Freshwater diversion, oyster reef restoration and fisheries sustainability on the Primary Public Seed Grounds of Louisiana

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***Advancing Ecological Modeling for Diversions and Hypoxia* in the Northern Gulf of Mexico**
Stennis Space Center
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Key Questions

1. How will freshwater diversions effect oyster habitat?
2. Where might oyster reefs be created post-diversion?
3. How can restored reefs be sustained *and* fished?

1&2 -- Habitat Suitability Index Model (HSI)

3 -- Shell Budget/Fisheries Model

Eastern oyster, Crassostrea virginica

- Euryhaline
  - 10 -15, optimum
  - > 15, predators and parasites
  - < 5, stress, reproductive failure
  - ~ 18 – 22, spawning optimum
  - < 2, massive mortality
- Eurythermal (9-32°C)
  - Spawn at ~25°C
- Hard bottom for larval attachment
- Spat (< 25 mm), seed (25-74), sack (≥75)

Photo and illustrations: P. Banks

HSI Model Concept

- Salinity over substrate

Salinity

- Mean annual salinity (mean of monthly average salinity in a year)
- Mean salinity during spawning season (mean of May to September monthly averages in a year)
- Minimum salinity (minimum monthly salinity in a year)
- Each resolved into a 500 x 500 m grid

Substrate

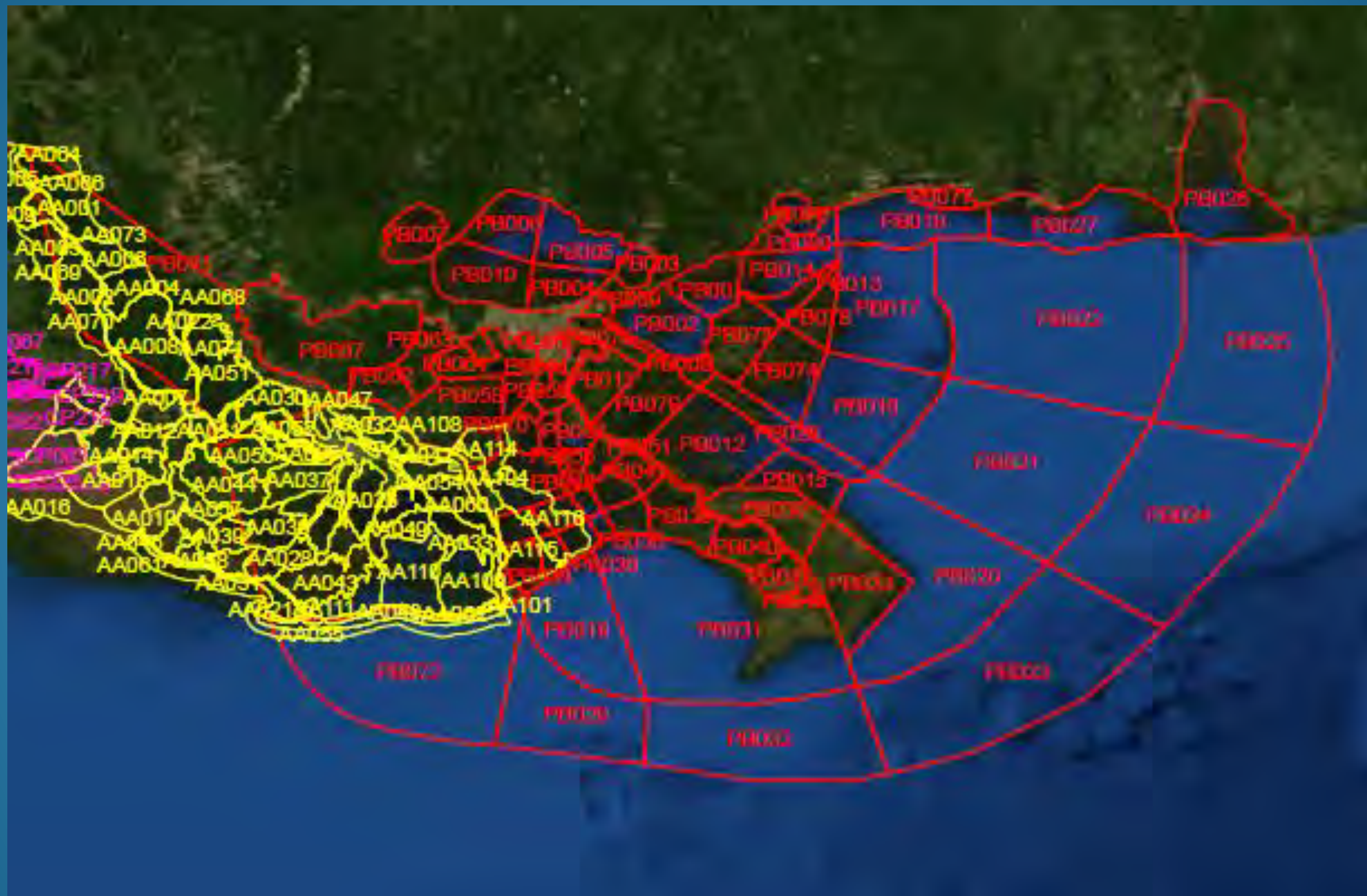
- Percent of bottom covered with suitable cultch, e.g. live reef, dead shell, limestone
  - Mapped reefs -- PC calculated within a GIS format and assigned to 500 x 500 m grid
  - Leases -- PC value of 10%
  - Public Grounds, non-reef -- PC of 3%
  - Other areas -- PC of 0%

HSI Calculation

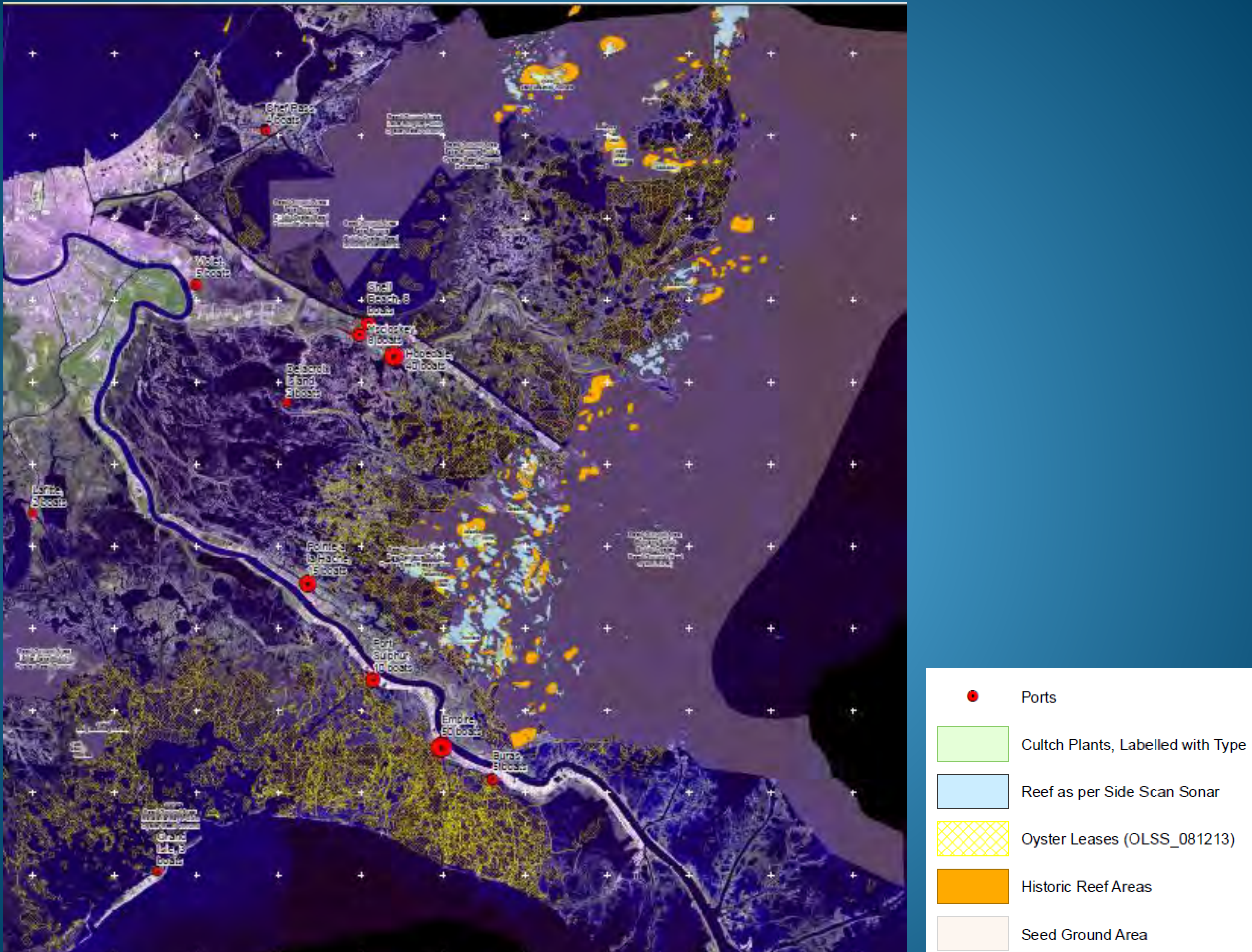
- An annual HSI value is calculated for each 500 m x 500 m grid.
- HSI is determined as the un-weighted geometric mean of the Suitability Index (SI) values for the component variables, where:

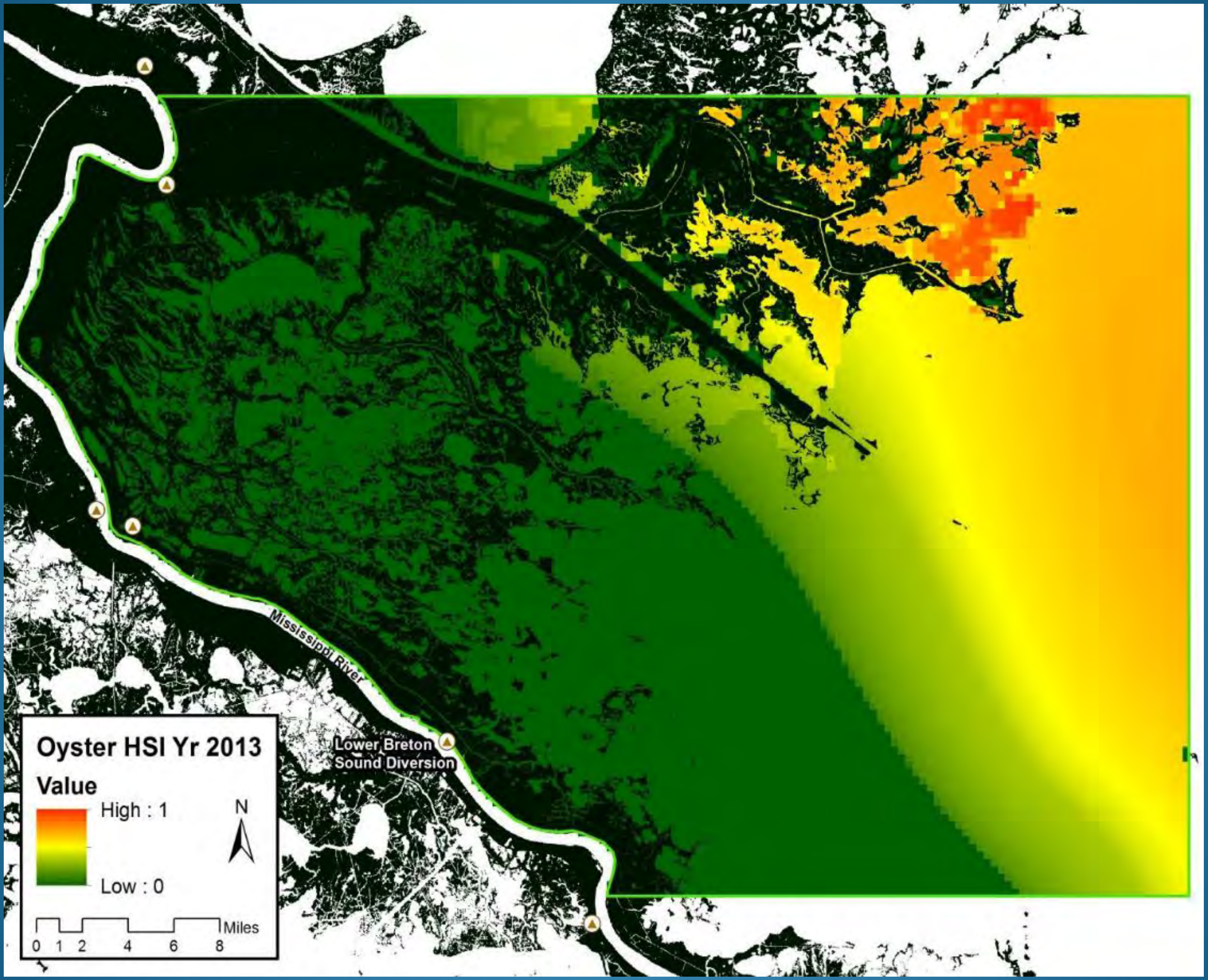
$$HSI = (SI_1 * SI_2 * SI_3 * SI_4 * SI_5)^{1/5}$$

Coastal 2012 MP Eco-hydro team provided salinity in polygons for various discharge scenarios

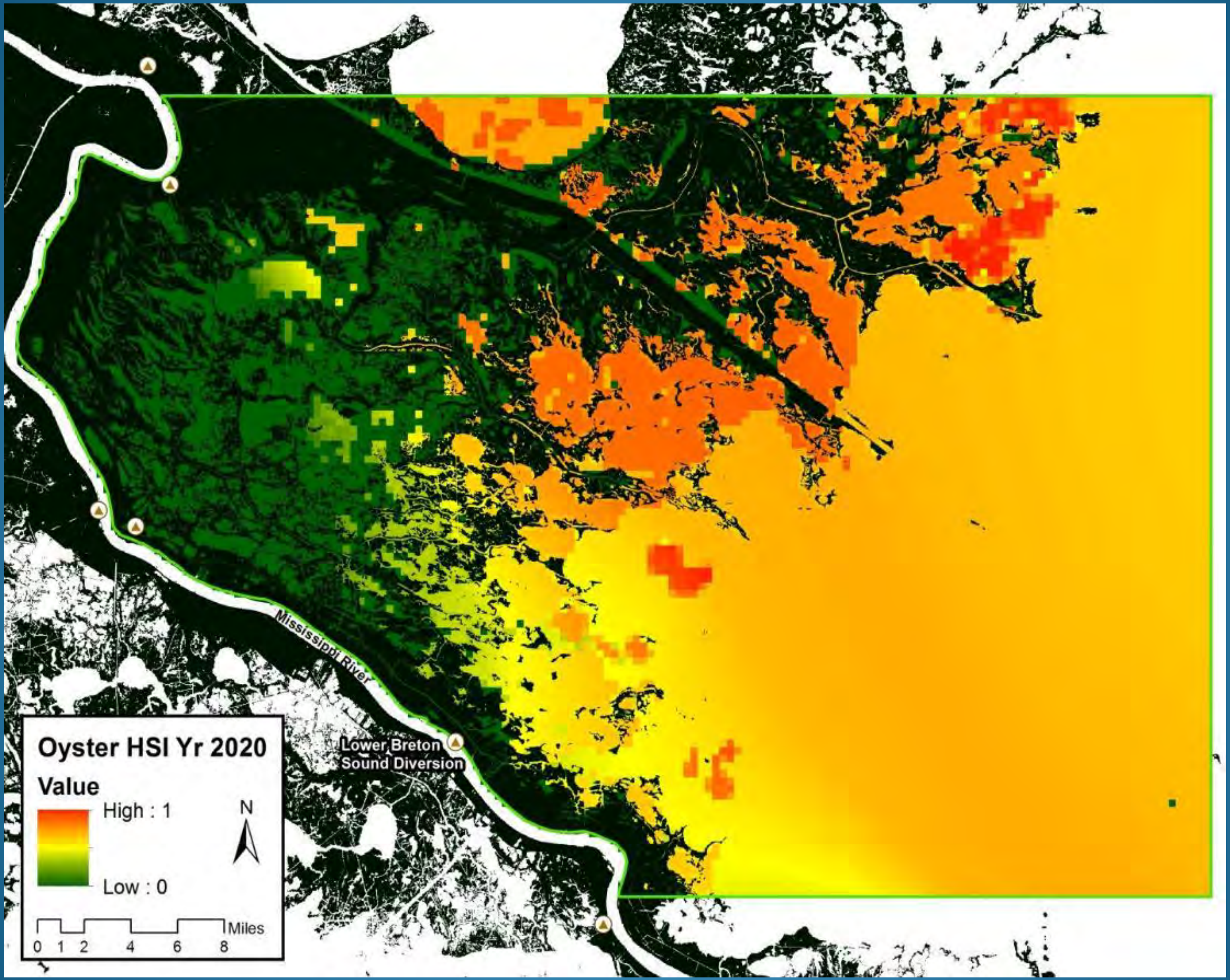


LBSD discharges 50,000 cfs when river flow is > 600,000 cfs, 8% of flows between 200,000 and 600,000 cfs, and 0 cfs at river flow < 200,000 cfs


Chef Pass, 4 boats
Violet, 5 boats
Shell Beach, 8 boats
Hopedale, 40 boats
Delacroix Island, 2 boats
Lafitte, 2 boats
Pointe a la Hache, 15 boats
Port Sulphur, 10 boats
Empire, 50 boats
Buras, 5 boats
Grand Isle, 3 boats
Ports
Cultch Plants, Labelled with Type
Reef as per Side Scan Sonar
Oyster Leases (OLSS_081213)
Historic Reef Areas
Seed Ground Area

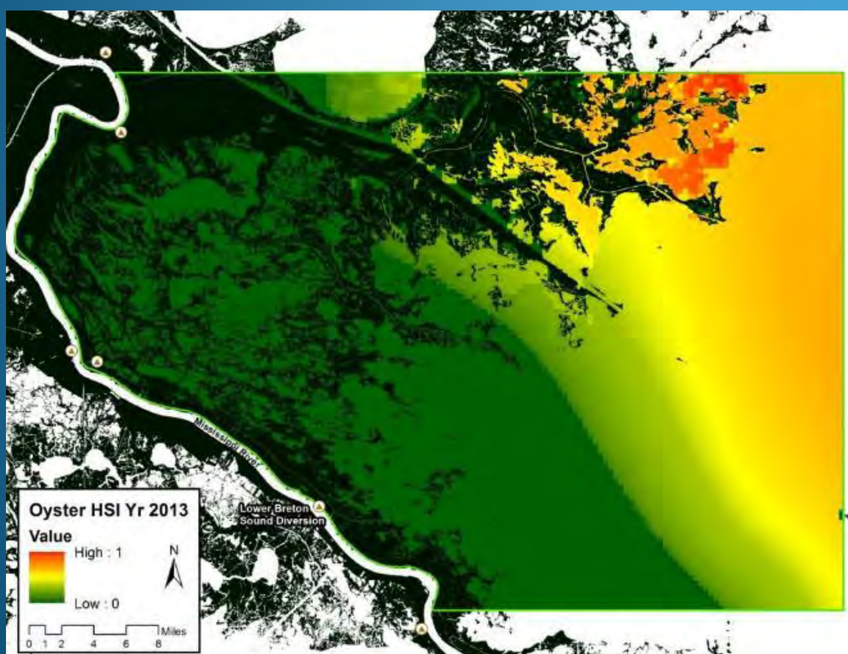


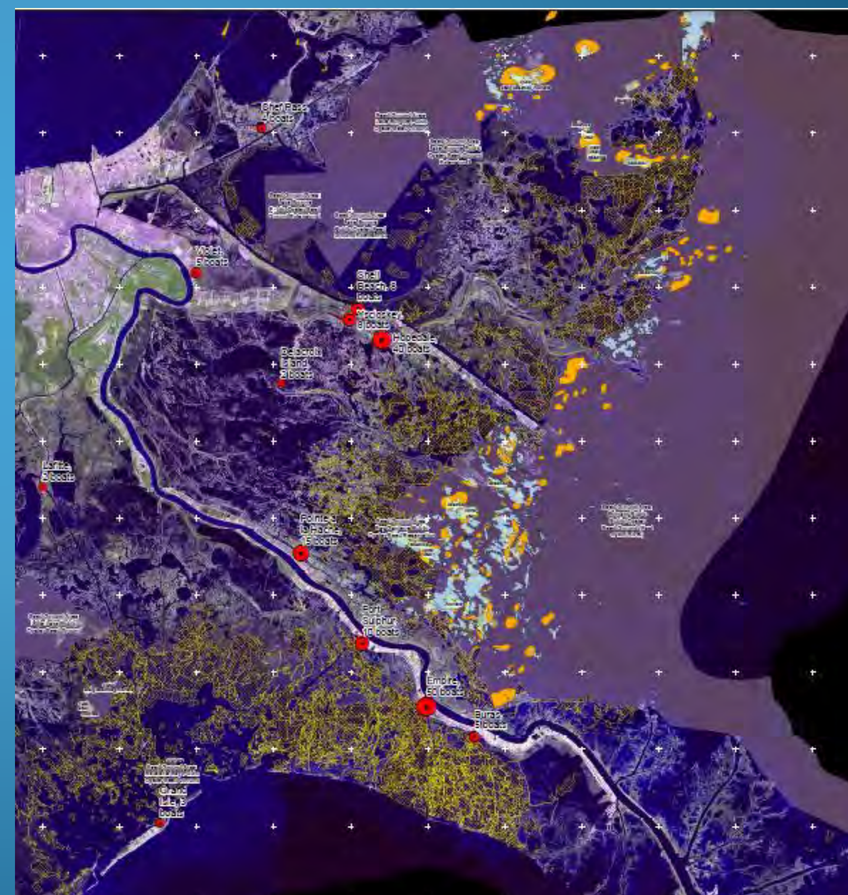
High-discharge year 2013 (data year 1993), Avg. mo. LBSD discharge = 47,750 cfs



Low discharge year 2020 (data year 2000), Avg. mo. LBSD discharge = 23,302 cfs

How will freshwater diversions effect oyster habitat? Where might oyster reefs be created post-diversion?





Shell Budget/Fisheries Model Concept

Powell and Klinck (2007) define sustainable reference points as:

$dN/dt = 0$	"oyster numbers stay the same"	(1)
$dS/dt = 0$	"shell volume stays the same"	(2)

- The equilibrium assumption (1) is *severely* violated by oyster populations, which show great inter-annual variations in numbers and biomass, and whose functional reef habitat is contacted or expanded with annual mean shifts in salinity
- The former depends on the latter for spat set & post-settlement survival. Substrate is likely the limiting factor
- An insistence on maintaining equilibrium yields of oyster numbers or biomass amidst extreme stock variability would likely result in periodic overfishing of shell

Shell Budget/Fisheries Model

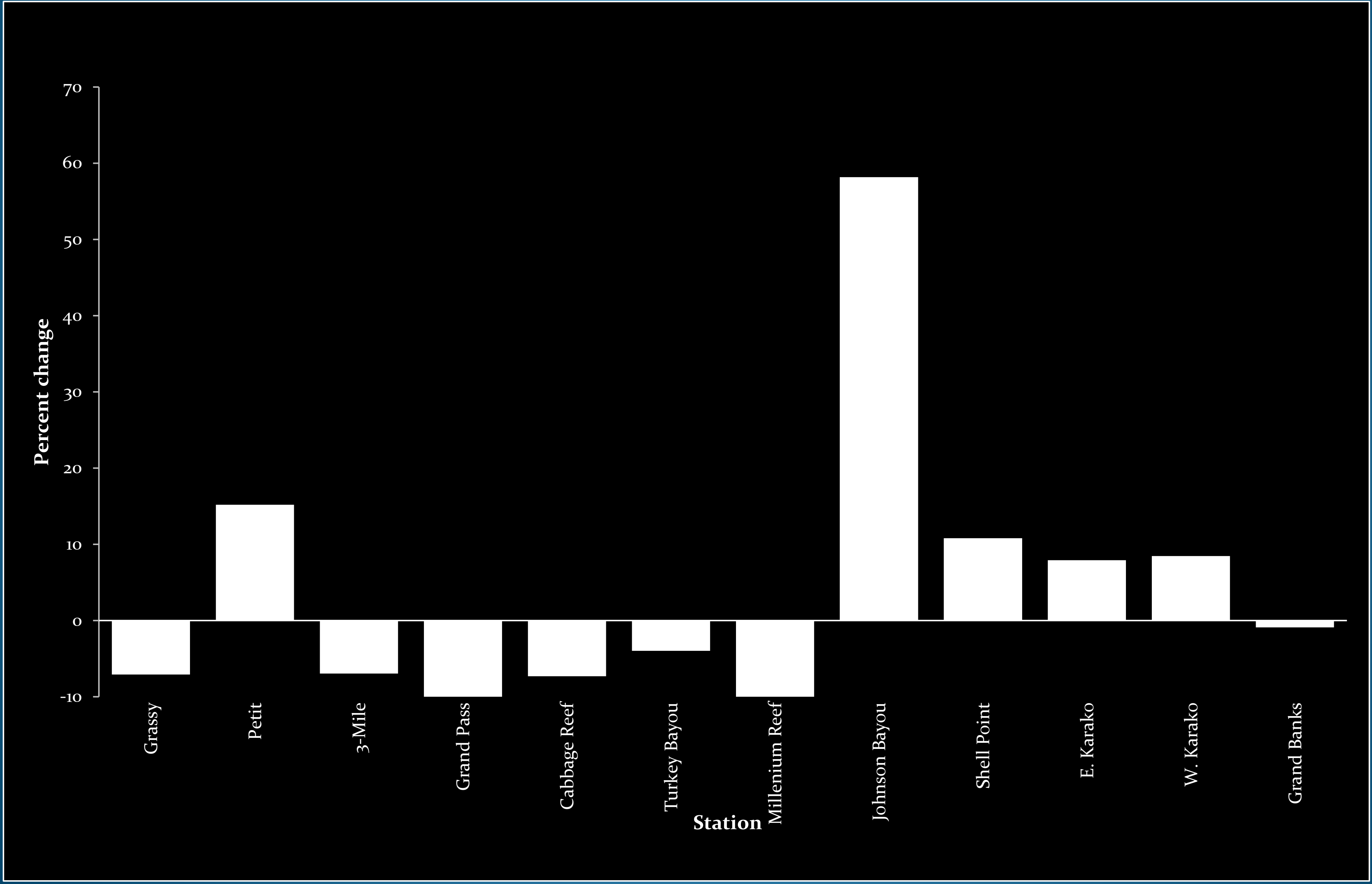
- Annual stock assessment provides: oyster density, oyster numbers and sizes, and reef area
- These are inputs into the model which grows, kills and fishes oysters
- Shells of dead oysters are added to the reef and shells of fished oysters are debited
- Growth and mortality are size and time dependent
- Fishing can occur for seed and/or sack oysters
- Fishing rate is time dependent

Shell Budget/Fisheries Model

Model output includes:

- Shell remaining and shell removed
- Harvest of sack and seed that can be removed by without depleting the reef of shell (i.e., the sustainable catch)

Shell Budget/Fisheries Model



Shell Budget/Fisheries Model

CSA	Mode	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
1N	Sack	0	0	2405	3741	2205	830	382	373	0	0	0	0	**9,936**
1N	Seed	0	0	4550	628	0	0	645	642	0	0	0	0	**6,464**
1S	Sack	0	0	6122	3705	0	126	45	38	63	0	0	0	**10,098**
1S	Seed	0	0	1101	155	0	0	160	0	0	0	0	0	**1,416**

Catch in sacks, 1 sack = 2 US bushels = 0.07 m^3

How can restored reefs be sustained *and* fished?

- Measure number and size of oysters
- Model oyster growth and mortality
- Manipulate fishing (rate and time) that results in no net shell loss

Acknowledgments/References

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www.oystersentinel.org

HSI Model Limitations and Improvements

- No meta-population dynamics
- Conversion of percent coverage with cultch to Suitability Index can be better constrained with scaling to grid size
- Lack of information on percent coverage limits model usefulness

Moving Forward – HSI

- Substrate is not easily or cheaply replaced
  - 200 cu. yd./acre x 69.70 $/cu. yd. = 13,940 $/acre

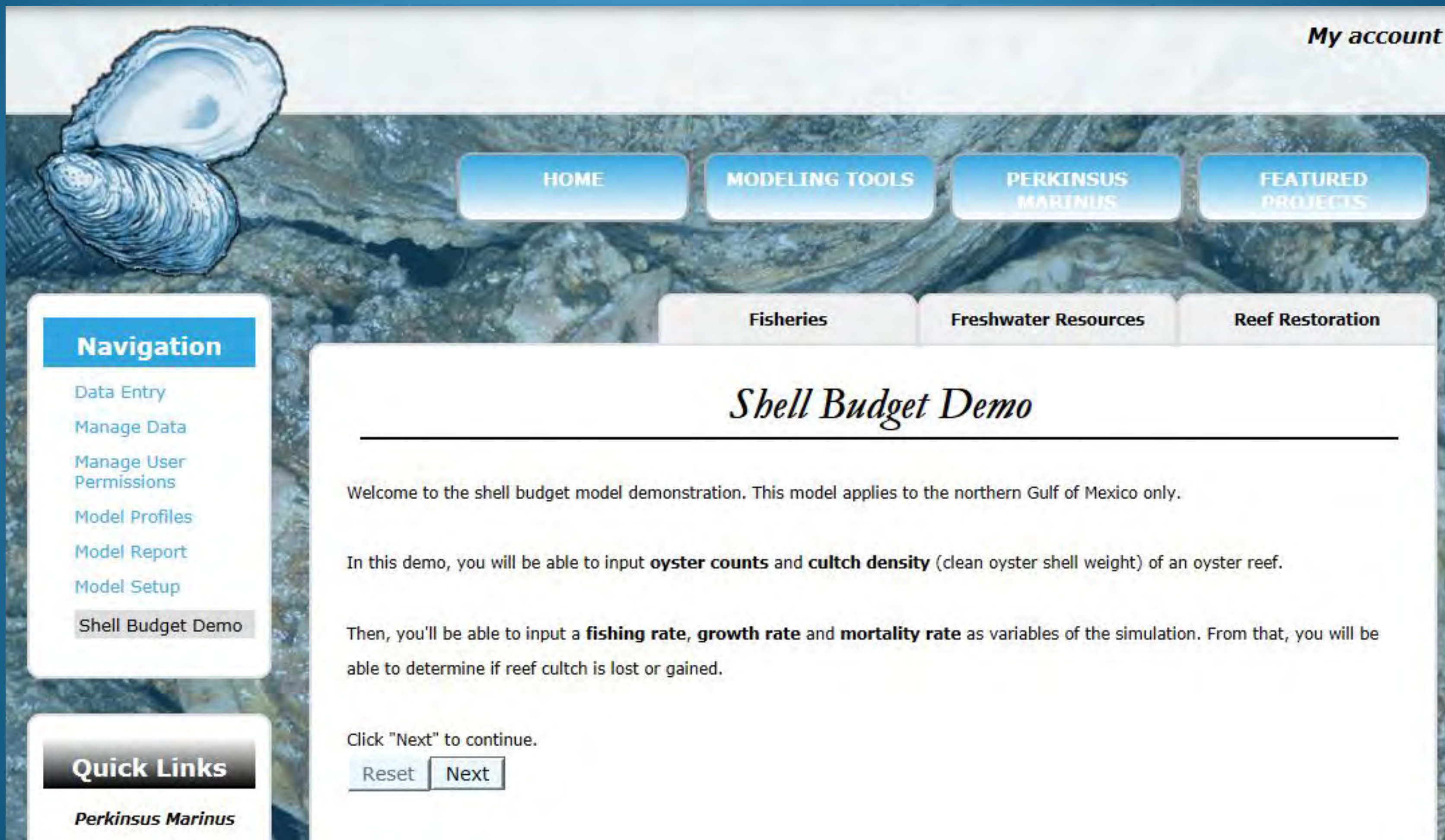
    (LDWF Oyster Statistics and Information Fact Sheet, 2010)
  - 13,940 $/acre x 15,254 acres =

    $ 212,640,760

Moving Forward –HSI

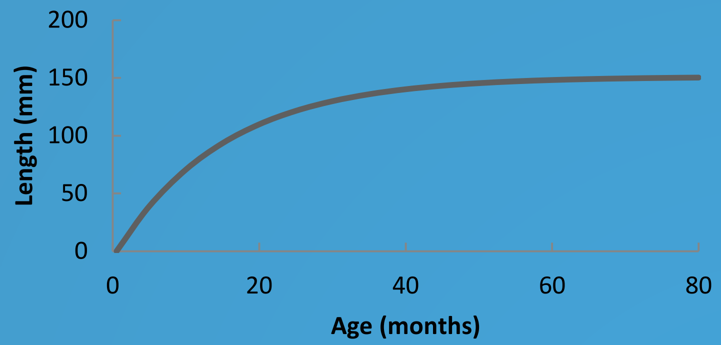
- HSI is useful in determining impacts of restoration projects which alter salinity (FW diversion), or build land or silt oyster reefs (sedimentation)
- Percent cultch grid is a receptacle for all future side scan surveys of oyster bottoms in Louisiana

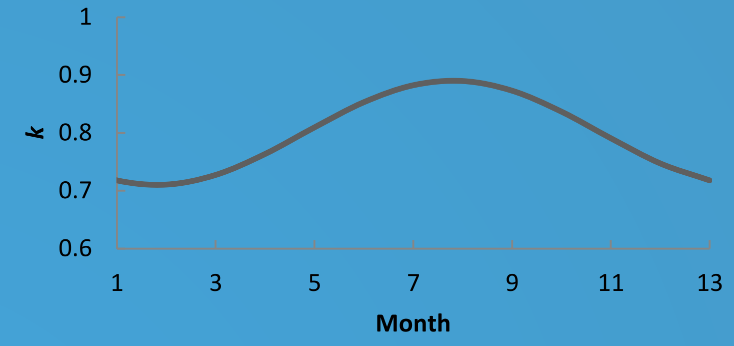
Shell Budget Model Tutorial

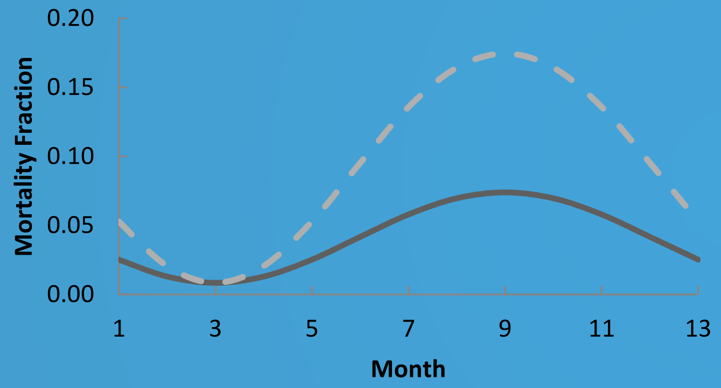


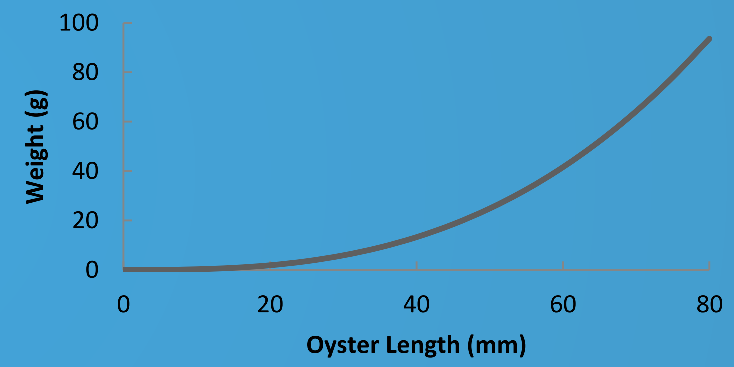
Shell Budget Model Fidelity

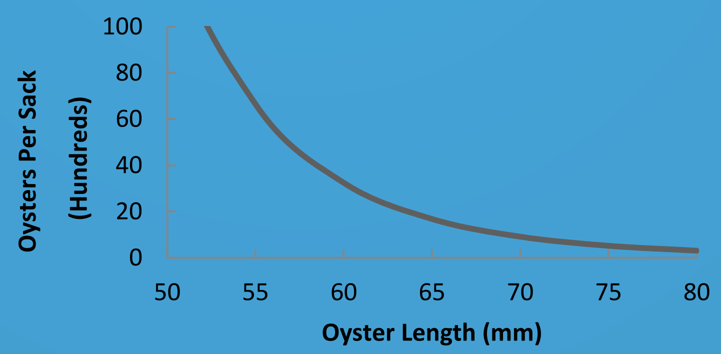
- Comparison of 2013 TAC estimate to 2012 harvest
  - 2013 statewide estimate of TAC is 76,763 sacks of sack oysters and 19,642 sacks of seed. 2012 estimated *harvest* of 64,897 sacks of sack oysters and 13,014 sacks of seed
- Experiment in Hackberry Bay
  - 2012 stock assessment data were used to set a TAC of 7,000 sacks of seed and 4,700 sacks of sack oysters. Harvest was monitored by LDWF biologists and the season closed when the estimated harvest appeared to reach the projected TAC. Actual harvest as percent of TAC was 71.9% for seed and 109.6% for sack oysters. The pre-fishing average cultch density (2012 Stock Assessment) in Hackberry Bay was 842 g/m^2, whereas the post-fishing (2013 Stock Assessment) density was 2,665 g/m^2


Length (mm)
200
150
100
50
0
0
20
40
60
80
Age (months)

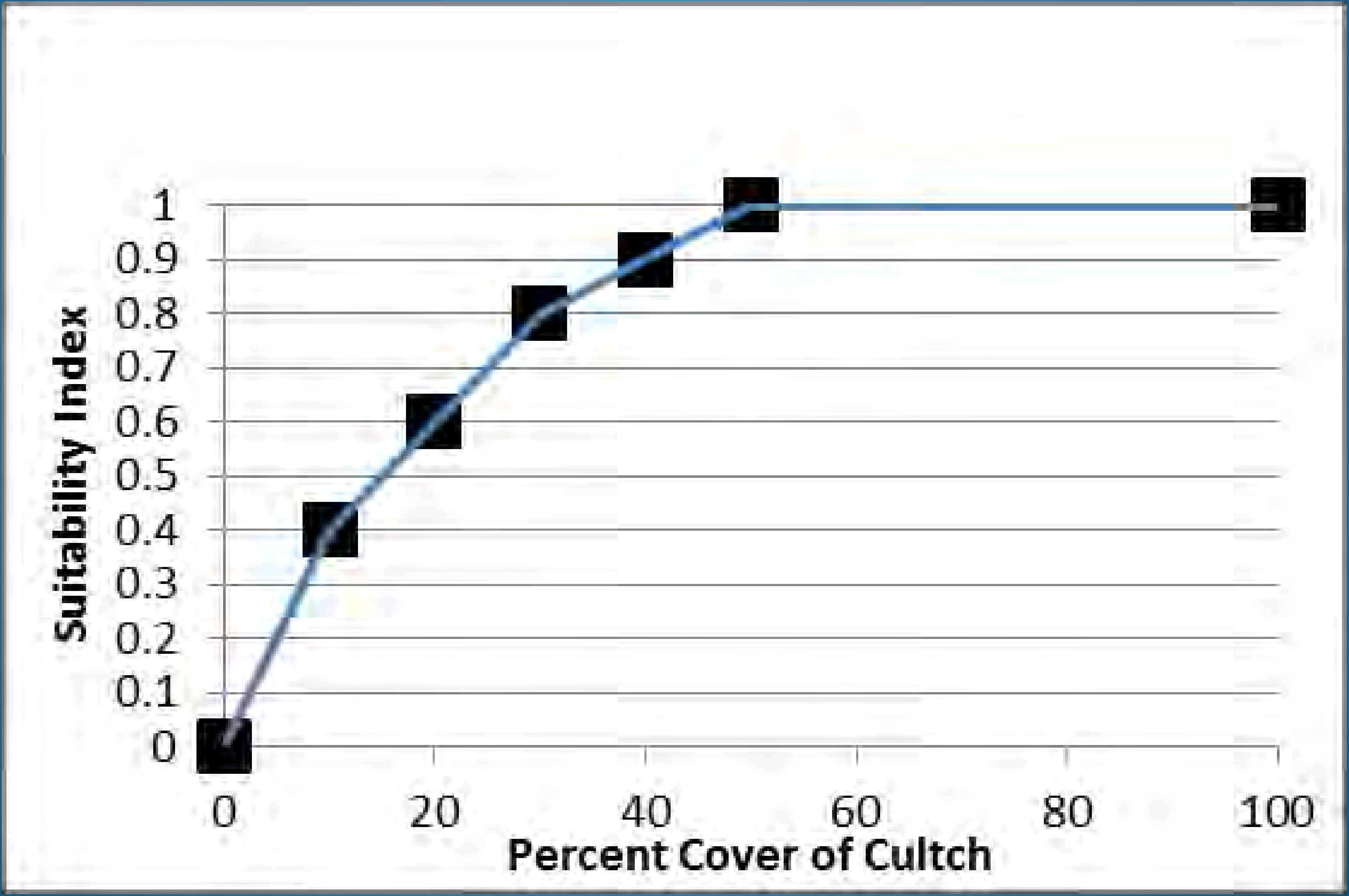

k
1
0.9
0.8
0.7
0.6
1
3
5
7
9
11
13
Month


Mortality Fraction
0.20
0.15
0.10
0.05
0.00
1
3
5
7
9
11
13
Month


Weight (g)
100
80
60
40
20
0
0
20
40
60
80
Oyster Length (mm)

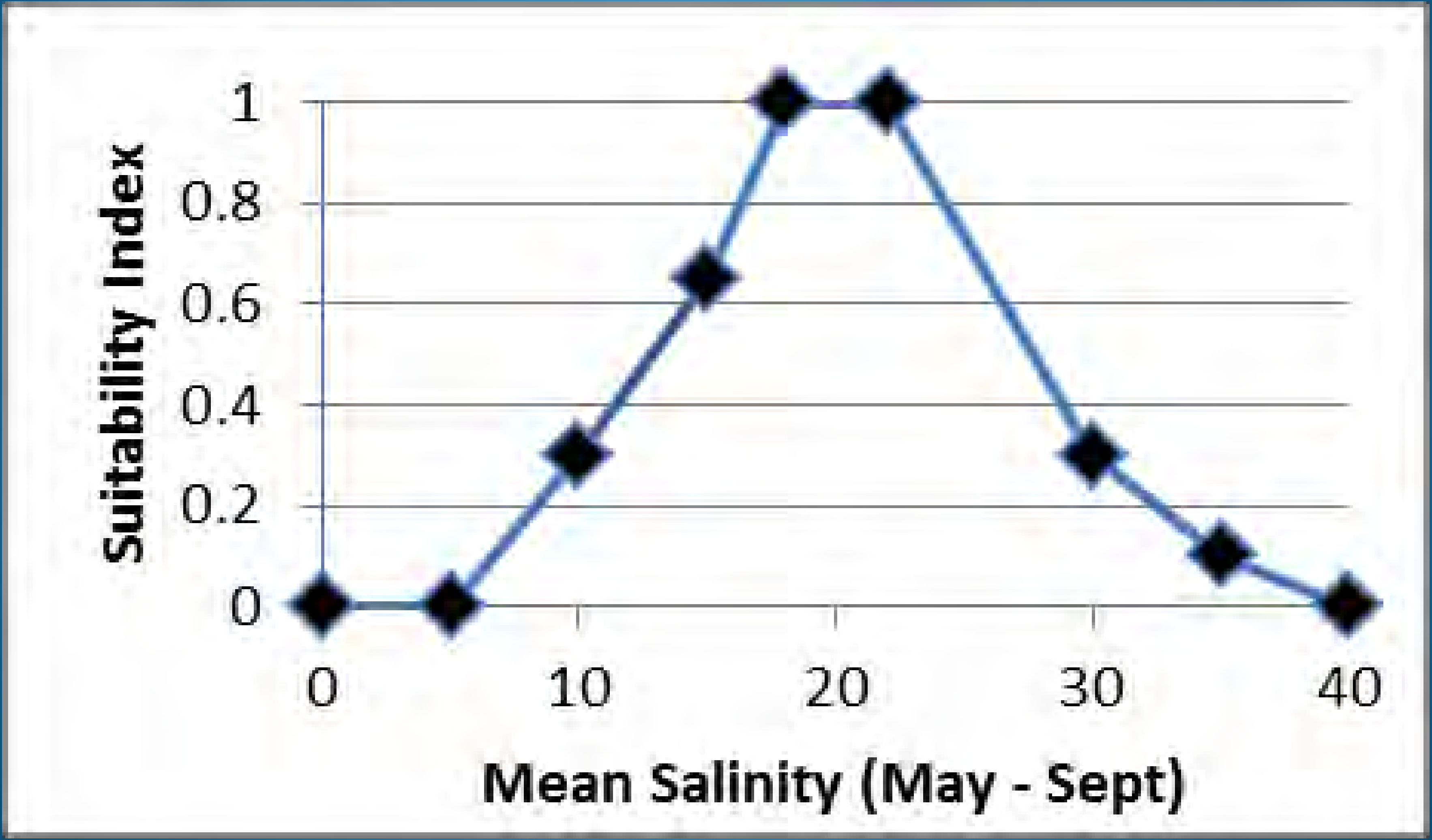

Oysters Per Sack
(Hundreds)
100
80
60
40
20
0
50
55
60
65
70
75
80
Oyster Length (mm)

Variable 1

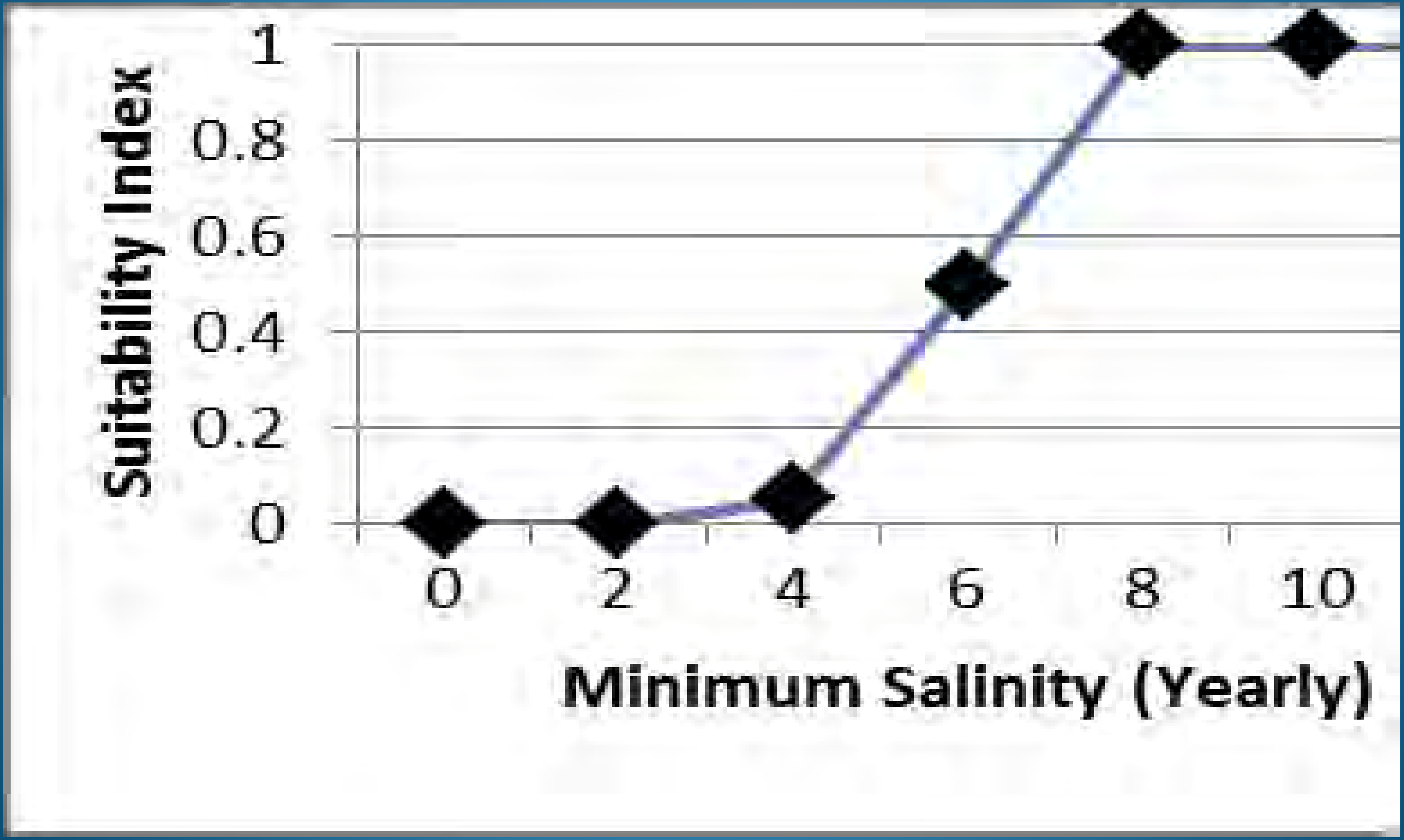


Suitability Index
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
Percent Cover of Cultch

Variable 2

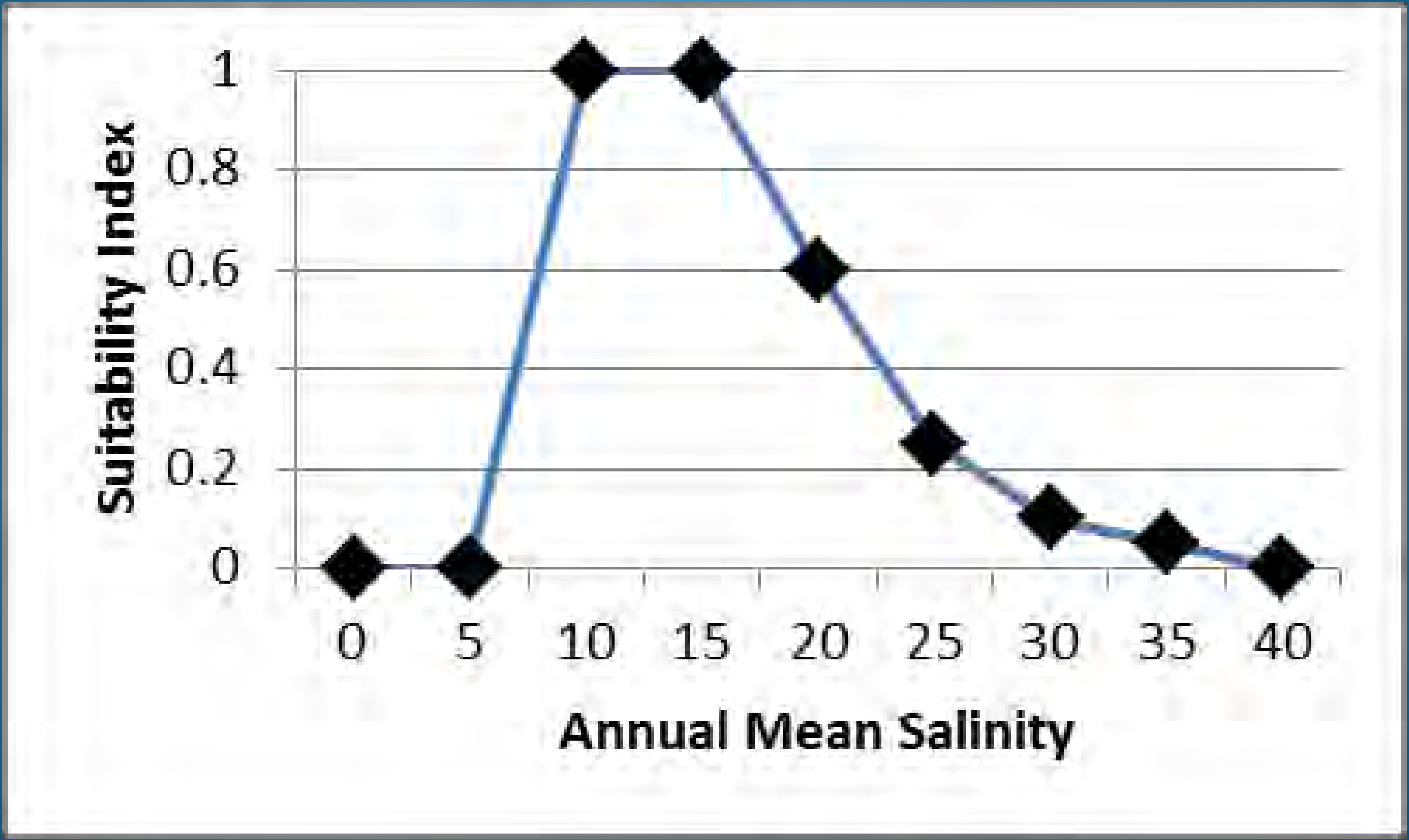

Suitability Index
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
Mean Salinity (May - Sept)

Variable 3



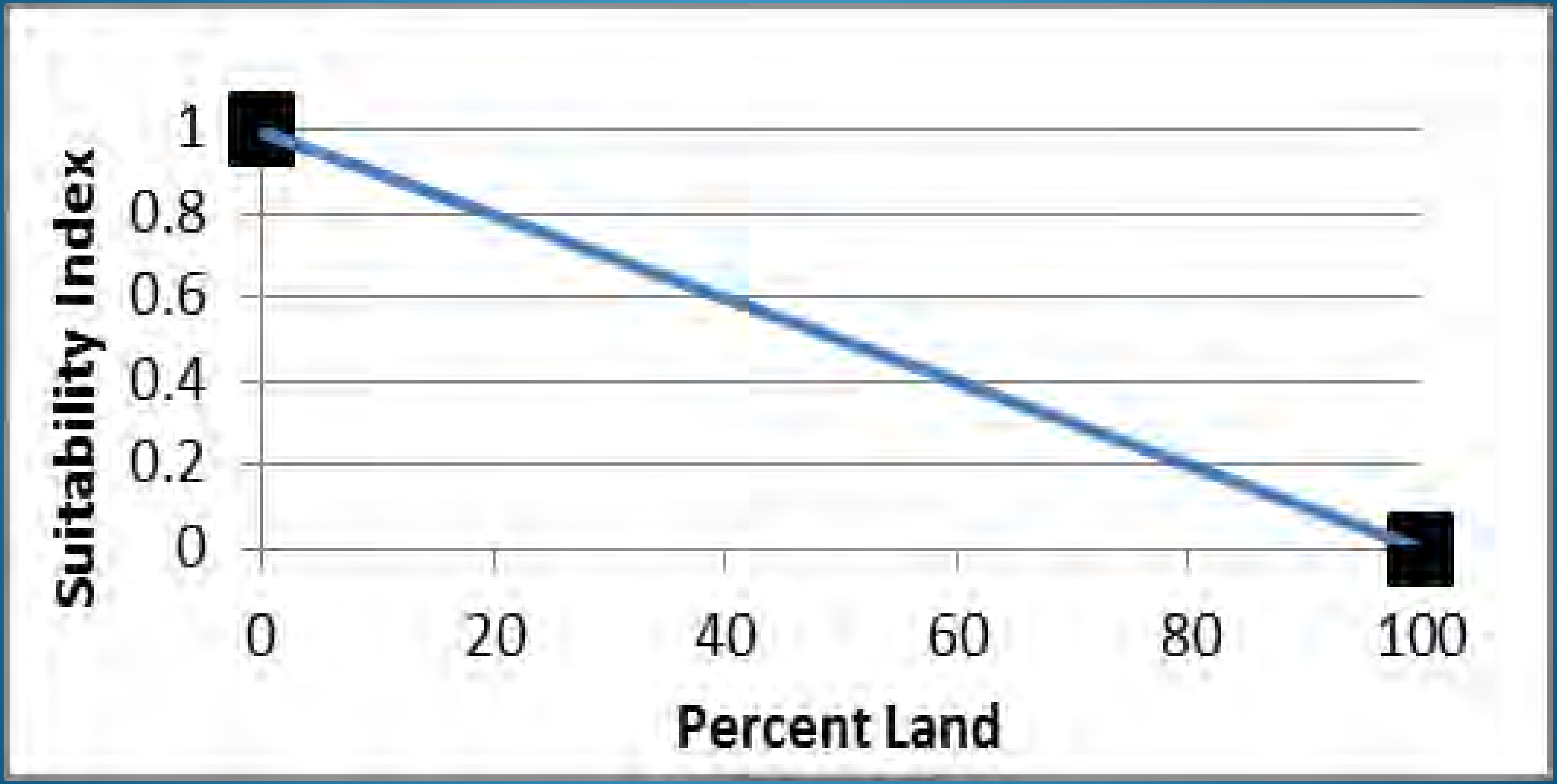
Suitability Index
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
Minimum Salinity (Yearly)

Variable 4



Suitability Index
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
Annual Mean Salinity

Variable 5



LDWF Coastal Study Areas (new designation)