ShrimpHSI Changes At Bay_Eloi
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)



OysterHSI Changes At Bay_Eloi
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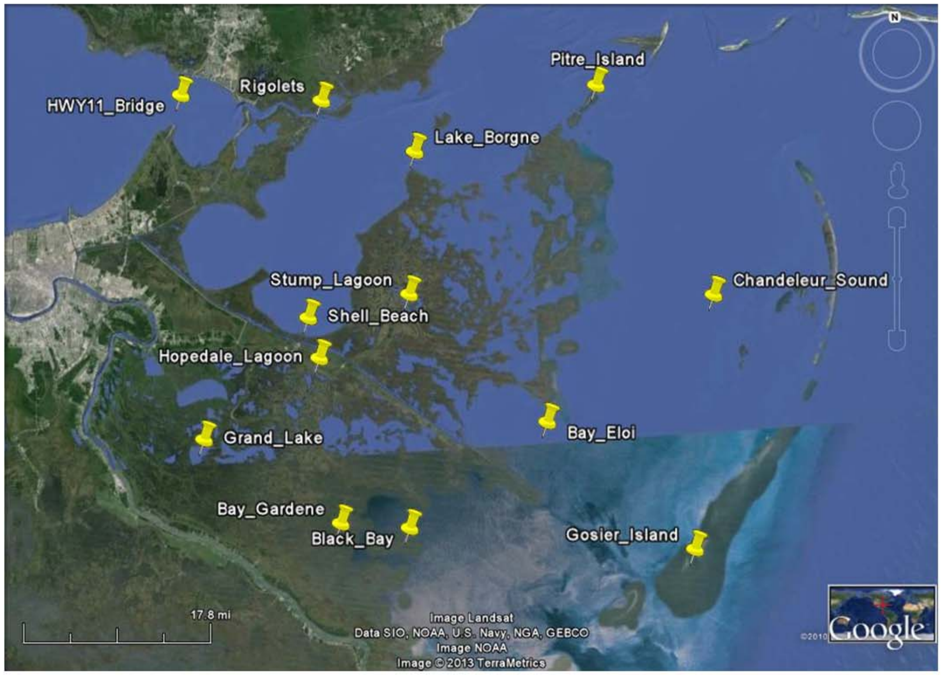
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


HWY11_Bridge
Rigolets
Pitre_Island
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Bay_Eloi
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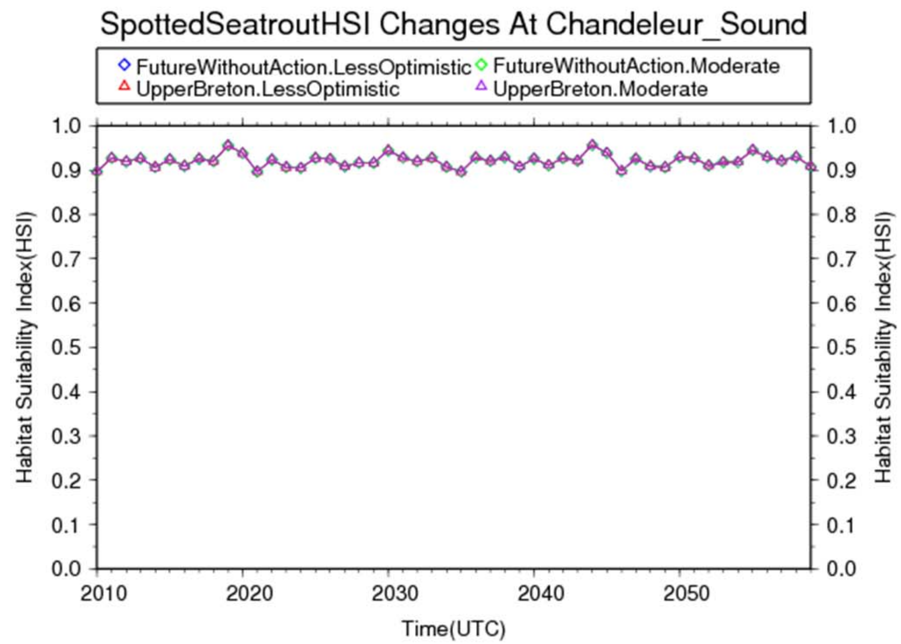
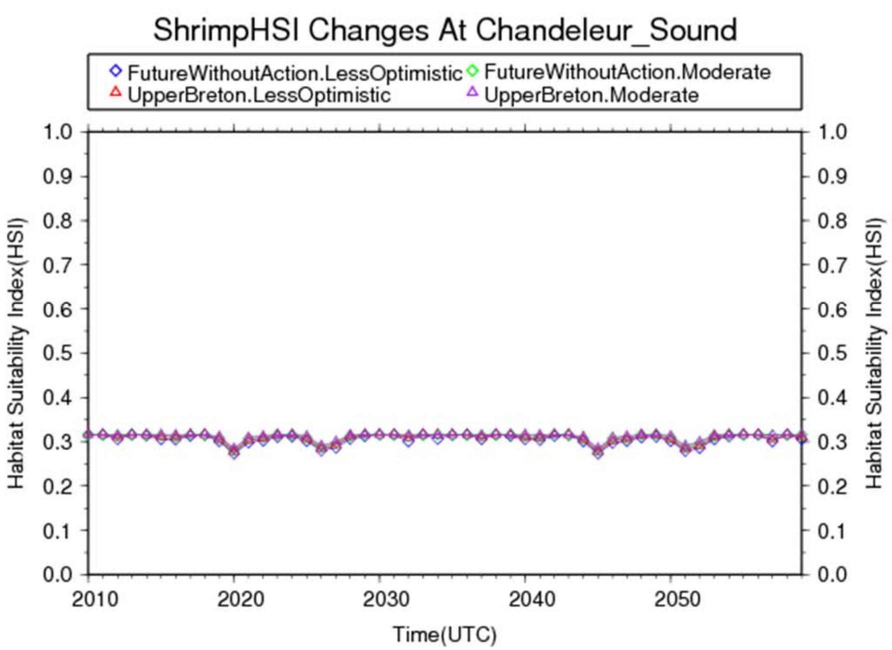
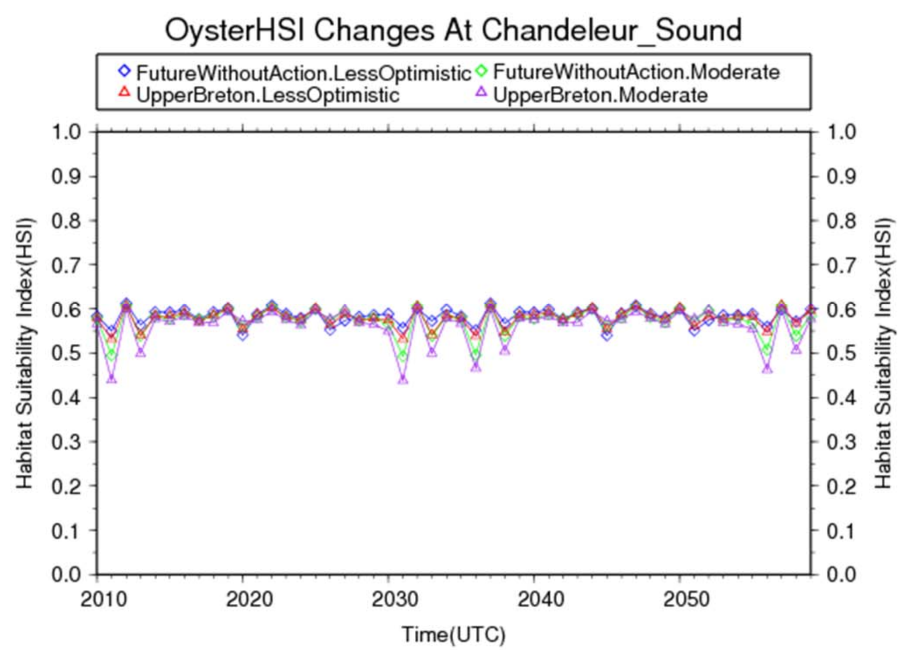
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google


SpottedSeatroutHSI Changes At Chandeleur_Sound
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Chandeleur_Sound
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Chandeleur_Sound
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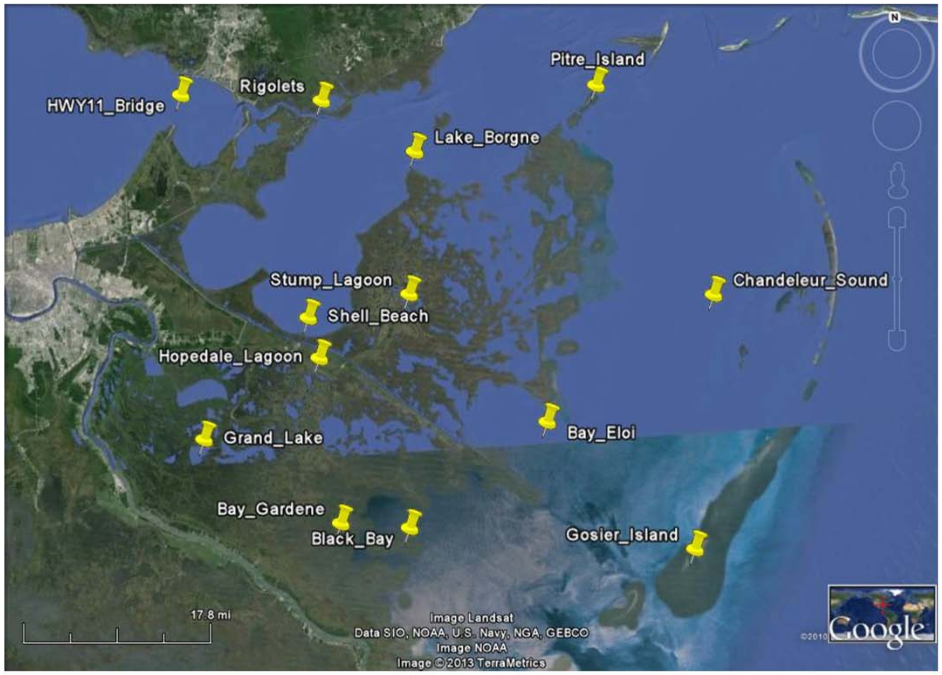
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)



HWY11_Bridge
Rigolets
Pitre_Island
Lake_Borgne
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Chandeleur_Sound
Shell_Beach
Hopedale_Lagoon
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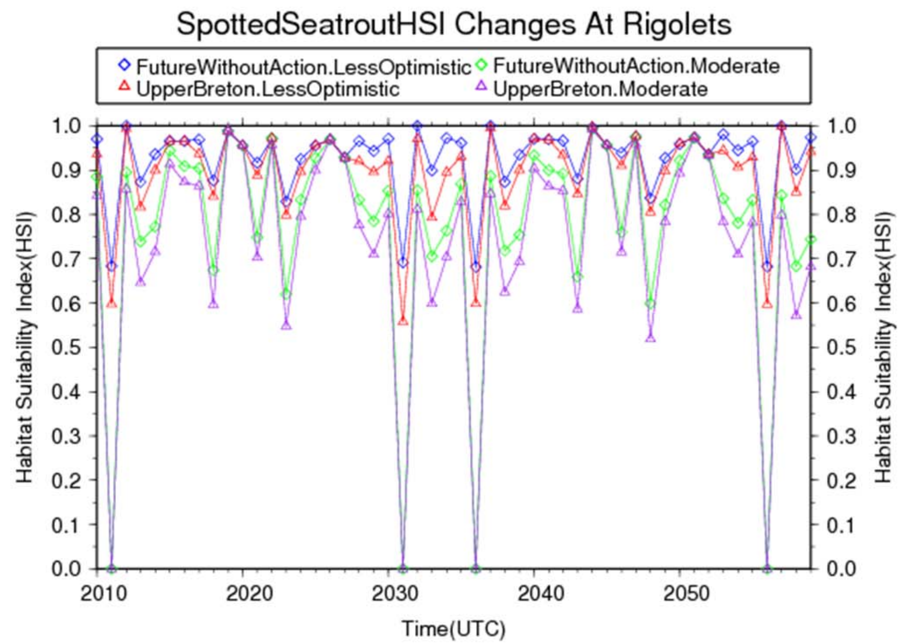
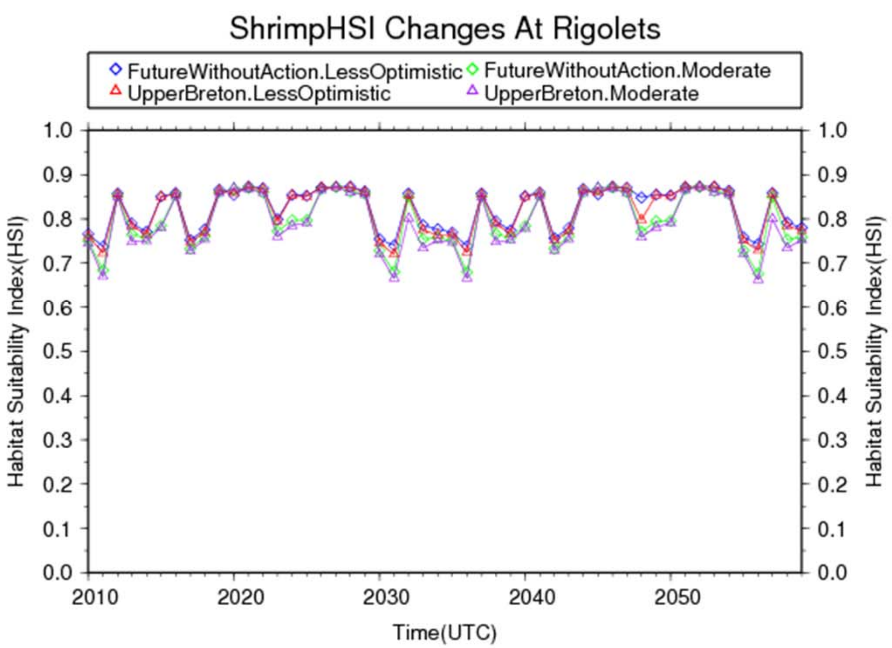
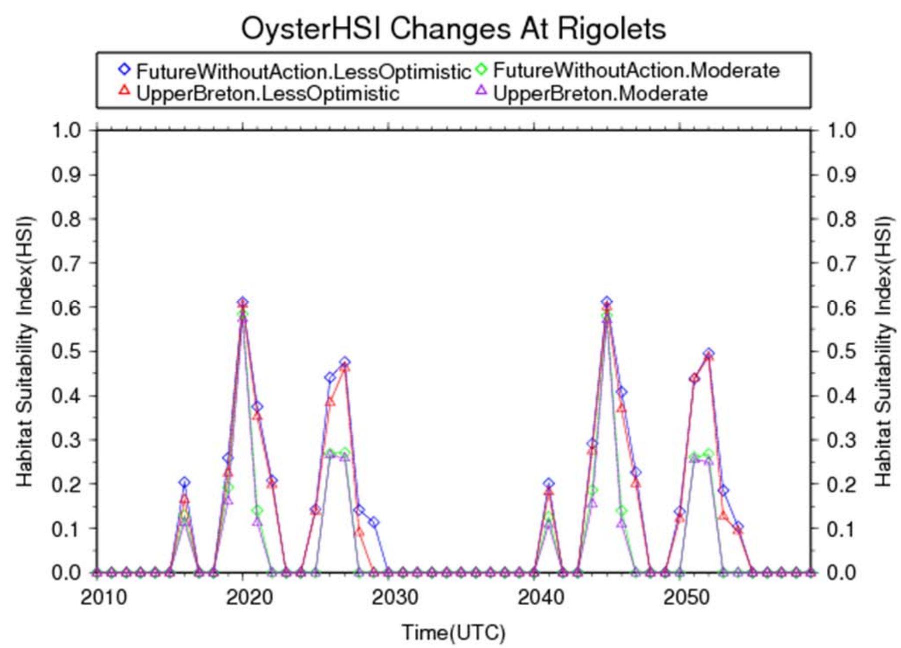
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google



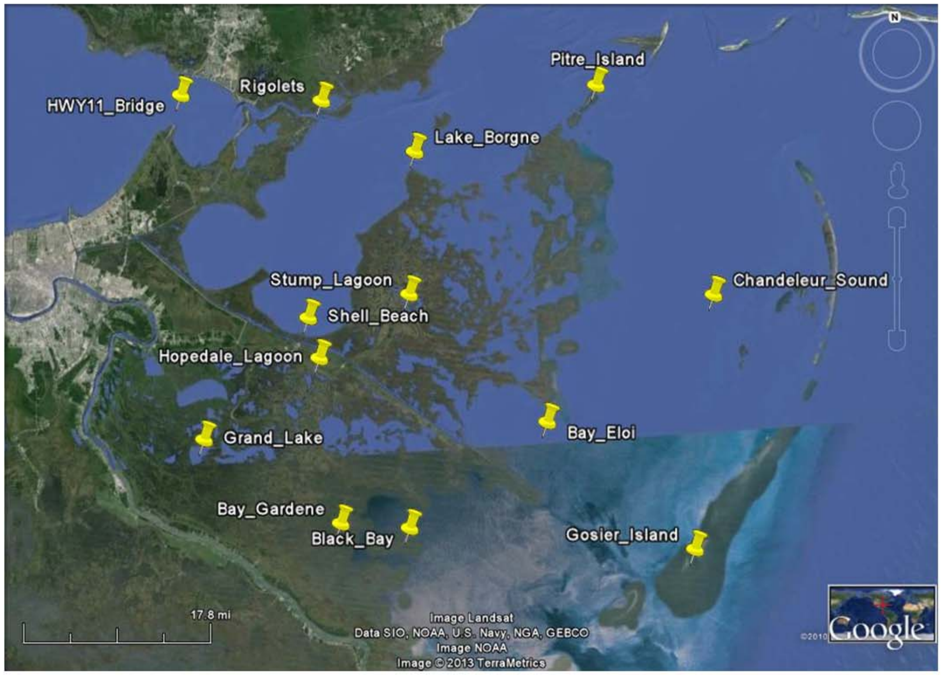
SpottedSeatroutHSI Changes At Rigolets
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

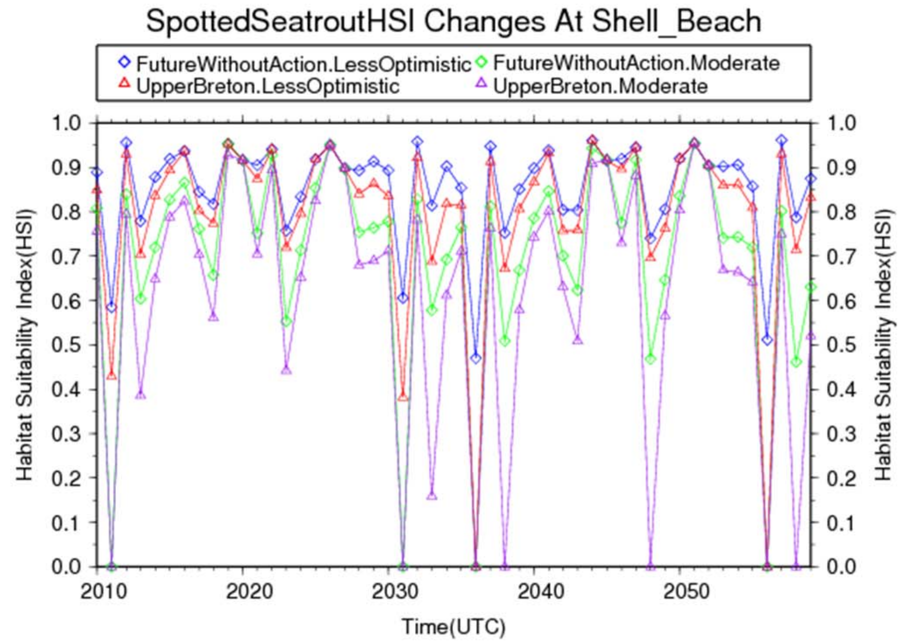


ShrimpHSI Changes At Rigolets
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

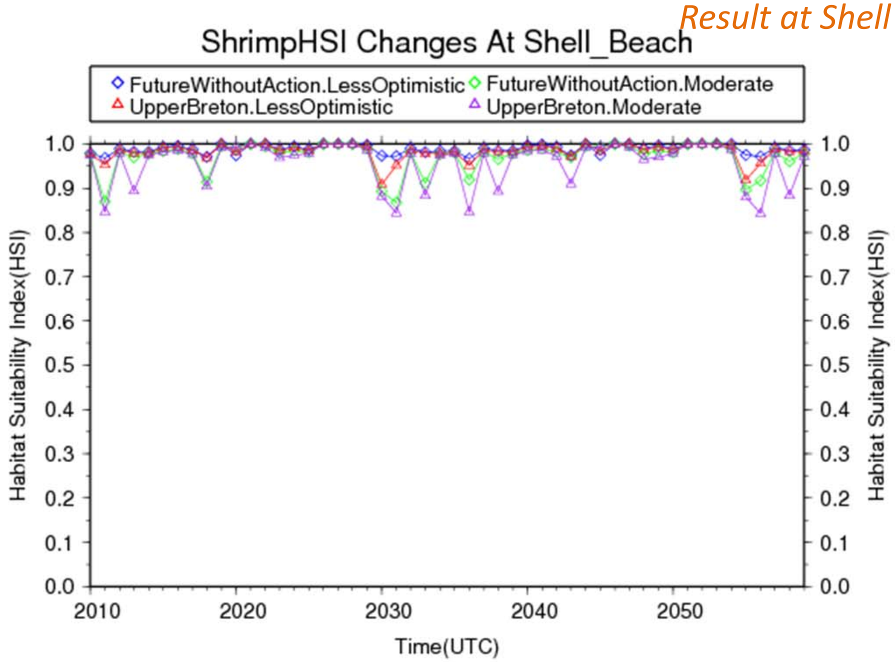


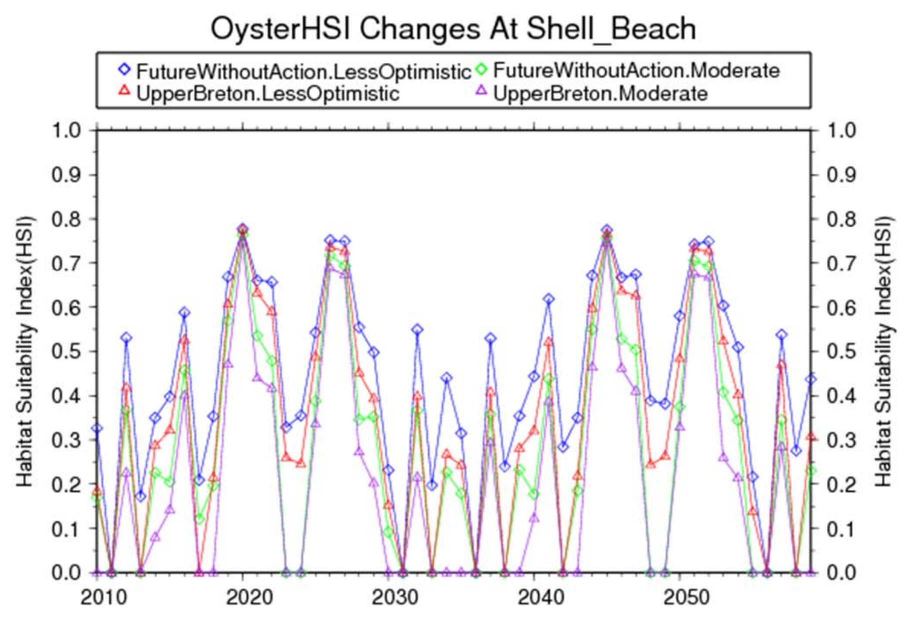
OysterHSI Changes At Rigolets
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

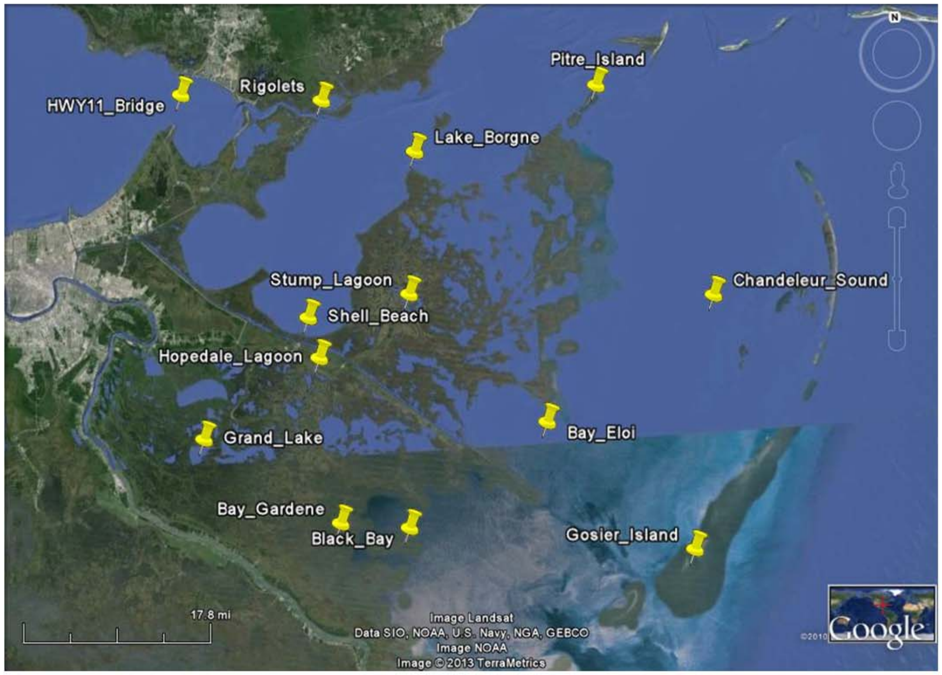




Note: Oyster HSI does not consider 3 years for oyster to reach marketable size
Result at Shell Beach and other places may be too optimistic






Pitre_Island
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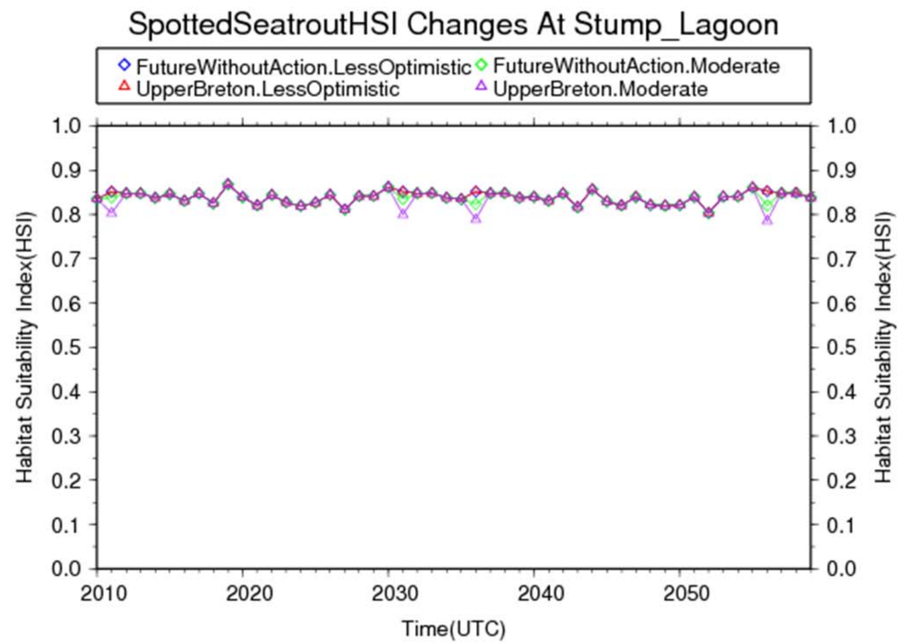
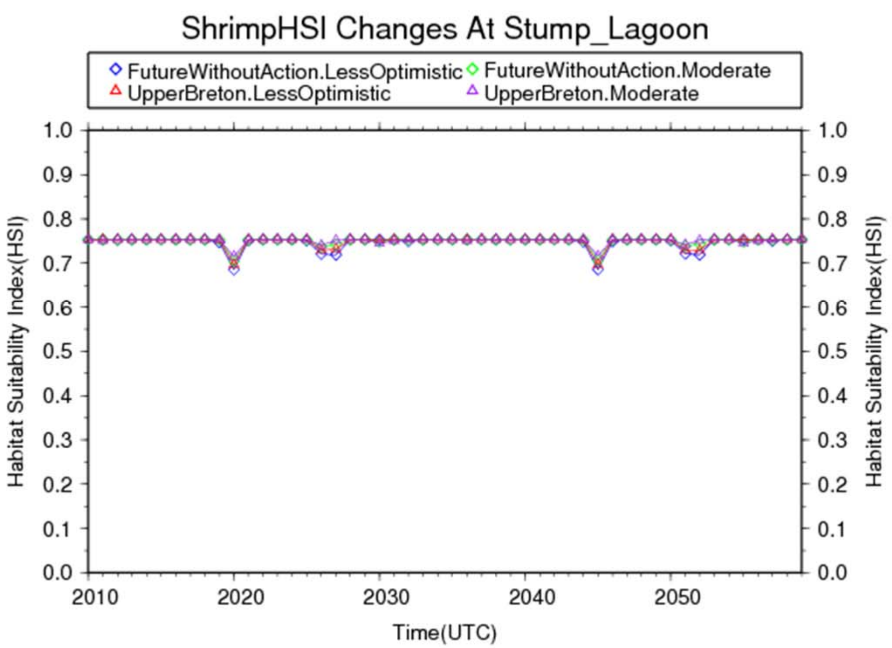
Bay_Gardene
Black_Bay
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google


SpottedSeatroutHSI Changes At Stump_Lagoon
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Stump_Lagoon
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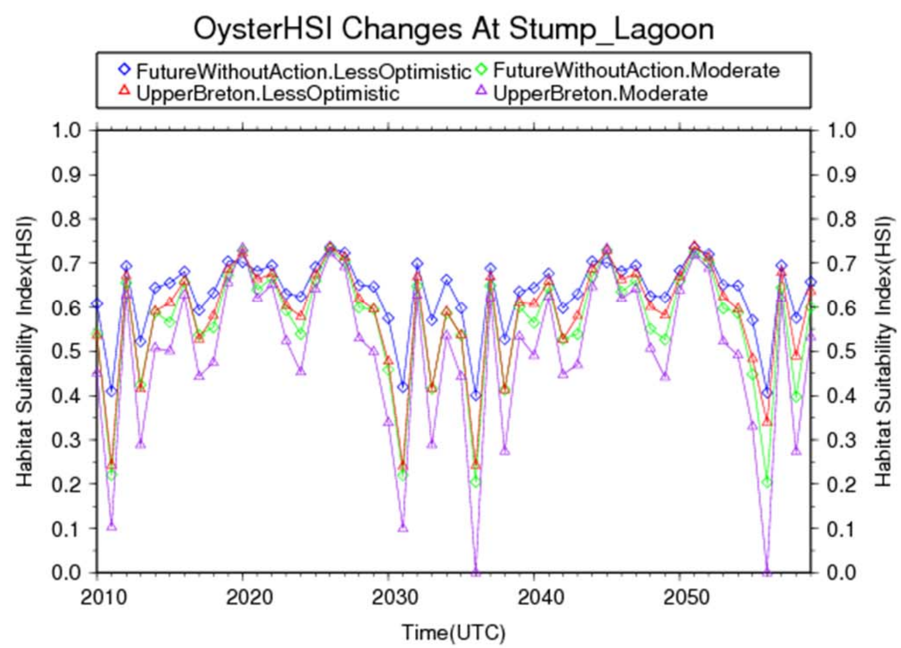
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Stump_Lagoon
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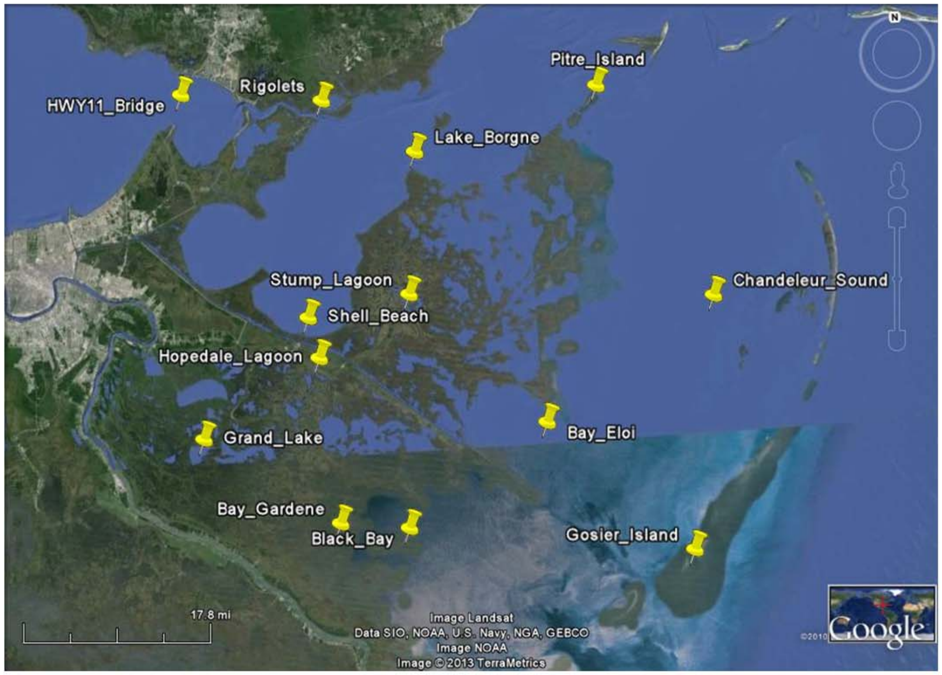
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)



HWY11_Bridge
Rigolets
Pitre_Island
Lake_Borgne
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Shell_Beach
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Hopedale_Lagoon
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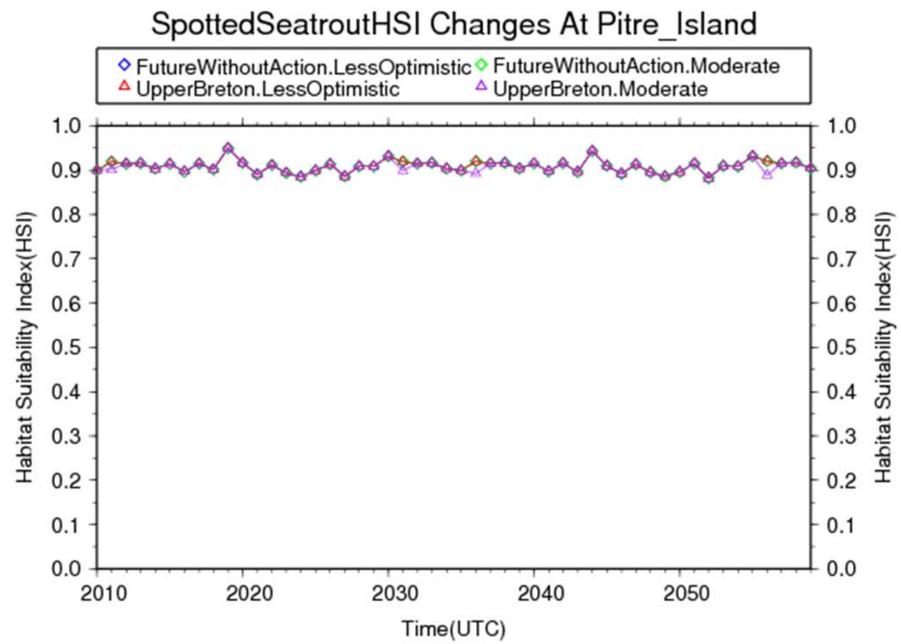
Black_Bay
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google



SpottedSeatroutHSI Changes At Pitre_Island
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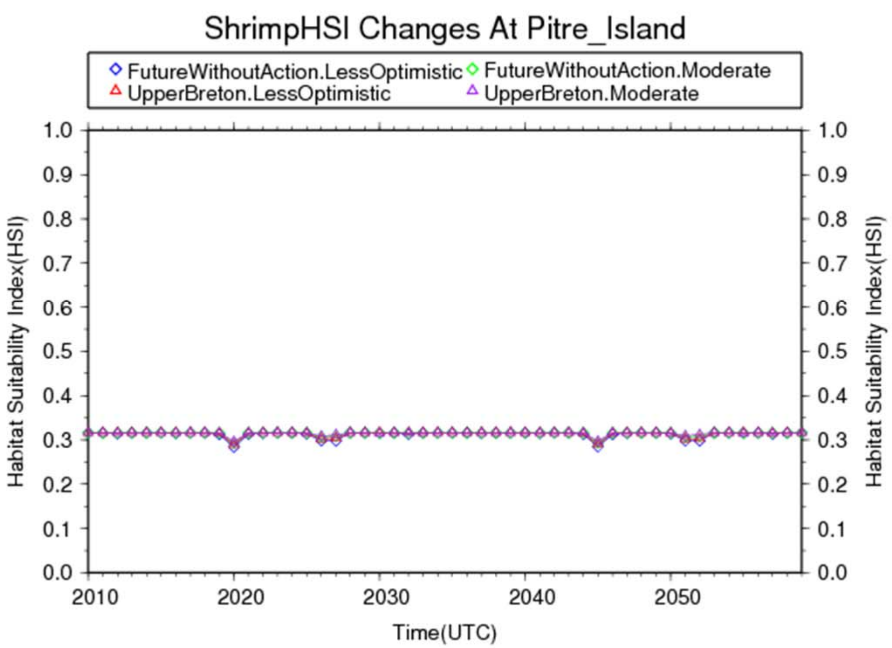
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)



ShrimpHSI Changes At Pitre_Island
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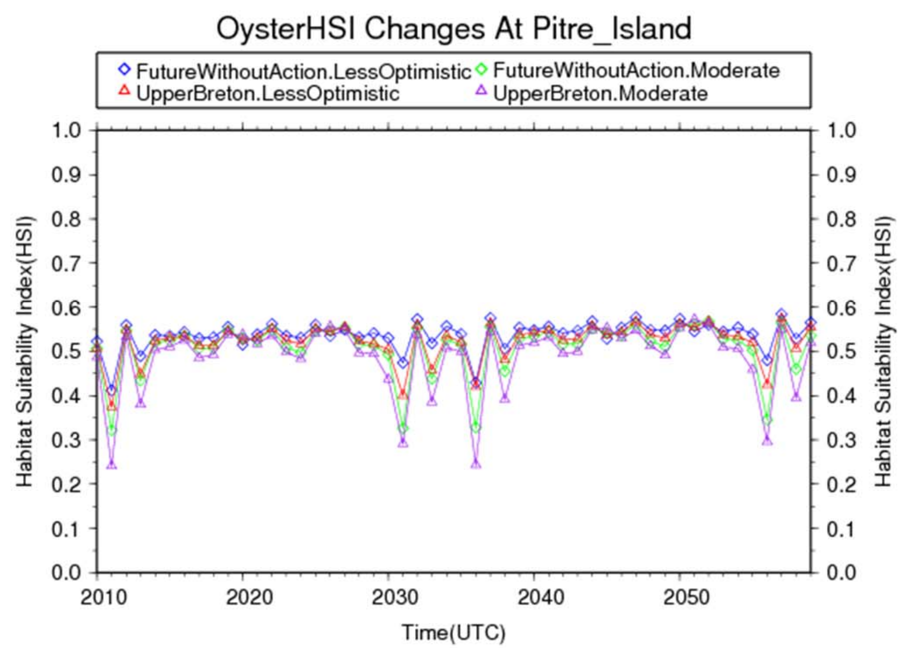
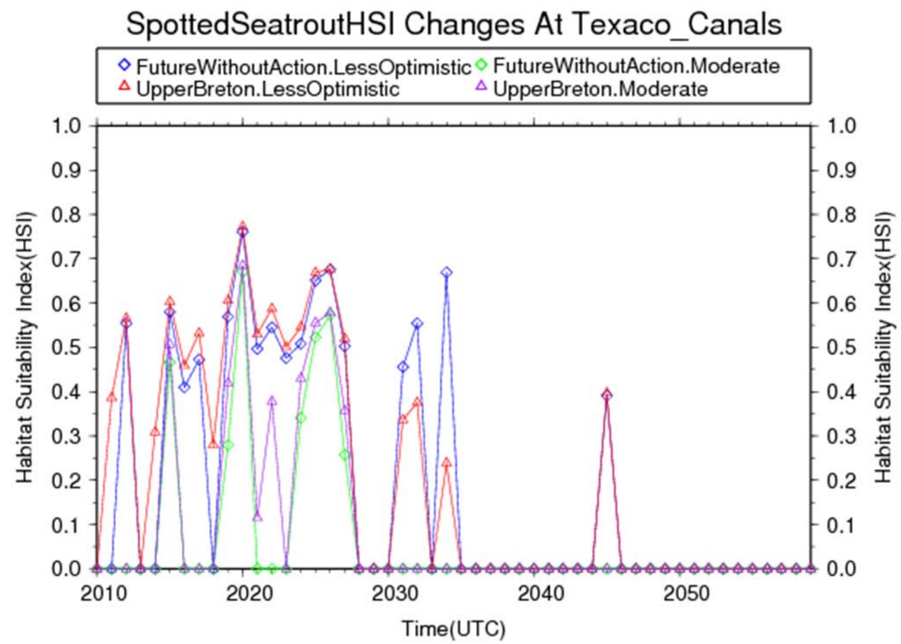
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

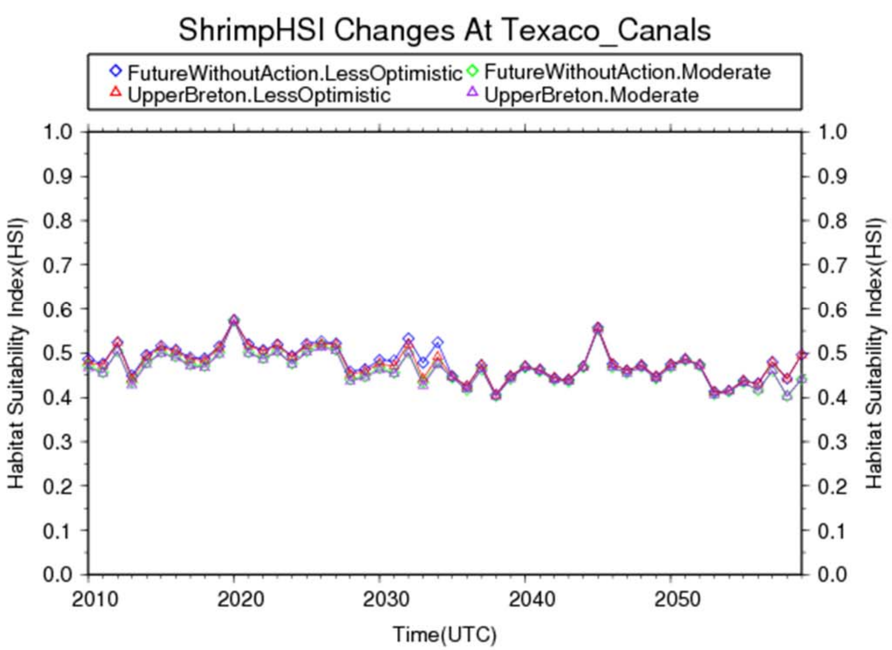


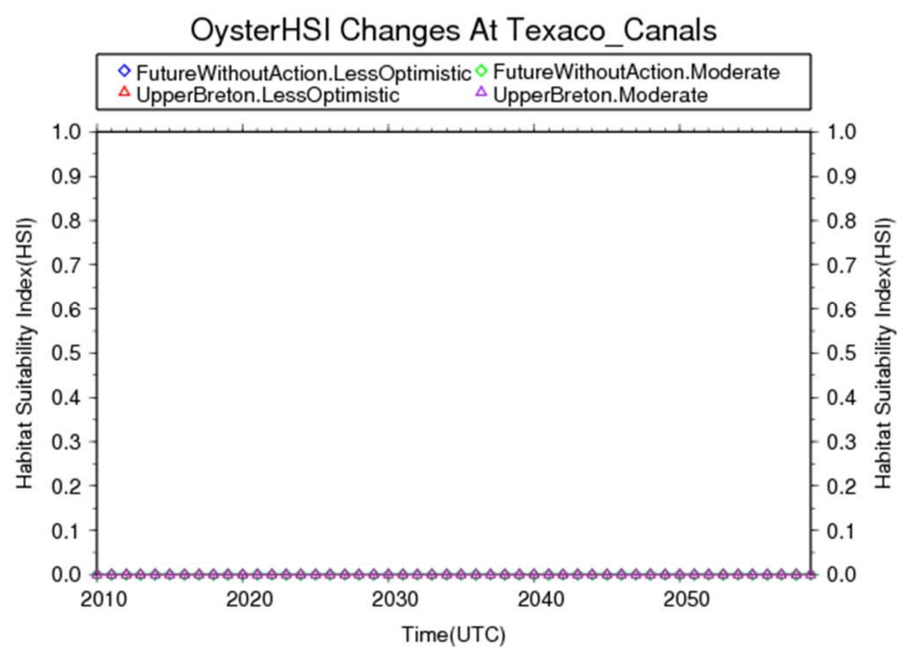
OysterHSI Changes At Pitre_Island
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

HSI results, West Bank

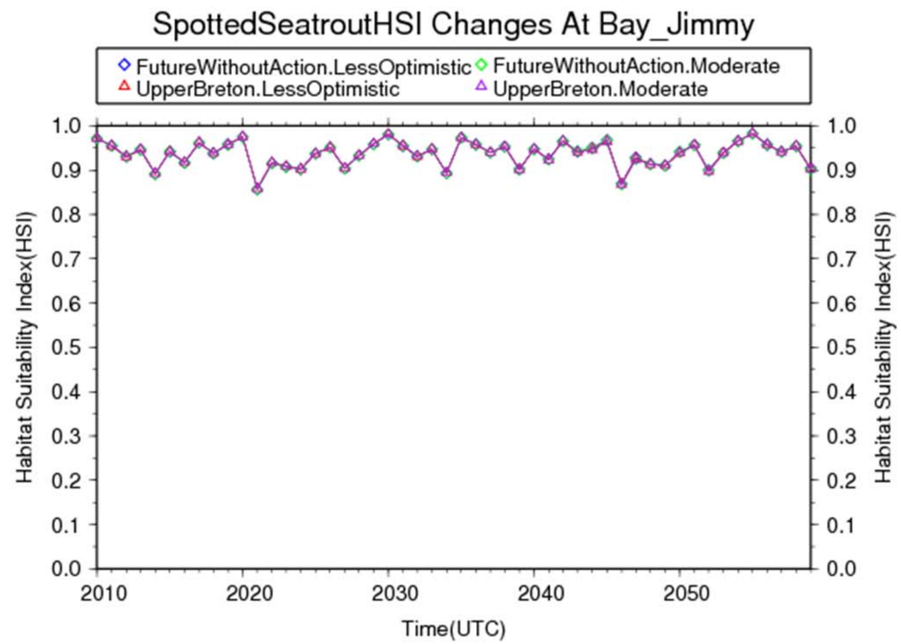

Texaco_Canals
Little_Lake
Bay_Jimmy
Adams_Bay
Bay_Rambo
Garden_Bay
Queen_Bess_Island
Bastian_Bay
Lake_Raccourci
Bayou_Rigaud
Scofield_Bayou
Lake_Palourde
Grand_Isle_Surf
Fourchon_Rocks
13.60 mi
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Google


SpottedSeatroutHSI Changes At Texaco_Canals
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Texaco_Canals
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Texaco_Canals
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


Texaco_Canals
Little_Lake
Bay_Jimmy
Adams_Bay
Bay_Rambo
Garden_Bay
Queen_Bess_Island
Bastian_Bay
Lake_Raccourci
Bayou_Rigaud
Scofield_Bayou
Lake_Palourde
Grand_Isle_Surf
Fourchon_Rocks
13.60 mi
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Google


SpottedSeatroutHSI Changes At Bay_Jimmy
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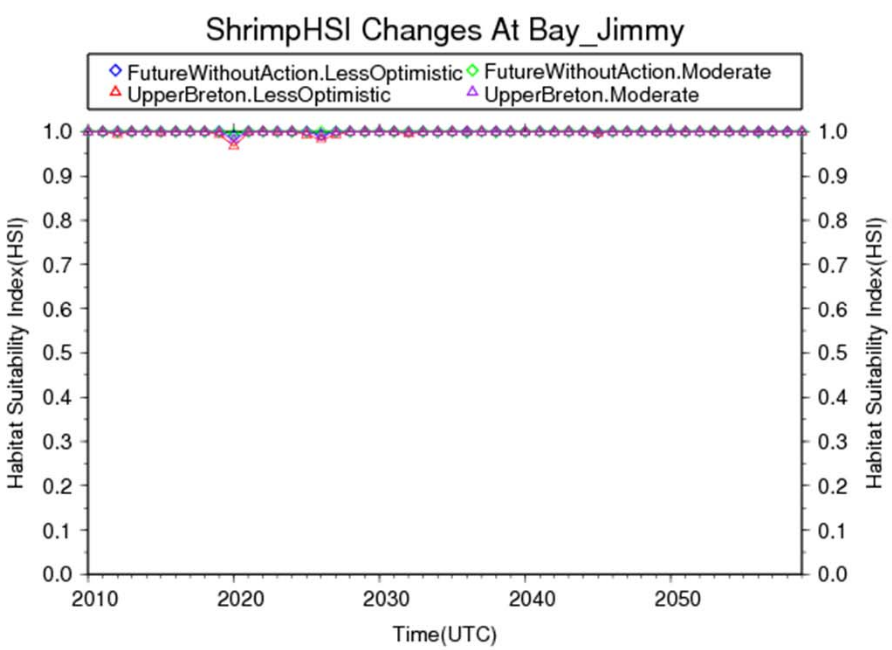
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Bay_Jimmy
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Habitat Suitability Index(HSI)
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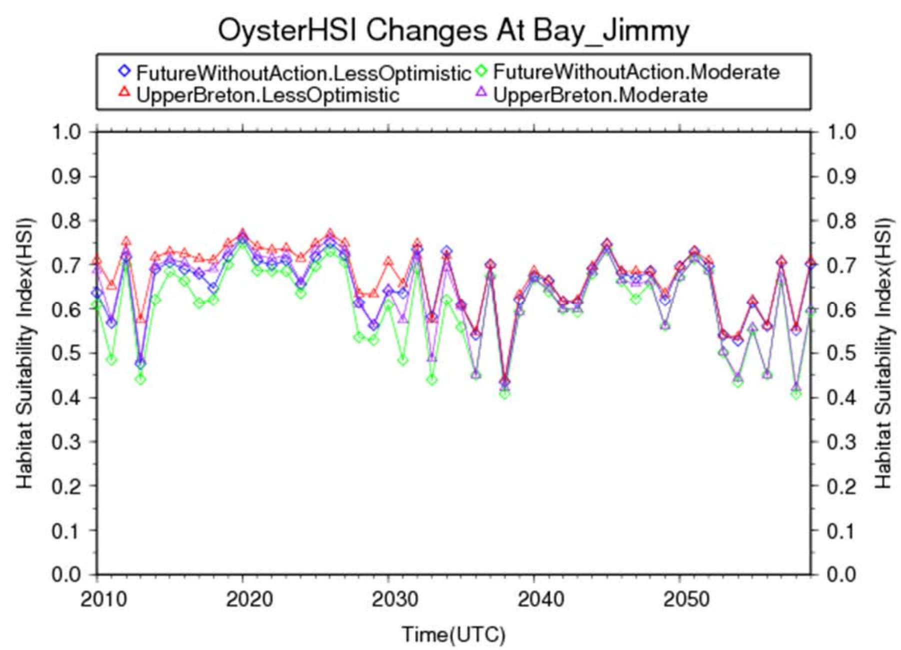
OysterHSI Changes At Bay_Jimmy
FutureWithoutAction.LessOptimistic
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UpperBreton.Moderate
Habitat Suitability Index(HSI)
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Texaco_Canals
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Lake_Palourde
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Fourchon_Rocks
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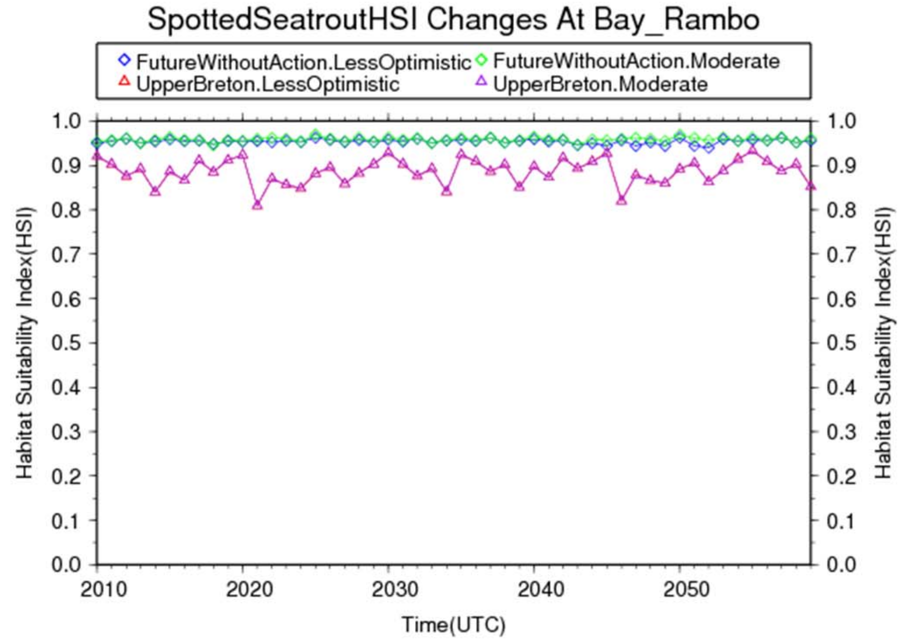
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Google


SpottedSeatroutHSI Changes At Bay_Rambo
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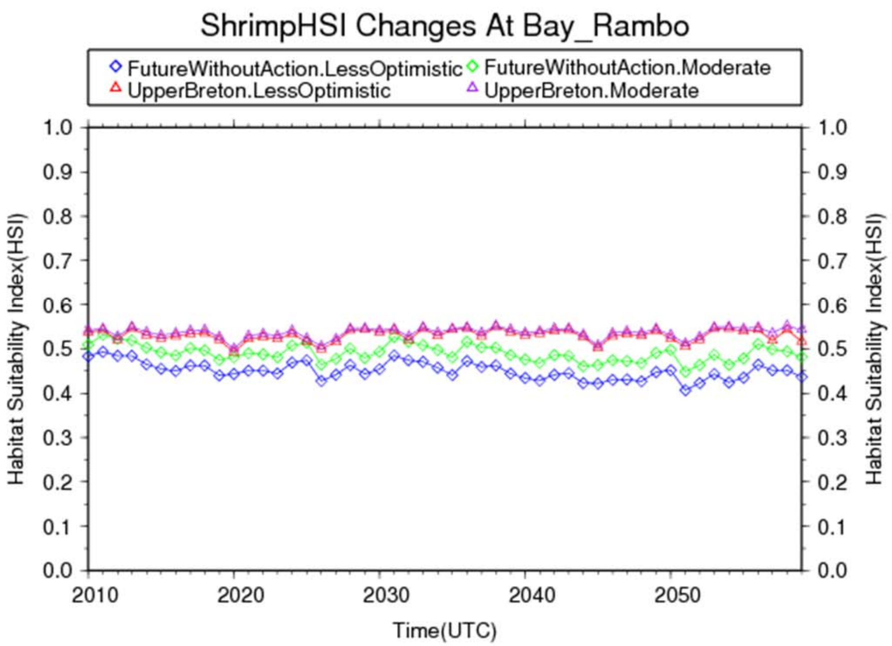
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Bay_Rambo
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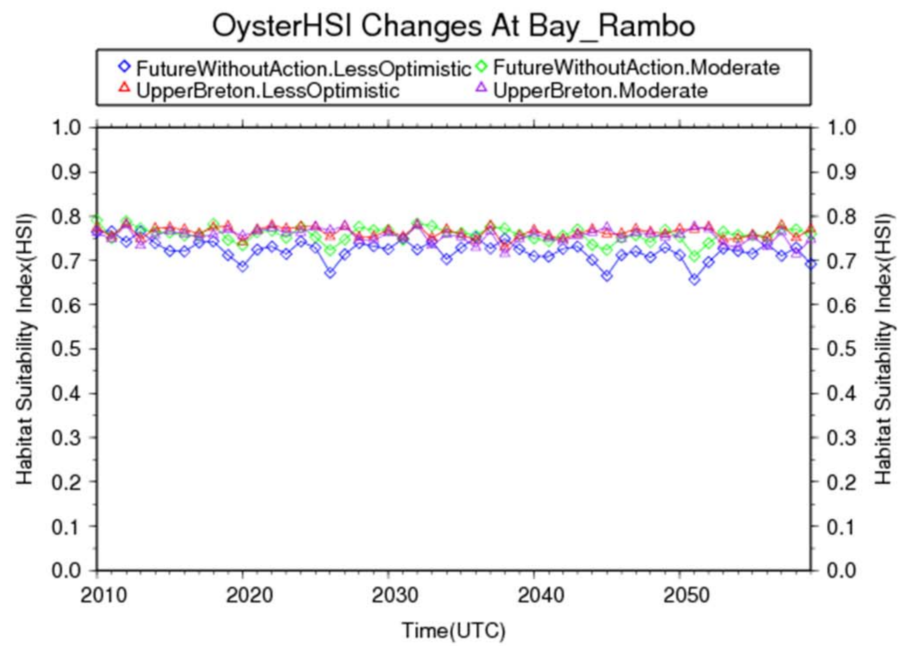
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Bay_Rambo
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
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Texaco_Canals
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Fourchon_Rocks
13.60 mi
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
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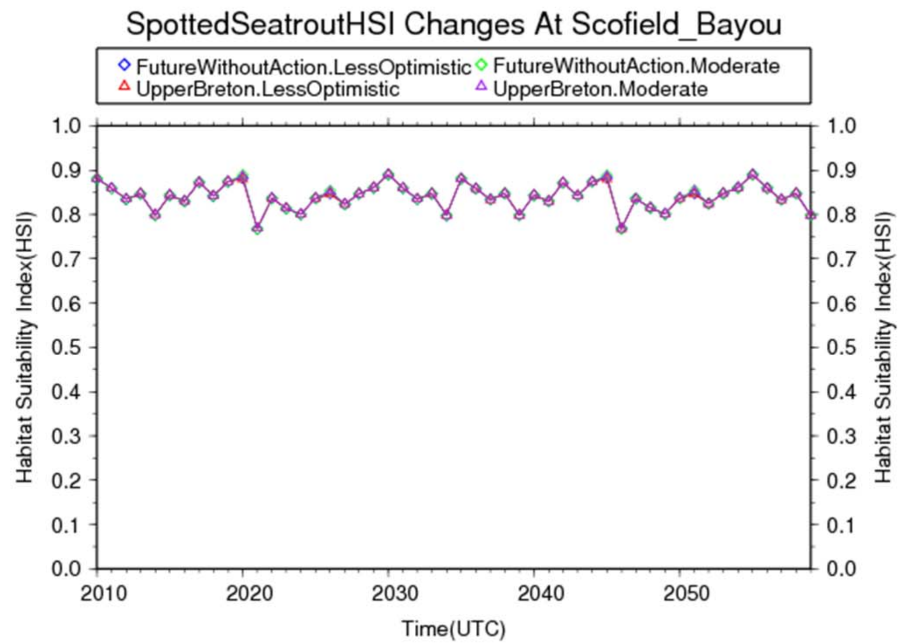
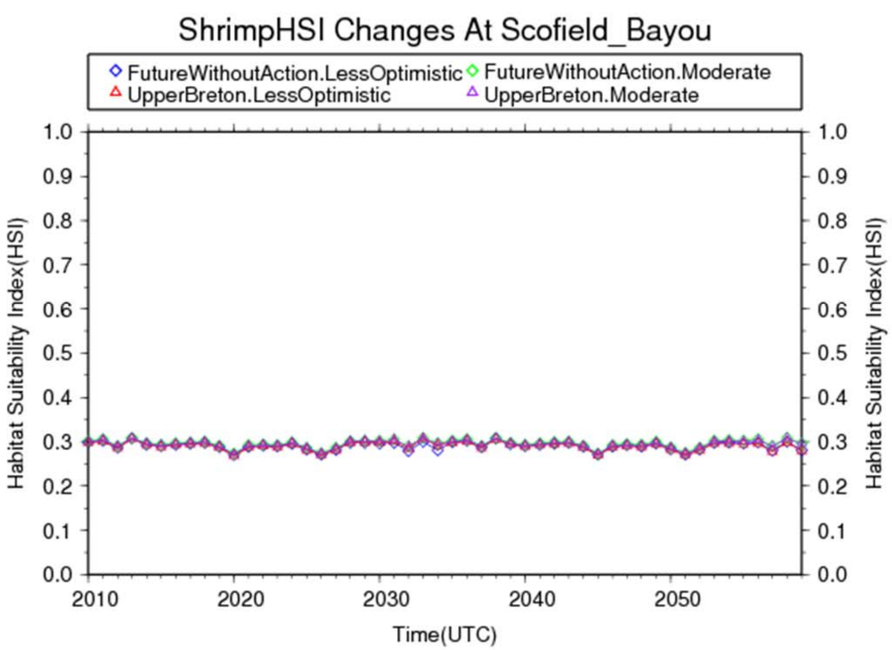

SpottedSeatroutHSI Changes At Scofield_Bayou
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Scofield_Bayou
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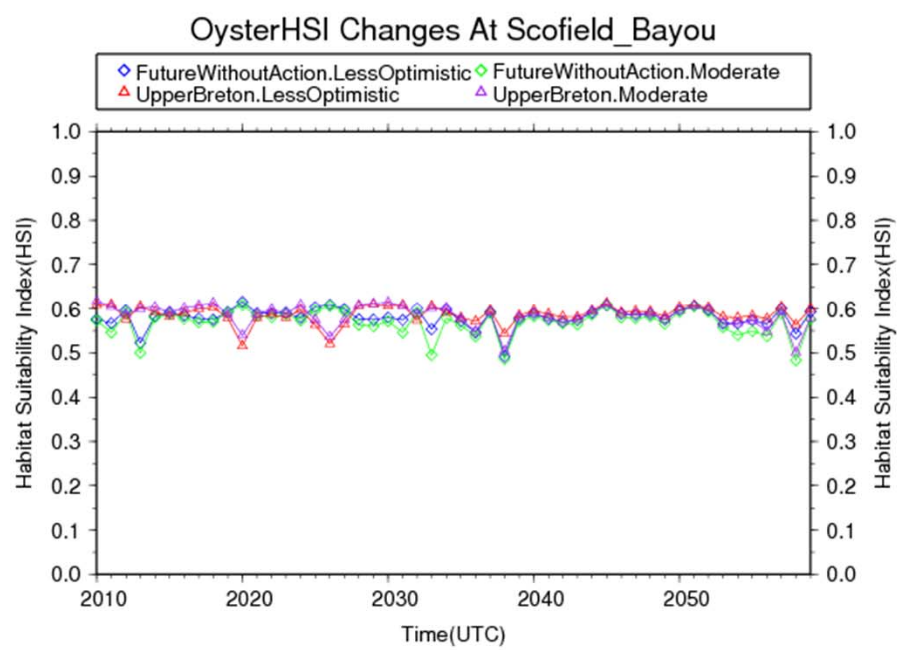
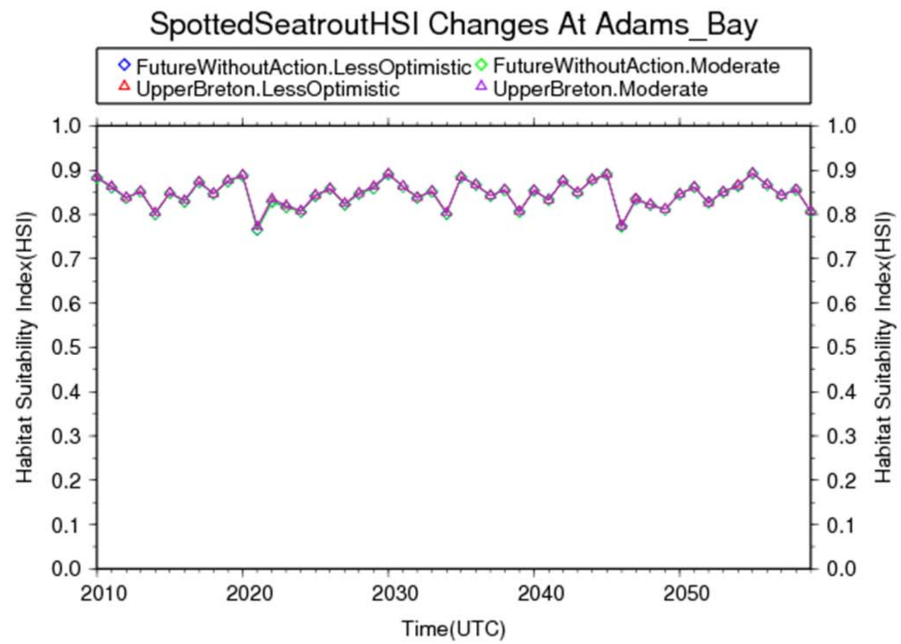
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Scofield_Bayou
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


Texaco_Canals
Little_Lake
Bay_Jimmy
Adams_Bay
Bay_Rambo
Garden_Bay
Queen_Bess_Island
Bastian_Bay
Lake_Raccourci
Bayou_Rigaud
Scofield_Bayou
Lake_Palourde
Grand_Isle_Surf
Fourchon_Rocks
13.60 mi
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Google


SpottedSeatroutHSI Changes At Adams_Bay
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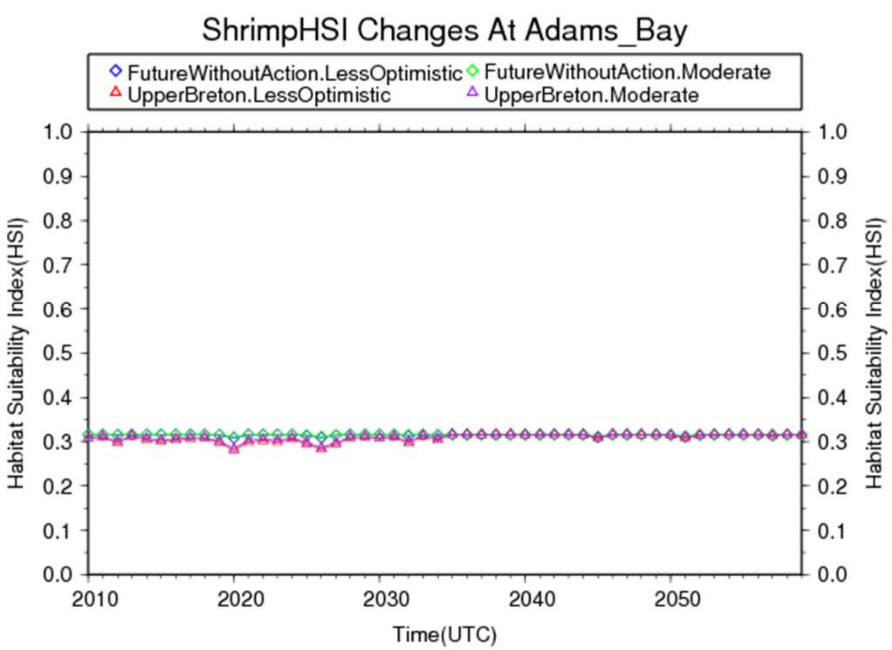
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


ShrimpHSI Changes At Adams_Bay
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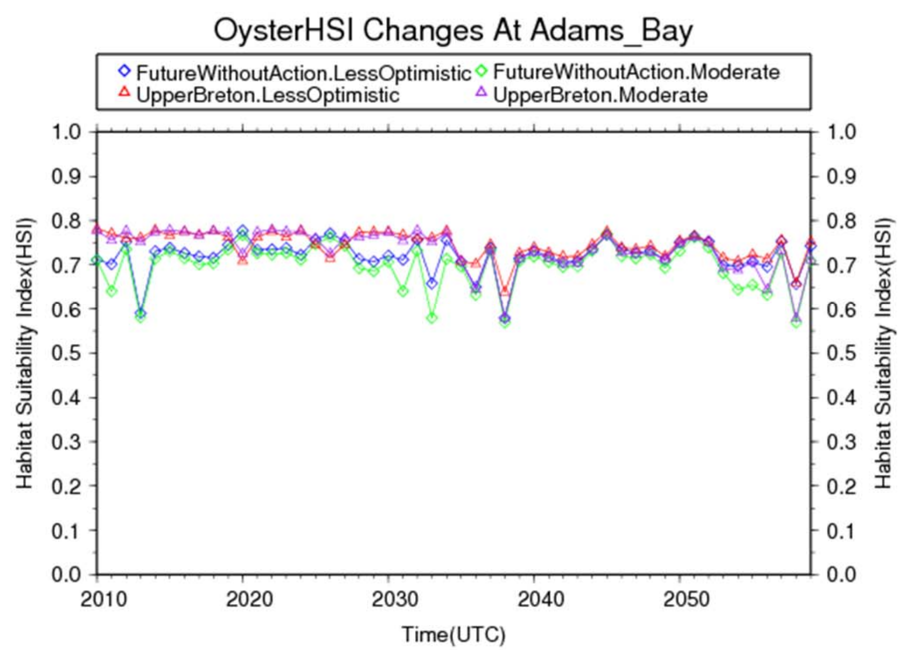
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Adams_Bay
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


Texaco_Canals
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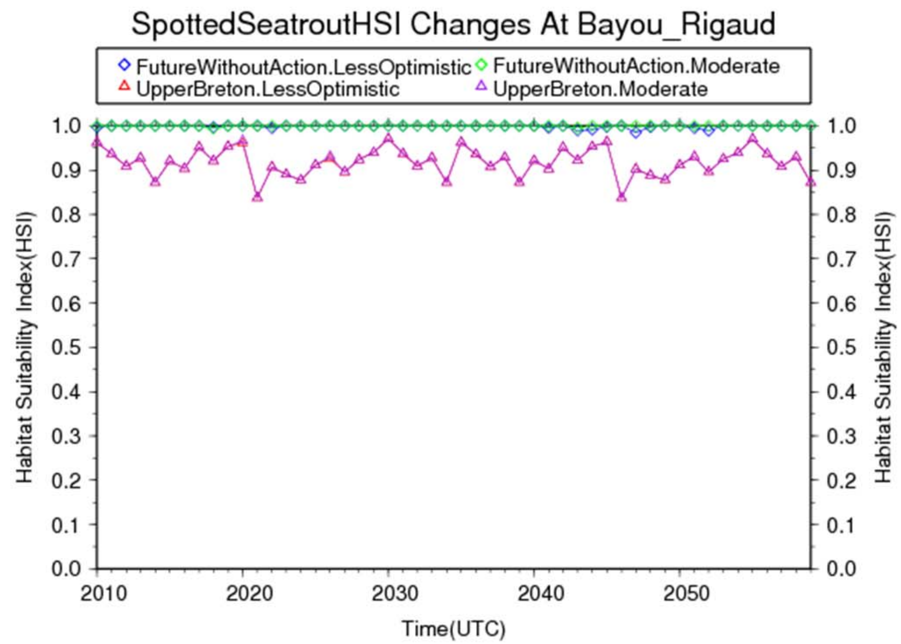
13.60 mi
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Google


SpottedSeatroutHSI Changes At Bayou_Rigaud
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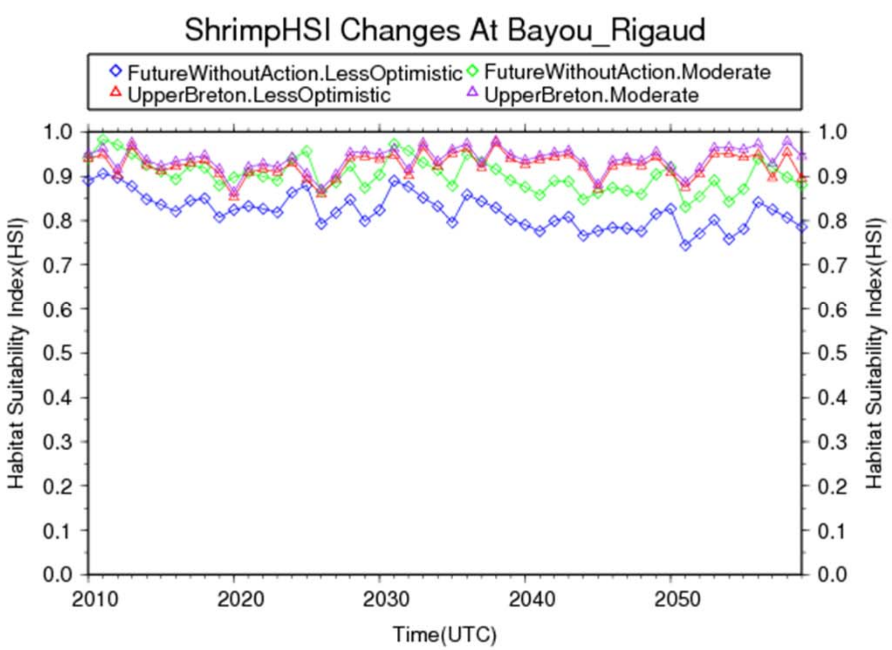
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)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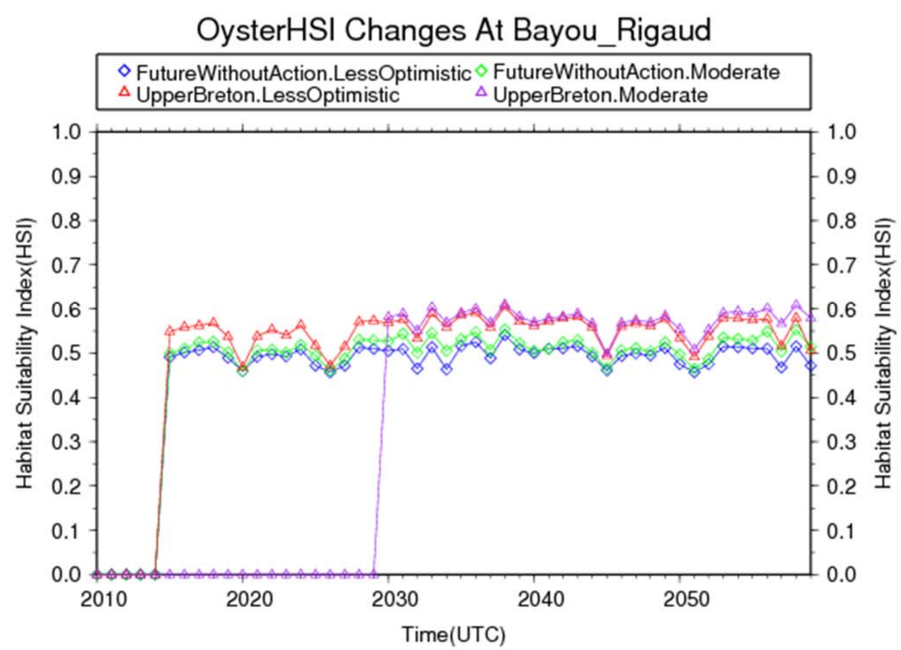
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


OysterHSI Changes At Bayou_Rigaud
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

Texaco_Canals
Little_Lake
Bay_Jimmy
Adams_Bay
Bay_Rambo
Garden_Bay
Queen_Bess_Island
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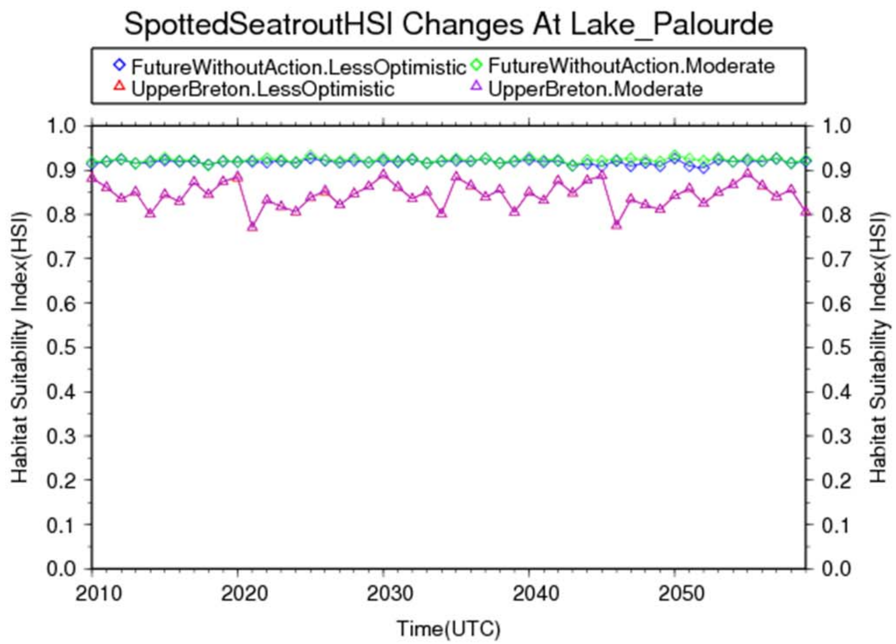
Bayou_Rigaud
Scofield_Bayou
Lake_Palourde
Grand_Isle_Surf
Fourchon_Rocks
13.60 mi
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Google



SpottedSeatroutHSI Changes At Lake_Palourde
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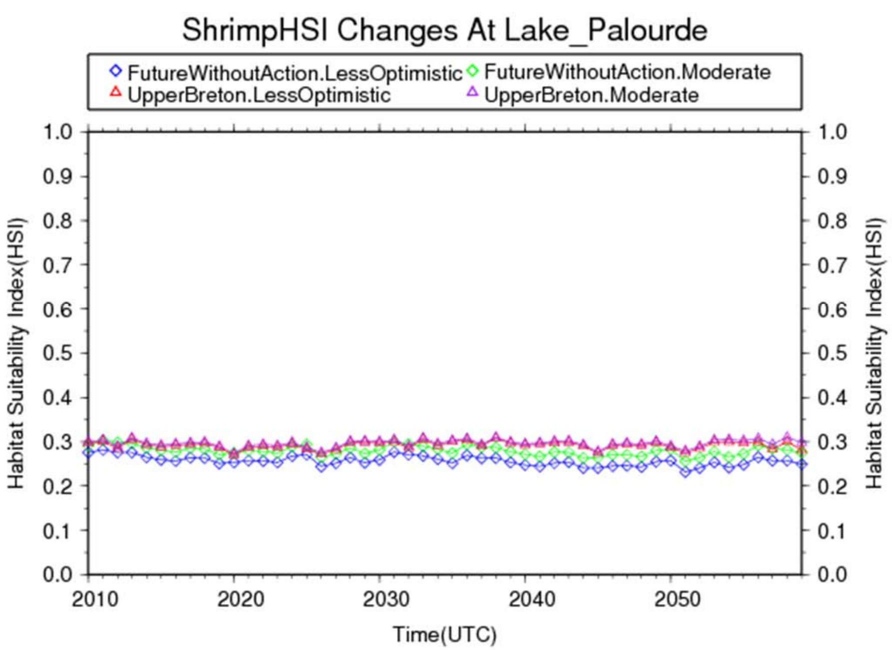
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)



ShrimpHSI Changes At Lake_Palourde
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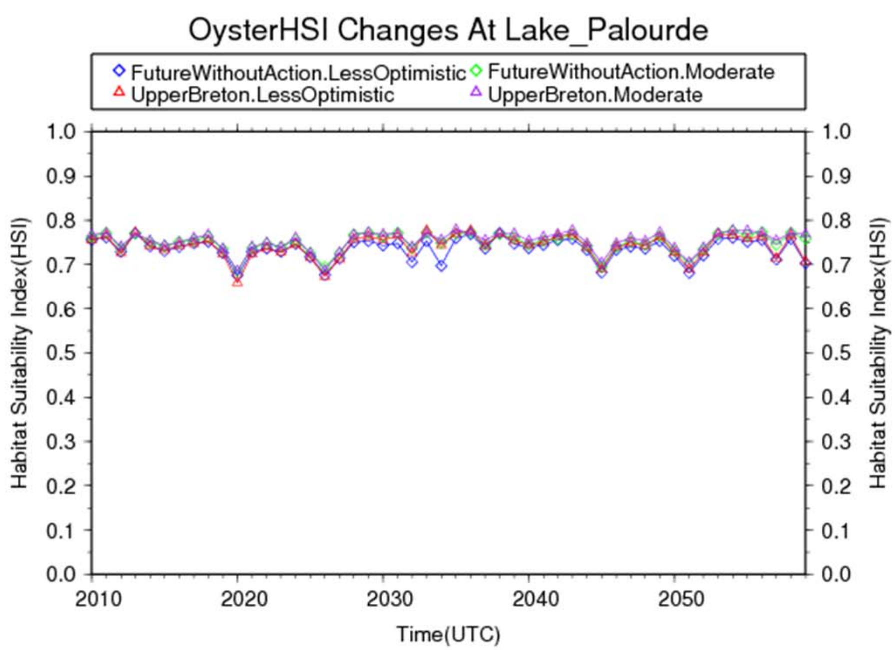
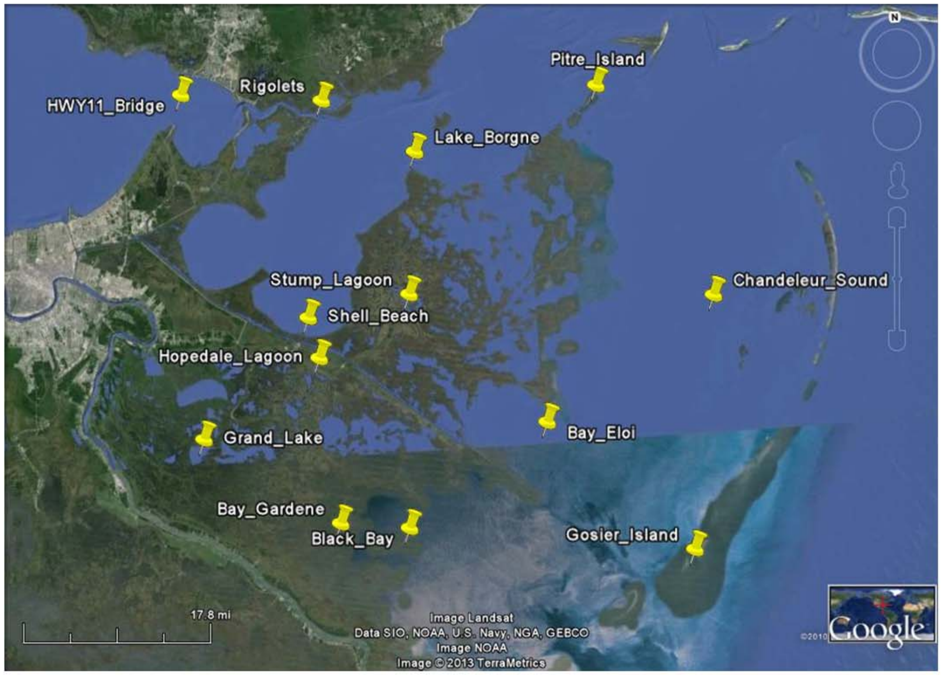
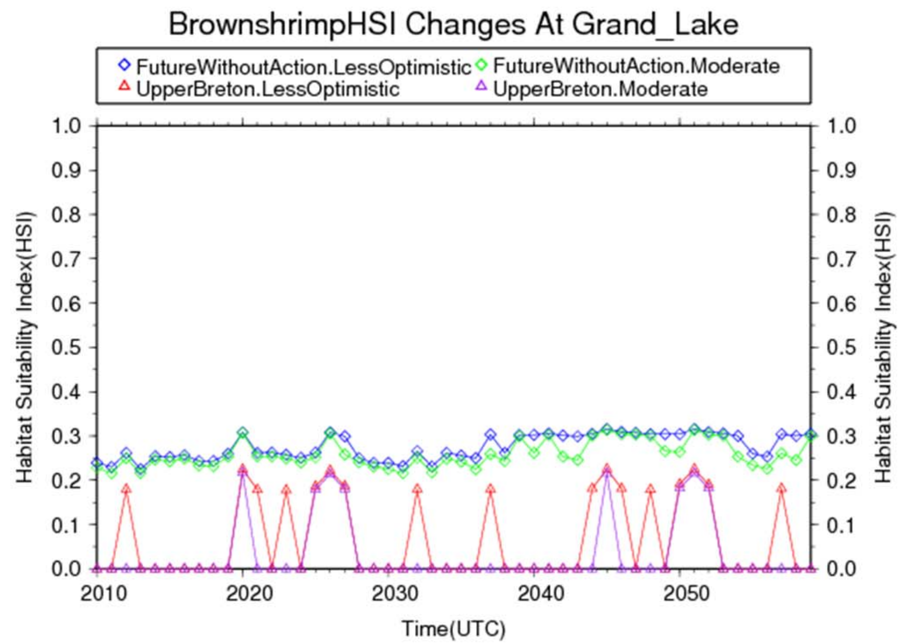
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)



OysterHSI Changes At Lake_Palourde
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

Locations with brown and white shrimp HSI differences


HWY11_Bridge
Rigolets
Pitre_Island
Lake_Borgne
Stump_Lagoon
Shell_Beach
Chandeleur_Sound
Hopedale_Lagoon
Bay_Eloi
Grand_Lake
Bay_Gardene
Black_Bay
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google


BrownshrimpHSI Changes At Grand_Lake
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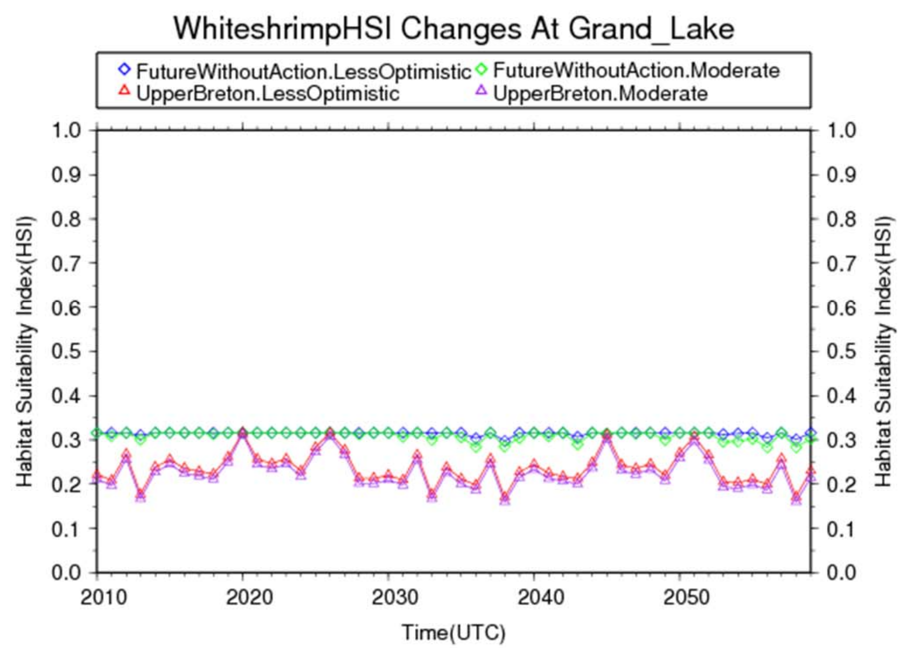
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


WhiteshrimpHSI Changes At Grand_Lake
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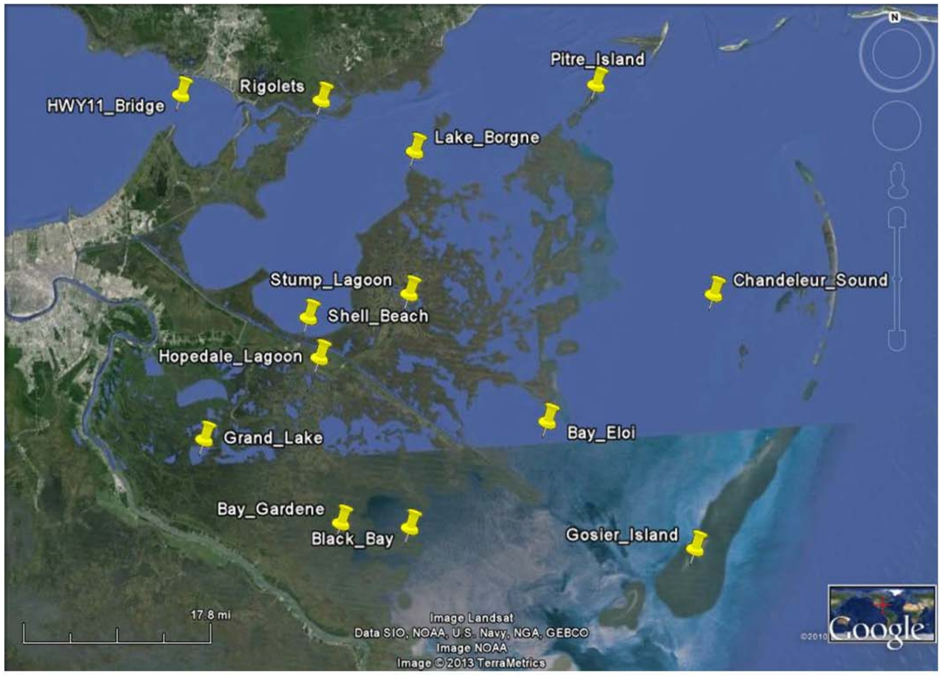
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


HWY11_Bridge
Rigolets
Pitre_Island
Lake_Borgne
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Shell_Beach
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Hopedale_Lagoon
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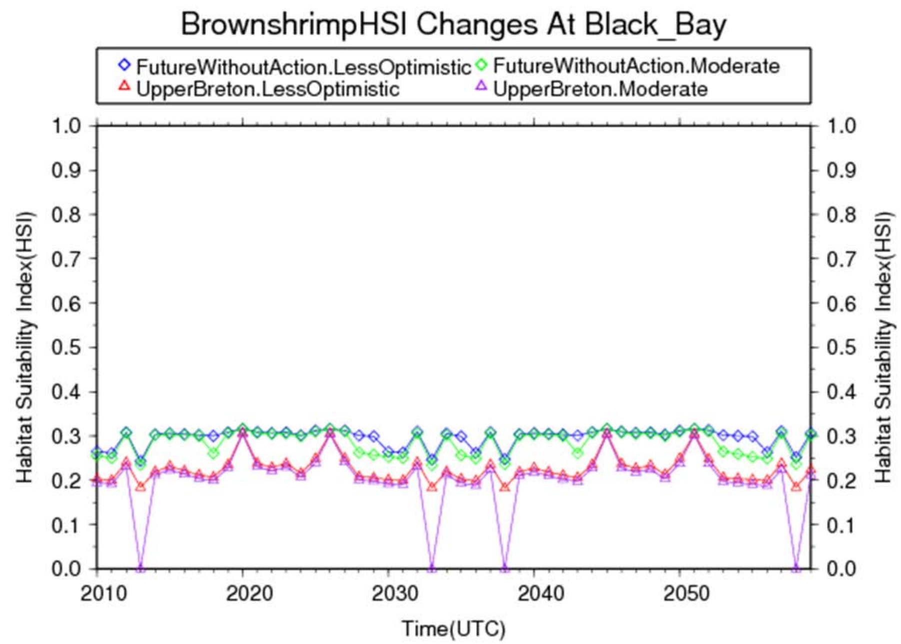
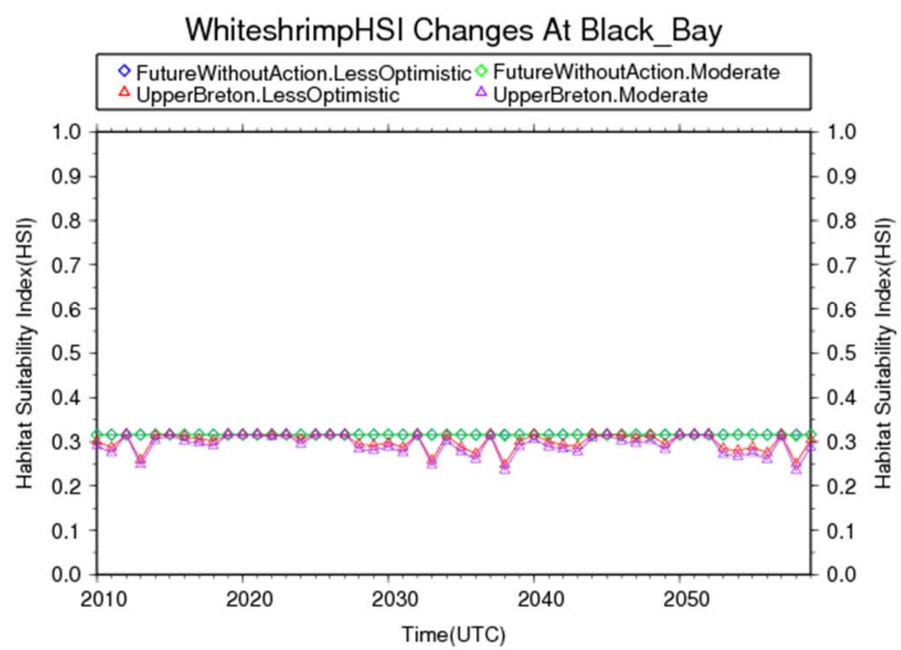
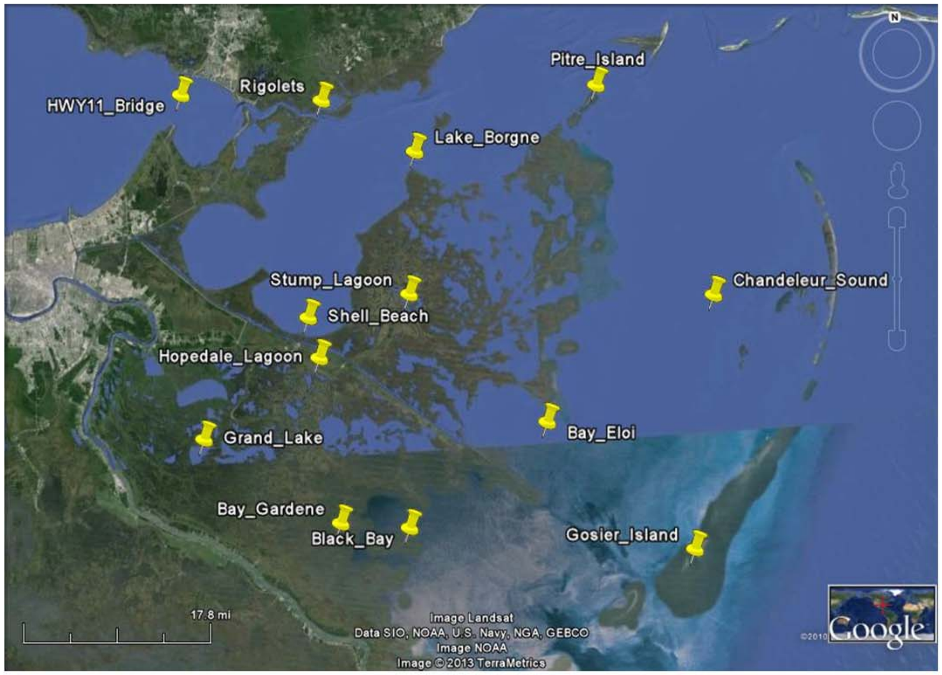
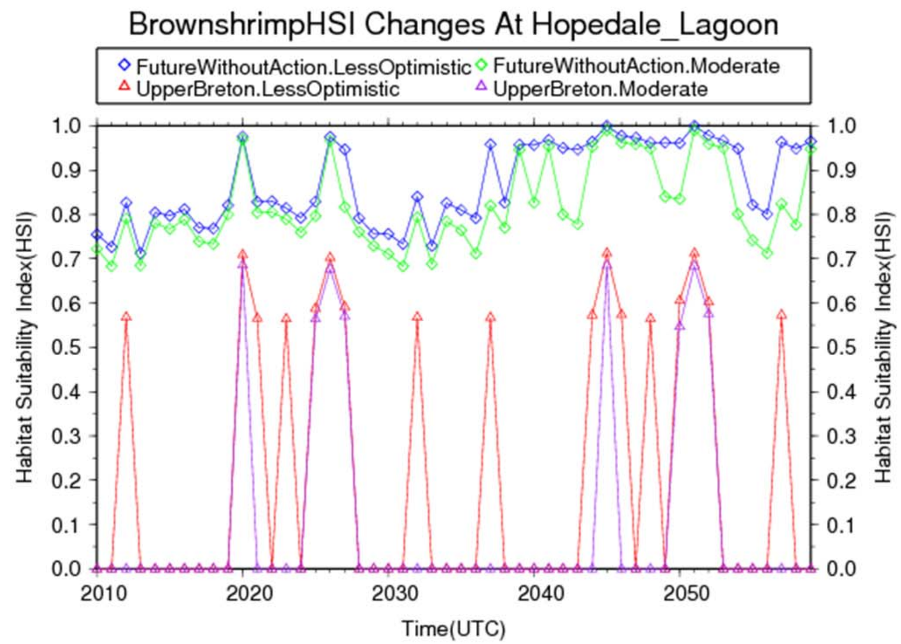
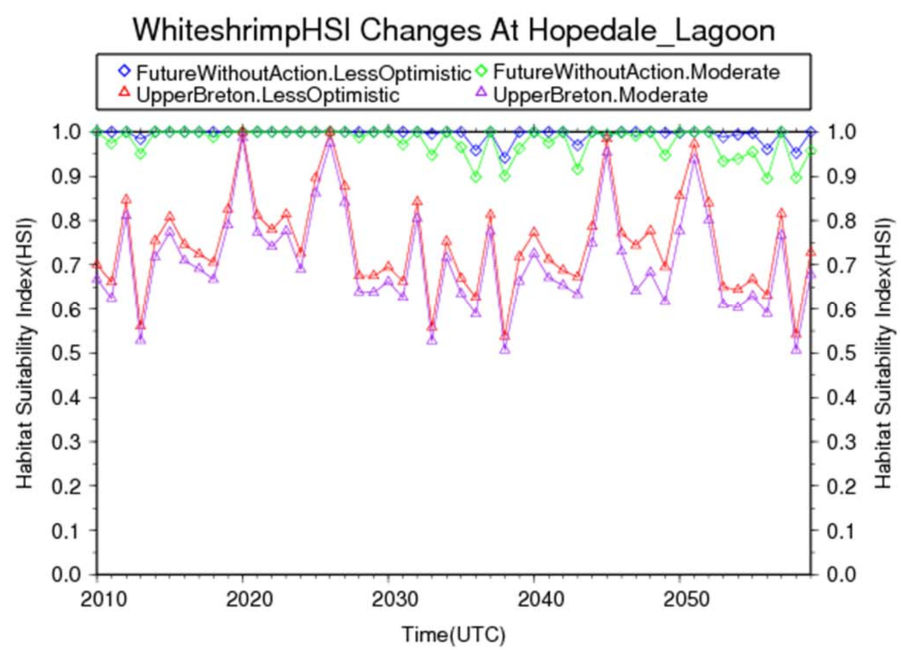
Black_Bay
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google


BrownshrimpHSI Changes At Black_Bay
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

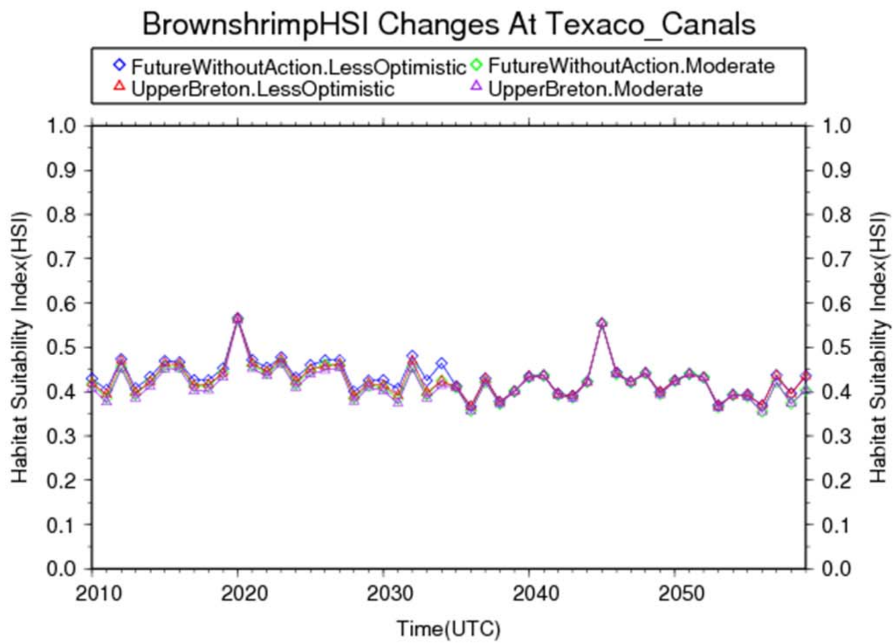

WhiteshrimpHSI Changes At Black_Bay
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)

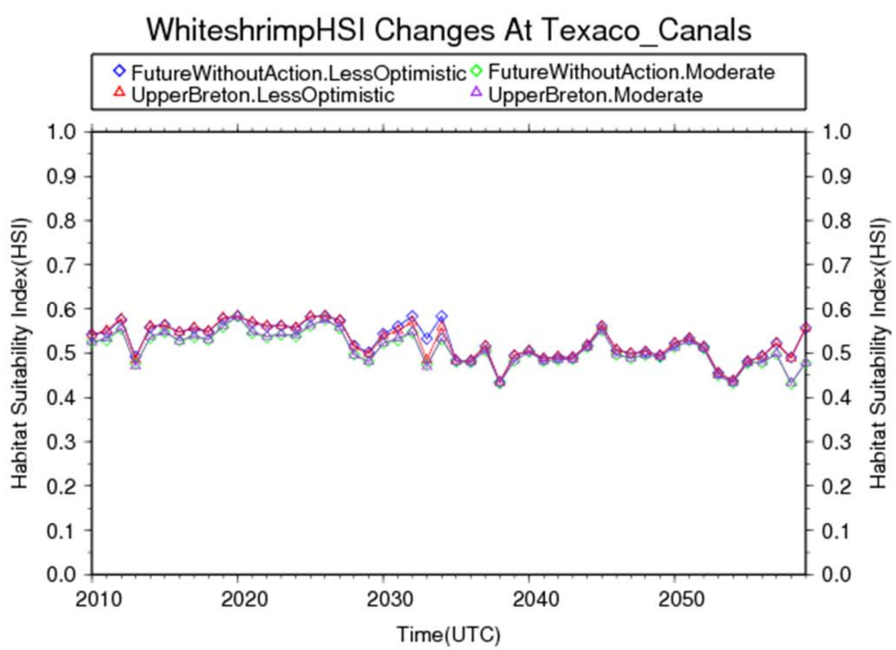

Pitre_Island
Rigolets
HWY11_Bridge
Lake_Borgne
Stump_Lagoon
Chandeleur_Sound
Shell_Beach
Hopedale_Lagoon
Bay_Eloi
Grand_Lake
Bay_Gardene
Black_Bay
Gosier_Island
17.8 mi
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Image © 2013 TerraMetrics
Google


BrownshrimpHSI Changes At Hopedale_Lagoon
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


WhiteshrimpHSI Changes At Hopedale_Lagoon
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)


Texaco_Canals
Little_Lake
Bay_Jimmy
Adams_Bay
Bay_Rambo
Garden_Bay
Queen_Bess_Island
Bastian_Bay
Lake_Raccourci
Bayou_Rigaud
Scofield_Bayou
Lake_Palourde
Grand_Isle_Surf
Fourchon_Rocks
13.60 mi
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Google


BrownshrimpHSI Changes At Texaco_Canals
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2010
2020
2030
2040
2050


WhiteshrimpHSI Changes At Texaco_Canals
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2010
2020
2030
2040
2050


Texaco_Canals
Little_Lake
Bay_Jimmy
Adams_Bay
Bay_Rambo
Garden_Bay
Queen_Bess_Island
Bastian_Bay
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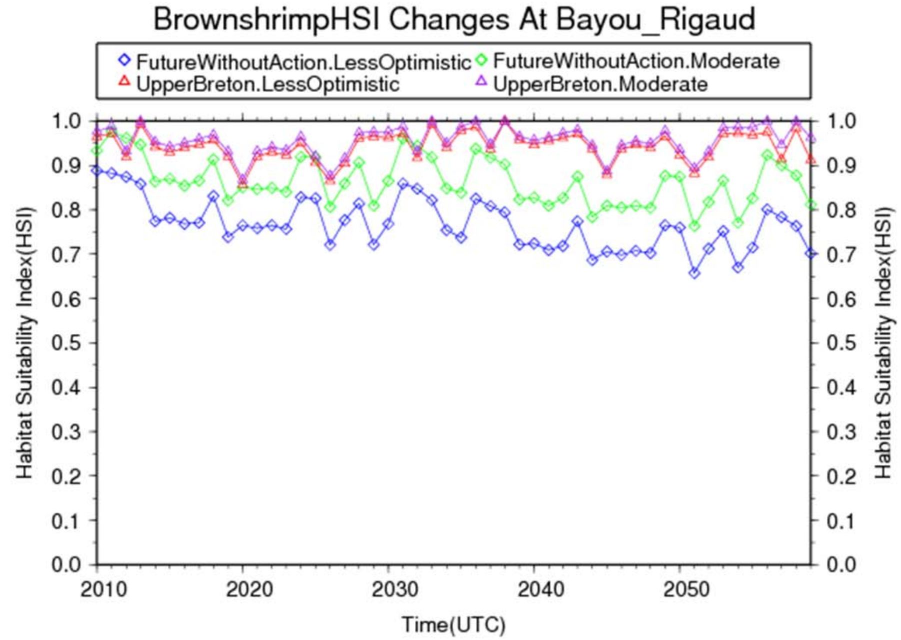
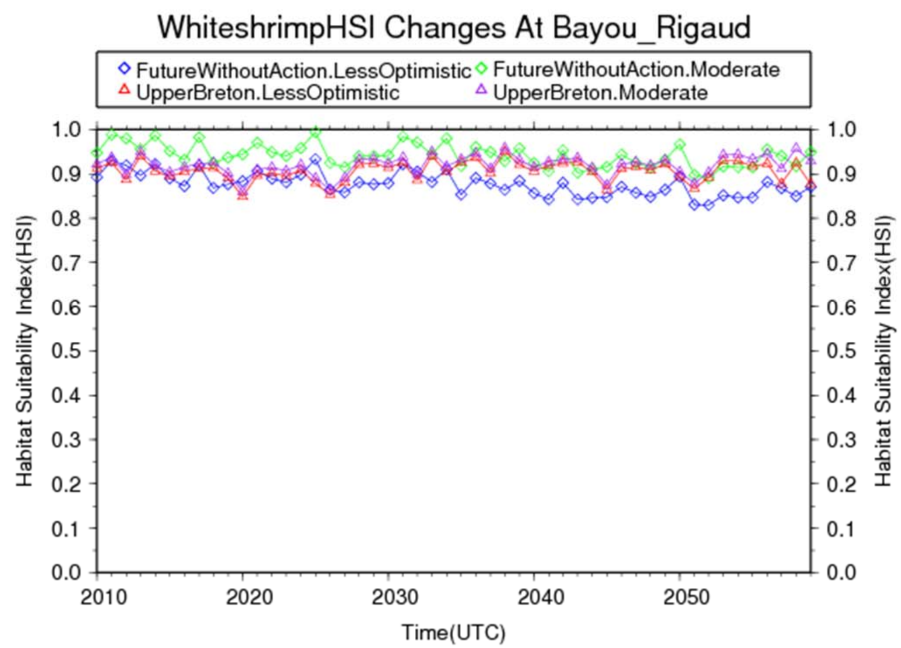
Bayou_Rigaud
Scofield_Bayou
Lake_Palourde
Grand_Isle_Surf
Fourchon_Rocks
13.60 mi
Image Landsat
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image NOAA
Google


BrownshrimpHSI Changes At Bayou_Rigaud
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)
2010 2020 2030 2040 2050
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0


WhiteshrimpHSI Changes At Bayou_Rigaud
FutureWithoutAction.LessOptimistic
FutureWithoutAction.Moderate
UpperBreton.LessOptimistic
UpperBreton.Moderate
Habitat Suitability Index(HSI)
Time(UTC)
2010 2020 2030 2040 2050
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

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.
• One exception is possibly behind Grand Isle for oysters.

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.

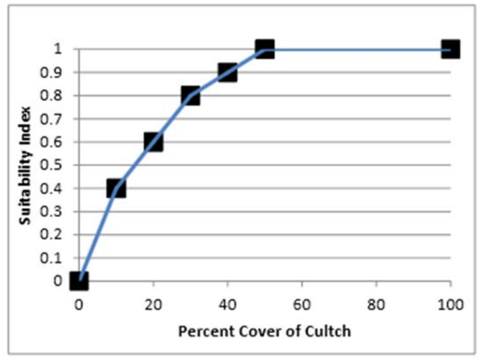
Extra material, oysters

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 ≥ 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 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).

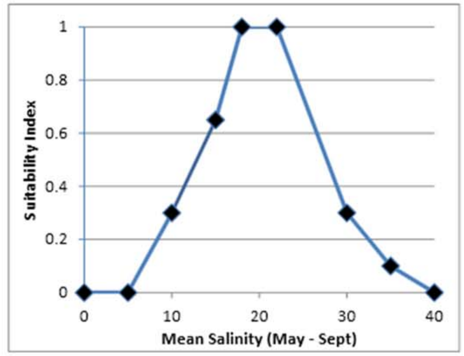
SI_1 =	0.0	for V1 = 0
	0.4	for V1 = 10
	0.6	for V1 = 20
	0.8	for V1 = 30
	0.9	for V1 = 40
	1.0	for V1 = 50
	1.0	for V1 = 100



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.

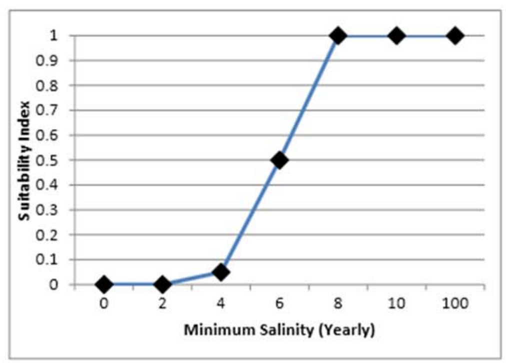
Variable 2 (V_2) is the mean salinity during the spawning season. The value applied is the mean of the monthly May through September salinities for each 500 x 500m grid. This variable reflects the higher optimal salinities required for spawning as opposed to the optimum salinity requirements of adults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

SI_2 =	0	for V2 = 0
	0	for V2 = 5
	0.3	for V2 = 10
	0.65	for V2 = 15
	1.0	for V2 = 18
	1.0	for V2 = 22
	0.3	for V2 = 30
	0.1	for V2 = 35
	0	for V2 = 40



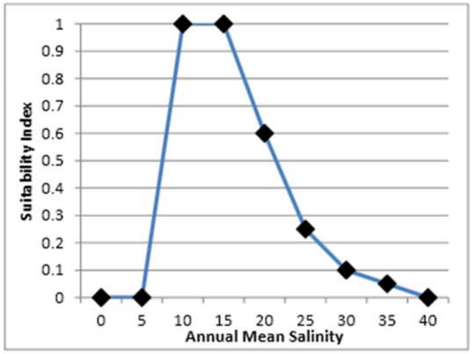
Variable 3 (V_3) is the minimum salinity, i.e. the minimum value of the 12 monthly mean salinities for each 500 x 500m grid. Minimum salinity values were derived from the spatially-referenced data in polygons provided by the Eco-Hydrology model after linear interpolations were made across salinity gradients, 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 Soniat 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 V3 = 0
	0.0	for V3 = 2
	0.05	for V3 = 4
	0.5	for V3 = 6
	1.0	for V3 = 8
	1.0	for V3 = 10



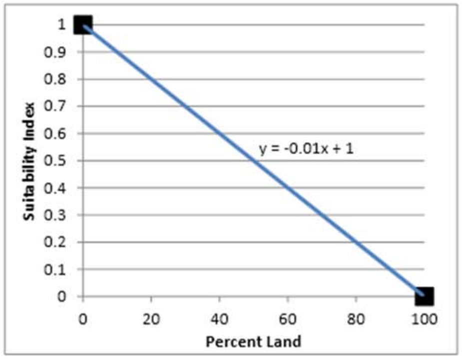
Variable 4 (V_4) is annual mean salinity. The value for V_4 is the grand mean of the 12 monthly mean salinities for each 500 x 500m grid. Annual mean salinity defines the range over which adult oysters survive and thrive (Gunter 1955, Calabrese and Davis 1970, Castagna and Chanley 1973, Cake 1983, Chatry 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 V4 = 0
	0.0	for V4 = 5
	1.0	for V4 = 10
	1.0	for V4 = 15
	0.6	for V4 = 20
	0.25	for V4 = 25
	0.1	for V4 = 30
	0.05	for V4 = 35
	0.0	for V4 = 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).

$V_5 = (-0.01 * \%Land) + 1$
$SI_5 = V_5$



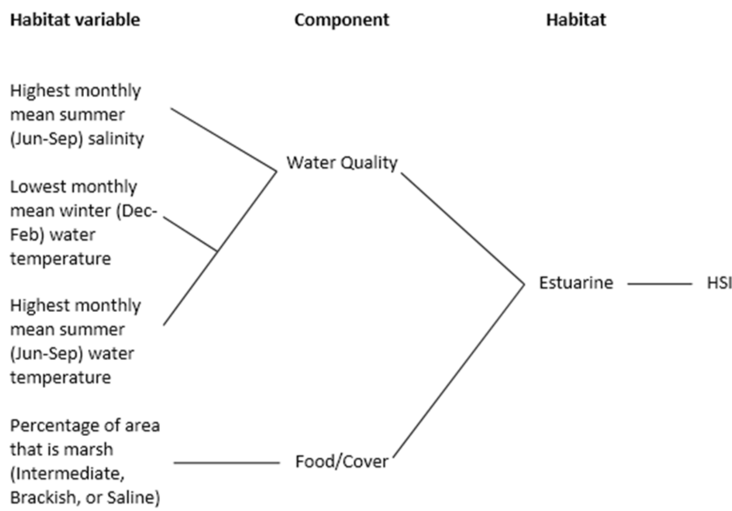
Extra material, trout

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).

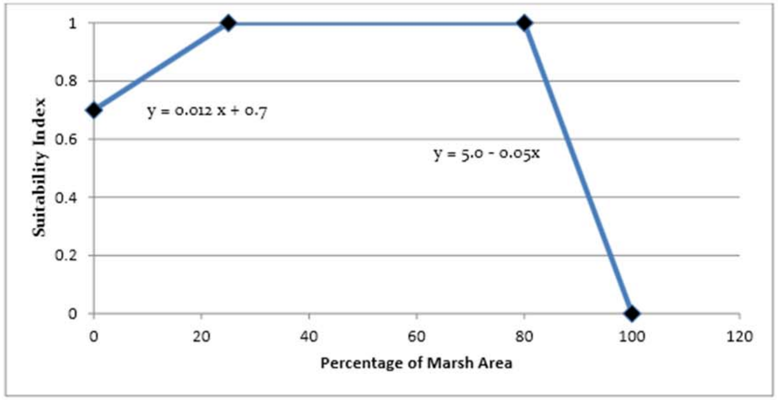
An index value between zero (unsuitable habitat) and one (optimal habitat) is generated by the model.



The variables included in this model are: V1 - the percentage of area km^2 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

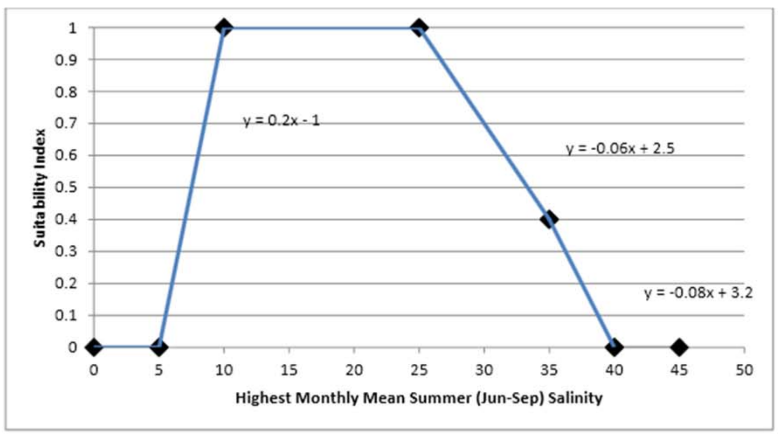
SI_1 =	0.012*V1+0.7	for $0 \le V1 \le 25$
	1.0	for $25 < V1 \le 80$
	5.0-0.05*V1	for $80 < V1 \le 100$



Variable 2: Highest monthly mean summer (Jun-Sep) salinity

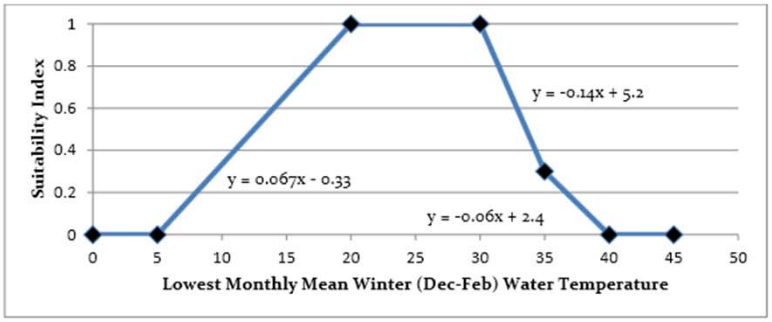
Suitability function for V2

SI_2 =	0	for V2 ≤ 5
	0.2*V2-1.0	for 5 < V2 ≤ 10
	1.0	for 10 < V2 ≤ 25
	-0.06*V2+2.5	for 25 < V2 ≤ 35
	-0.08*V2+3.2	for 35 < V2 ≤40
	0	for V2 > 40



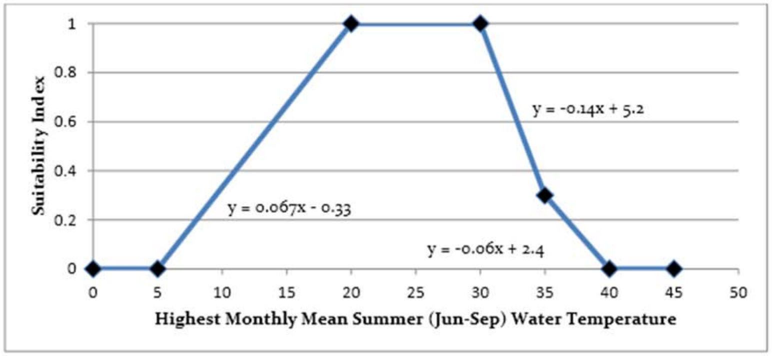
Variable 3: Lowest monthly mean winter (Dec-Feb) water temperature
Suitability function for V3

SI_3 =	0	for V3 ≤ 5
	0.067*V3-0.33	for 5 < V3 ≤ 20
	1	for 20 < V3 ≤ 30
	-0.14*V3+5.2	for 30 < V3 ≤ 35
	-0.06*V3+2.4	for 35 < V3 ≤ 40
	0	for V3 > 40



Variable 4: Highest monthly mean summer (Jun-Sep) water temperature
Suitability function for V4

SI_4 =	0	for V4 ≤ 5
	0.067 * V4 - 0.33	for 5 < V4 ≤ 20
	1	for 20 < V4 ≤ 30
	-0.14*V4+5.2	for 30 < V4 ≤ 35
	-0.06 * V4 + 2.4	for 35 < V4 ≤ 40
	0	for V4 > 40



Habitat Suitability Index

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

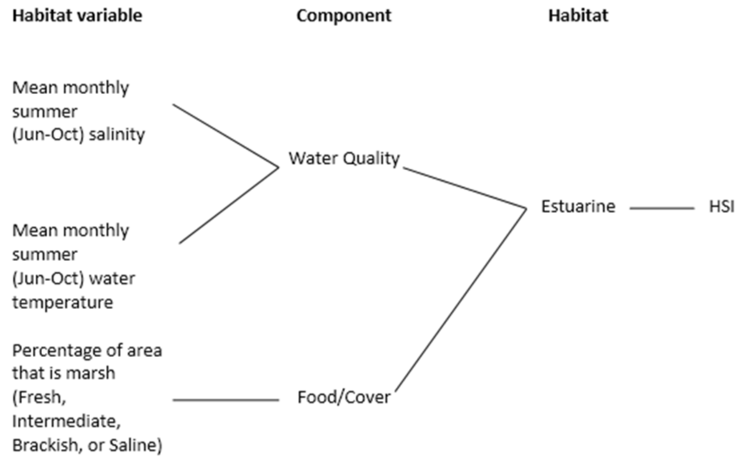
Extra material, white shrimp

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.

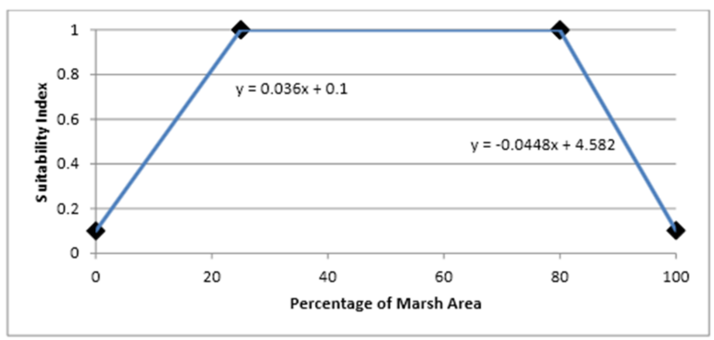
The model is generated by using two primary habitat components: water quality & food/cover.



The variables included in this model are: V1 - Percentage of area km^2 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.

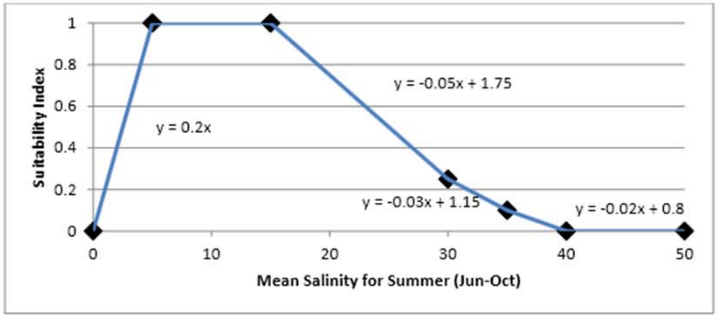
Variable 1: Percentage of Area (km2) Covered by Marsh Vegetation

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



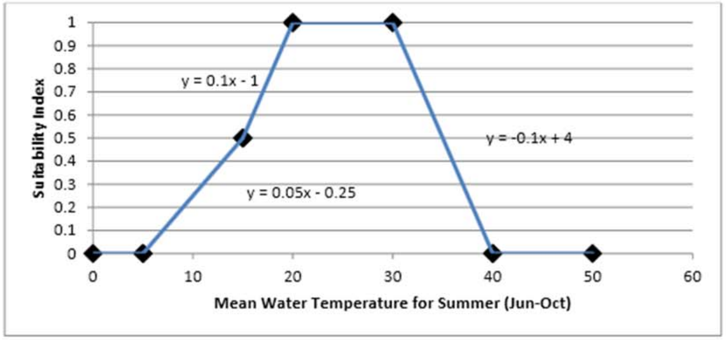
Variable 2: Mean Salinity for Summer (June-October)

SI_2 =	0.2 * V2	for V2 ≤ 5
	1.0	for 5 < V2 ≤ 15
	-0.05 * V2 + 1.75	for 15 < V2 ≤ 30
	-0.03 * V2 + 1.15	for 30 < V2 ≤ 35
	-0.02 * V2 + 0.8	for 35 < V2 ≤ 40
	0.0	for V2 > 40



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

SI_3 =	0.0	for V3 ≤ 5
	0.05 * V3 - 0.25	for 5 < V3 ≤ 15
	0.1 * V3 - 1.0	for 15 < V3 ≤ 20
	1.0	for 20 < V3 ≤ 30
	-0.1 * V3 + 4.0	for 30 < V3 ≤ 40
	0.0	for V3 > 40



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

Habitat Suitability Index

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

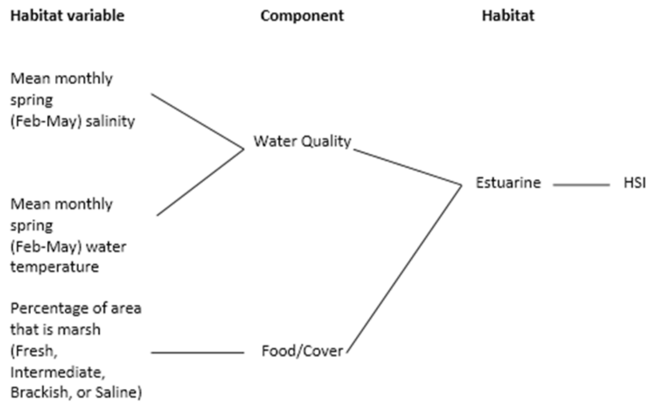
Extra material, brown shrimp

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.

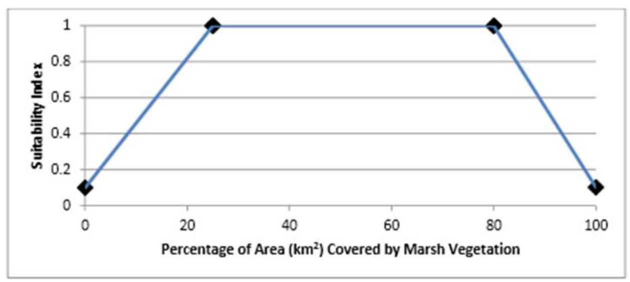
The model is generated by using two primary habitat components: water quality & food/cover.



The variables included in this model are: V1 - Percentage of area km^2 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^2) Covered by Marsh Vegetation
The decision rules for variable one are:

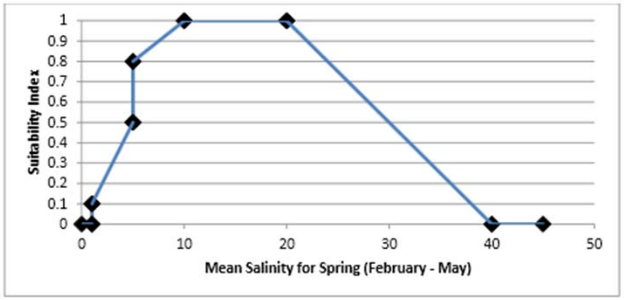
$SI_1 =$	$0.036 * V1 + 0.1$	for $0 < V1 \le 25$
	1.0	for $25 < V1 \le 80$
	$4.582 - 0.0448 * V1$	for $80 < V1 \le 100$



Variable 2: Mean Salinity for Spring (February-May)
The decision rules for variable two are:

$SI_2 =$	0.0	for $V2 < 1$

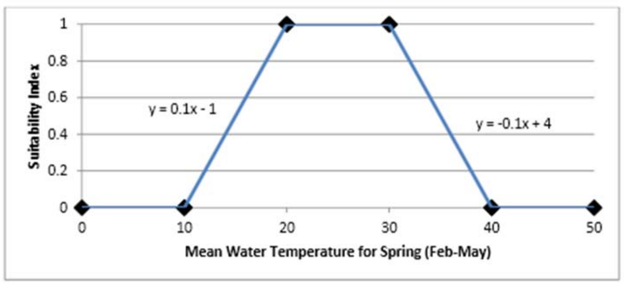
0.1 * V2	for 1 ≤ V2 ≤ 5
0.04 * V2 + 0.6	for 5 < V2 ≤ 10
1.0	for 10 < V2 ≤ 20
-0.05 * V2 + 2.0	for 20 < V2 ≤ 40
0.0	for V2 > 40



Variable 3: Mean Water Temperature for Spring (February-May)

The decision rules for variable three are:

SI_3 =	0.0	for V3 ≤ 10
	0.1 * V3 - 1.0	for 10 < V3 ≤ 20
	1.0	for 20 < V3 ≤ 30
	-0.1 * V3 + 4.0	for 30 < V3 ≤ 40
	0.0	for V3 > 40



Habitat Suitability Index

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