2023 COASTAL MASTER PLAN

2023 HABITAT SUITABILITY INDEX (HSI) MODEL

ATTACHMENT C10

REPORT: VERSION 03
DATE: FEBRUARY 2023
PREPARED BY: DAVID C. LINDQUIST

COASTAL PROTECTION AND
RESTORATION AUTHORITY
150 TERRACE AVENUE
BATON ROUGE, LA 70802
WWW.COASTAL.LA.GOV

COASTAL PROTECTION AND RESTORATION AUTHORITY

This document was developed in support of the 2023 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every six years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

CITATION

Lindquist, D. C. (2023). 2023 Coastal Master Plan: Attachment C10: 2023 Habitat Suitability Index (HSI) Model. Version 3. (pp. 1-35). Baton Rouge, Louisiana: Coastal Protection and Restoration Authority.

ACKNOWLEDGEMENTS

This document was developed as part of a broader Model Improvement Plan in support of the 2023 Coastal Master Plan under the guidance of the Modeling Decision Team:

- Coastal Protection and Restoration Authority (CPRA) of Louisiana – Elizabeth Jarrell (formerly CPRA), Stuart Brown, Ashley Cobb, Madeline LeBlanc Hatfield, Valencia Henderson, Krista Jankowski, David Lindquist, Sam Martin, and Eric White
- University of New Orleans – Denise Reed

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CPRA .... COASTAL PROTECTION AND RESTORATION AUTHORITY

HSI .... HABITAT SUITABILITY INDEX

SI .... SUITABILITY INDICES

1.0 INTRODUCTION

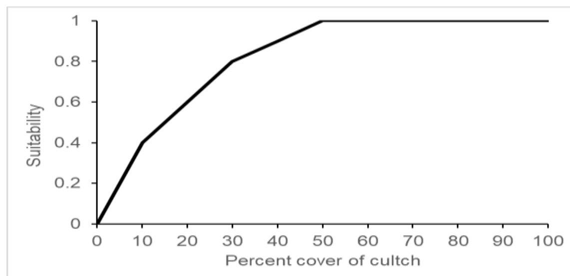
This document provides the habitat suitability index (HSI) models for all species included in the 2023 Coastal Master Plan. The source code for these models is available at github.com/CPRA-MP; however, for convenience and transportability, the full models are also described here. Information about how these models were developed and improved can be found in Attachment D5: Habitat Suitability Index Model Improvements on CPRA's website (www.coastal.la.gov).

2.0 EASTERN OYSTER

The eastern oyster (Crassostrea virginica) is a sessile, planktivorous, estuarine bivalve that provides a number of ecosystem services and supports an important commercial fishery in Louisiana. The eastern oyster HSI model is used to calculate the annual habitat suitability score of a model cell for post-settlement life stages in coastal Louisiana. The model primarily includes suitability indices (SIs) describing optimal salinity conditions for oyster persistence and productivity, but indices related to sedimentation and available settlement substrate are also incorporated. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2 \times SI_3 \times SI_4 \times SI_5 \times SI_6)^{1/6}$.

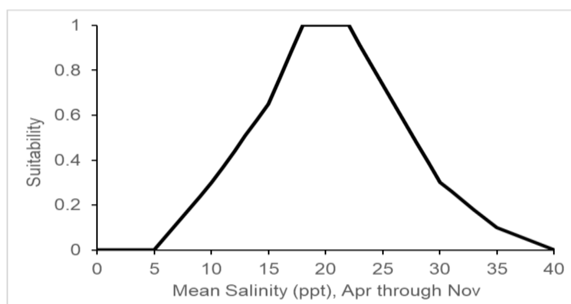
SI_1 = Percent of cell covered by cultch (V_1).

$SI_1 = 0.04*V_1$, when $V_1 \leq 10\%$
$(0.02*V_1) + 0.2$, when $10 < V_1 \leq 30$
$(0.01*V_1) + 0.5$, when $30 < V_1 \leq 50$
1.0, when $V_1 > 50$



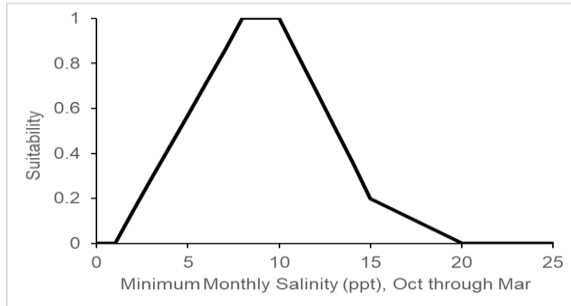
SI_2 = Mean salinity during the spawning season, April through November (V_2).

$SI_2 = 0.0$, when $V_2 < 5$ parts per thousand (ppt)
$(0.06*V_2) - 0.3$, when $5 \leq V_2 < 10$
$(0.07*V_2) - 0.4$, when $10 \leq V_2 < 15$
$(0.1167*V_2) - 1.1$, when $15 \leq V_2 < 18$
1.0, when $18 \leq V_2 < 22$
$(-0.0875*V_2) + 2.925$, when $22 \leq V_2 < 30$
$(-0.04*V_2) + 1.5$, when $30 \leq V_2 < 35$
$(-0.02*V_2) + 0.8$, when $35 \leq V_2 < 40$

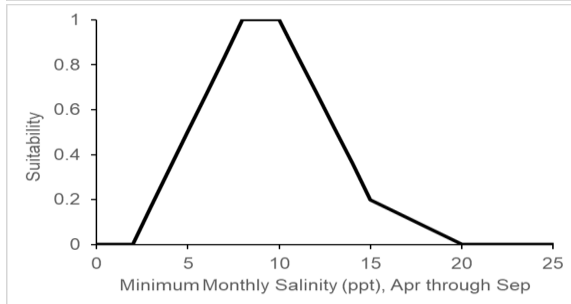


SI_3 = Minimum monthly mean salinity (V_3). Two relationships are used: one for cool months, October through March, and one for warm months, April through September. The SI is derived by calculating the suitability of the lowest monthly mean salinity for each time period using the relationships described below; then the overall SI is calculated using the equation: $SI_3 = (SI_3\text{ cool} \times SI_3\text{ warm})^{1/2}$.

$SI_{3\ cool}$ = 0.0, when $V_3 \leq 1$ ppt
$(0.1429*V_3) - 0.1429$, when $1 < V_3 < 8$
1.0, when $8 \leq V_3 < 10$
$(-0.16*V_3) + 2.6$, when $10 \leq V_3 < 15$
$(-0.04*V_3) + 0.8$, when $15 \leq V_3 < 20$
0.001, when $V_3 \geq 20$

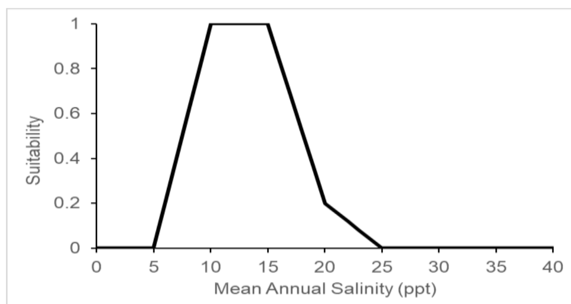


$SI_{3\ warm}$ = 0.0, when $V_3 \leq 2$ ppt
$(0.1668*V_3) - 0.33$, when $2 < V_3 < 8$
1.0, when $8 \leq V_3 < 10$
$(-0.16*V_3) + 2.6$, when $10 \leq V_3 < 15$
$(-0.04*V_3) + 0.8$, when $15 \leq V_3 < 20$
0.001, when $V_3 \geq 20$



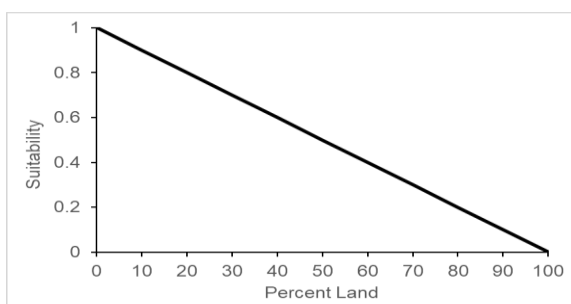
<u>SI_4 = Mean annual salinity (V_4).</u>

SI_4 = 0.0, when $V_4 < 5$
$(0.2*V_4) - 1.0$, when $5 \leq V_4 < 10$
1.0, when $10 \leq V_4 < 15$
$(-0.16*V_4) + 3.4$, when $15 \leq V_4 < 20$
$(-0.04*V_4) + 1.0$, when $20 \leq V_4 < 25$
0.001, when $V_3 \geq 25$



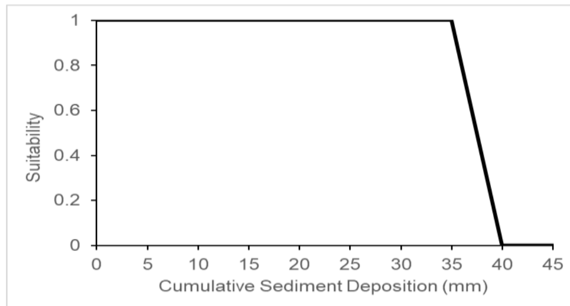
<u>SI_5 = Percent of cell covered by land (V_5).</u>

$SI_5 = (-0.01*V_5) + 1.0$



SI$_6$ = Cumulative sediment deposition (V$_6$). The annual amount of sediment deposition for the open water parts of a cell is calculated by summing mean monthly sediment deposition, then the SI is derived using the relationship described below.

SI$_6$ = 1.0, when $V_6 < 35$ mm
$(-0.2*V_6) + 8.0$, when $35 \le V_6 < 40$
0.0, when $V_6 \ge 40$

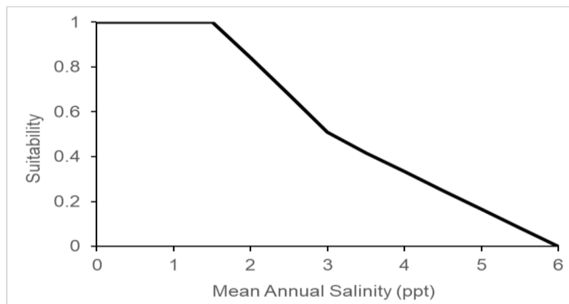


3.0 CRAYFISH

The crayfish (*Procambarus clarkii* and *P. zonangulus*) are benthic crustaceans that are primarily associated with freshwater habitats and support an important commercial fishery in Louisiana. The HSI model for the two species combined is used to calculate the annual habitat suitability score of a model cell for all life stages of the crayfish. The model is comprised of three component indices that describe suitable water conditions for foraging (SI_1 and SI_2), vegetated habitat types (SI_3), and conditions needed for reproduction (SI_4). These indices are then used in the following equation: $HSI = (SI_1 \times SI_2)^{1/6} \times (SI_3)^{1/3} \times (SI_4)^{1/3}$.

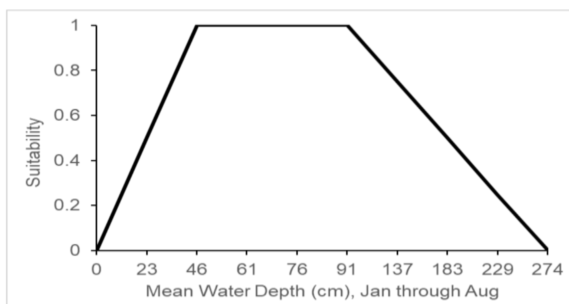
SI_1 = Mean annual salinity (V_1).

$SI_1 = 1.0$, when $V_1 \leq 1.5$ ppt
$1.5 - (0.333*V_1)$, when $1.5 < V_1 \leq 3.0$
$1.0 - (0.167*V_1)$, when $3.0 < V_1 \leq 6.0$
0.0, when $V_1 > 6.0$



SI_2 = Mean water depth from January through August (V_2).

$SI_2 = 0.0$, when $V_2 \leq 0$ or > 274 cm
$0.02174*V_2$, when $0 < V_2 \leq 46$
1.0, when $46 < V_2 \leq 91$
$1.5 - (0.00547*V_2)$, when $91 < V_2 \leq 274$



SI_3 = Proportion of cell covered by habitat types (V_3).

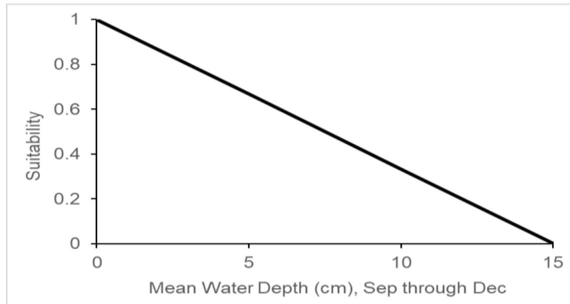
$SI_3 = [(1.0 \times V_{3a}) + (0.85 \times V_{3b}) + (0.75 \times V_{3c}) + (0.6 \times V_{3d}) + (0.2 \times V_{3e}) + (0.0 \times V_{3f}) + (0.0 \times V_{3g})]$

Where: V_{3a} = the proportion of a model cell that is swamp or bottomland hardwood
V_{3b} = the proportion of a model cell that is fresh marsh
V_{3c} = the proportion of a model cell that is open water
V_{3d} = the proportion of a model cell that is intermediate marsh
V_{3e} = the proportion of a model cell that is brackish marsh

V_{3f} = the proportion of a model cell that is saline marsh
V_{3g} = the proportion of a model cell that is bare ground

<u>SI_4 = Mean water depth from September through December (V_4).</u>

SI_4 = 0.0, when $V_4 > 15$ cm
1.0 – (0.06667*V_4), when $V_4 \leq 15$
1.0, when $V_4 \leq 0$

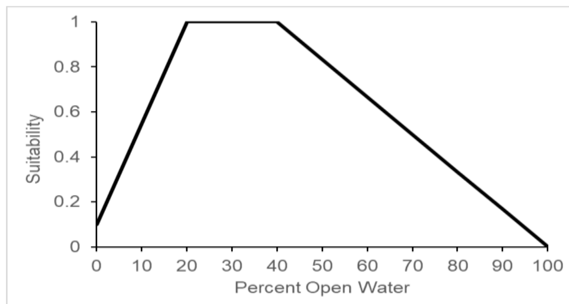


4.0 AMERICAN ALLIGATOR

The American alligator (*Alligator mississippiensis*) is an upper trophic level reptile that is primarily associated with low-salinity marsh and swamp habitats, and is a commercially- and recreationally-harvested species in Louisiana. The alligator HSI model is used to calculate the annual habitat suitability score of a model cell for the entire alligator life cycle in coastal Louisiana. Therefore, the model includes suitability indices (SIs) that describe environmental conditions important for nesting, foraging, physiology, and predator avoidance. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2 \times SI_3 \times SI_4 \times SI_5)^{1/5}$.

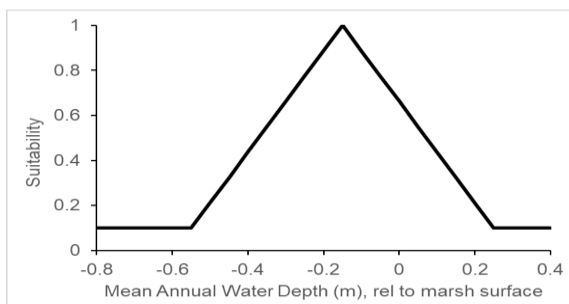
<u>SI_1 = Percent of cell that is open water (V_1).</u>

$SI_1 = ((4.5*V_1)/100) + 0.1$, when $V_1 < 20\%$
1.0, when $20 \leq V_1 \leq 40$
$((-1.667*V_1)/100) + 1.667$, when $V_1 > 40$



<u>SI_2 = Mean annual water depth relative to the marsh surface (V_2).</u>

$SI_2 = 0.1$, when $V_2 \leq -0.55$ or ≥ 0.25 m
$(2.25*V_2) + 1.3375$, when $-0.55 < V_2 < -0.15$
1.0, when $V_2 = -0.15$
$(-2.25*V_2) + 0.6625$, when $-0.15 < V_2 < 0.25$



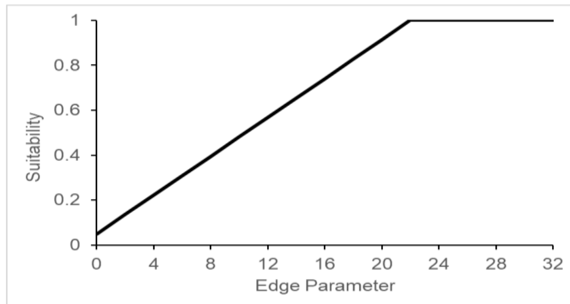
<u>SI_3 = Proportion of cell covered by habitat types (V_3).</u> Habitat types other than swamp, fresh marsh, intermediate marsh, and brackish marsh are given a suitability score of 0.0.

$SI_3 = [(0.551 \times V_{3a}) + (0.713 \times V_{3b}) + (1.0 \times V_{3c}) + (0.408 \times V_{3d})]$
Where: V_{3a} = the proportion of a model cell that is swamp or bottomland hardwood
V_{3b} = the proportion of a model cell that is fresh marsh

V_{3c} = the proportion of a model cell that is intermediate marsh
V_{3d} = the proportion of a model cell that is brackish marsh

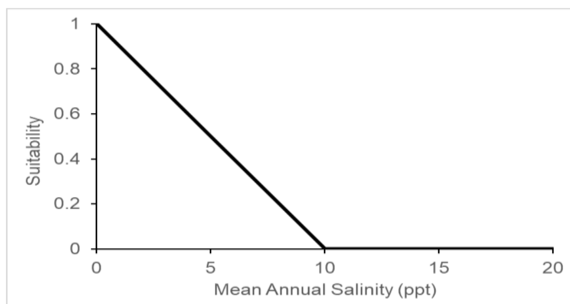
$\underline{SI_4 = \text{Edge } (V_4).}$ This SI is based on output produced from the ICM-Morphology subroutine, which scales estimated edge such that the median value has an SI value of 0.5 and values at the 90th percentile and above have a value of 1.0.

$SI_4 = 0.05 + (0.95*(V_4/22.0))$, when $0 \leq V_4 \leq 22$
1.0, when $V_4 > 22$



$\underline{SI_5 = \text{Mean annual salinity } (V_5).}$

$SI_5 = (-0.1*V_5) + 1.0$, when $0 \leq V_5 \leq 10$ ppt
0.0, when $V_5 > 10$



5.0 GADWALL

The gadwall (*Anas strepera*) is a migratory waterfowl that overwinters in coastal Louisiana, and is a popular recreationally-hunted duck species. The gadwall HSI model is used to calculate the annual habitat suitability score of a model cell for gadwall wintering in coastal Louisiana from October through April. The model includes three suitability indices (SIs) that describe optimal habitat conditions for foraging. These SIs are then used in the following equation: $HSI = (SI_1 \times SI_2 \times SI_3)^{1/3}$.

<u>SI_1 = Proportion of cell covered by habitat types and associated open water (V_1).</u> When there is no emergent vegetation in a cell, the cell should be assigned to one of following habitat types based on average annual salinity: fresh marsh <1.5 ppt; intermediate marsh $\geq$ 1.5 to < 4.5 ppt; brackish marsh $\geq$ 4.5 to < 9.5 ppt; and saline marsh $\geq$ 9.5 ppt.

$SI_1 = [(0.68 \times V_{1a}) + (1.0 \times V_{1b}) + (0.5 \times V_{1c}) + (0.09 \times V_{1d}) + (0.05 \times V_{1e}) + (0.0 \times V_{1f})]$

Where: V_{1a} = the proportion of a model cell that is fresh attached or fresh floating marsh

V_{1b} = the proportion of a model cell that is intermediate marsh

V_{1c} = the proportion of a model cell that is brackish marsh

V_{1d} = the proportion of a model cell that is saline marsh

V_{1e} = the proportion of a model cell that is swamp or bottomland hardwood

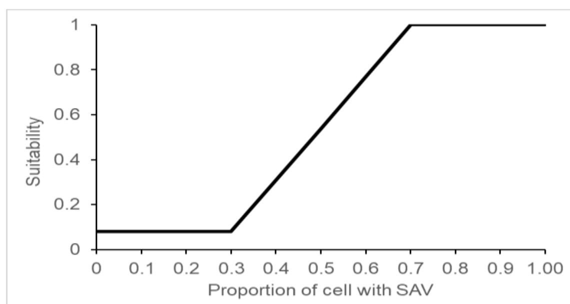
V_{1f} = the proportion of a model cell that is non-wetland habitat

<u>SI_2 = Proportion of cell with submerged aquatic vegetation (SAV) (V_2).</u>

SI_2 = 0.08, when V_2 <0.30

$(2.3 * V_2) - 0.61$, when $0.30 \leq V_2 < 0.70$

1.0, when $V_2 \geq 0.70$



<u>SI_3 = Mean water depths from October through April (V_3).</u> This SI is derived by calculating the mean water depth for each 30-meter pixel of a model cell, estimating the proportion of the model cell covered by each depth category, then plugging these estimates into the following equation:

$SI_3 = [(0.05*V_3a) + (0.15*V_3b) + (0.35*V_3c) + (0.60*V_3d) + (0.83*V_3e) + (1.0*V_3f) + (0.86*V_3g) + (0.61*V_3h) + (0.37*V_3i) + (0.20*V_3j) + (0.10*V_3k) + (0.05*V_3l)]$

Where: V_{3a} = the proportion of cell with mean water depth $\leq$ 4 cm

V_{3b} = the proportion of cell with mean water depth >4 to $\leq$ 8

V_{3c} = the proportion of cell with mean water depth >8 to ≤ 12
V_{3d} = the proportion of cell with mean water depth >12 to ≤ 18
V_{3e} = the proportion of cell with mean water depth >18 to ≤ 22
V_{3f} = the proportion of cell with mean water depth >22 to ≤ 28
V_{3g} = the proportion of cell with mean water depth >28 to ≤ 32
V_{3h} = the proportion of cell with mean water depth >32 to ≤ 36
V_{3i} = the proportion of cell with mean water depth >36 to ≤ 40
V_{3j} = the proportion of cell with mean water depth >40 to ≤ 44
V_{3k} = the proportion of cell with mean water depth >44 to ≤ 78
V_{3l} = the proportion of cell with mean water depth >78 to ≤ 150

6.0 MOTTLED DUCK

The mottled duck (*Anas fulvigula*) is a year-round resident of coastal Louisiana, and is a species of conservation need. The mottled duck HSI model is used to calculate the annual habitat suitability score of a model cell for post-fledgling juvenile and adult mottled duck in coastal Louisiana. The model includes four suitability indices (SIs) that describe optimal habitat conditions for foraging and brood rearing. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2 \times SI_3 \times SI_4)^{1/4}$.

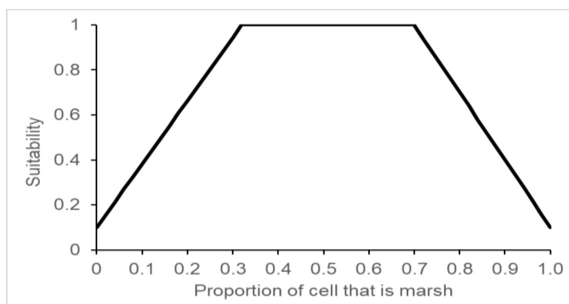
<u>SI_1 = Proportion of cell covered by habitat types and associated open water (V_1).</u> When there is no emergent vegetation in a cell, the cell should be assigned to one of following habitat types based on average annual salinity: fresh marsh <1.5 ppt; intermediate marsh $\geq$ 1.5 to < 4.5 ppt; brackish marsh $\geq$ 4.5 to < 9.5 ppt; and saline marsh $\geq$ 9.5 ppt.

$SI_1 = [(1.0 \times V_{1a}) + (0.67 \times V_{1b}) + (0.55 \times V_{1c}) + (0.23 \times V_{1d}) + (0.0 \times V_{1e}) + (0.0 \times V_{1f})]$

Where: V_{1a} = the proportion of a model cell that is fresh attached or fresh floating marsh
V_{1b} = the proportion of a model cell that is intermediate marsh
V_{1c} = the proportion of a model cell that is brackish marsh
V_{1d} = the proportion of a model cell that is saline marsh
V_{1e} = the proportion of a model cell that is swamp or bottomland hardwood
V_{1f} = the proportion of a model cell that is non-wetland habitat

<u>SI_2 = Proportion of cell that is emergent marsh (V_2).</u>

$SI_2 = (2.81*V_2) + 0.1$, when $V_2 < 0.32$
1.0, when $0.32 \leq V_2 \leq 0.70$
$(-3.0*V_2) + 3.1$, when $V_2 > 0.70$



<u>SI_3 = Mean annual water depth.</u> This SI is derived by calculating the mean water depth for each 30-meter pixel of a model cell, estimating the proportion of the model cell covered by each depth category, then plugging these estimates into the following equation:

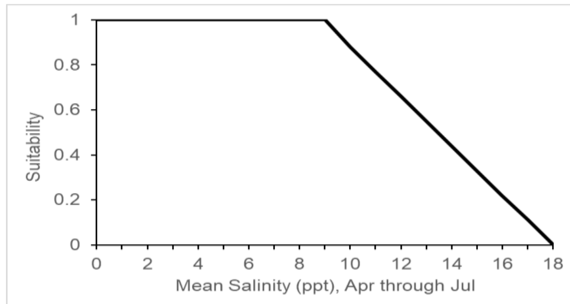
$SI_3 = [(0.6*V_{3a}) + (1.0*V_{3b}) + (0.83*V_{3c}) + (0.57*V_{3d}) + (0.35*V_{3e}) + (0.22*V_{3f}) + (0.09*V_{3g}) + (0.0*V_{3h})]$

Where: V_{3a} = the proportion of cell with mean water depth ≥ 0 to $\leq$ 8 cm

V_{3b} = the proportion of cell with mean water depth >8 to ≤ 30
V_{3c} = the proportion of cell with mean water depth >30 to ≤ 36
V_{3d} = the proportion of cell with mean water depth >36 to ≤ 42
V_{3e} = the proportion of cell with mean water depth >42 to ≤ 46
V_{3f} = the proportion of cell with mean water depth >46 to ≤ 50
V_{3g} = the proportion of cell with mean water depth >50 to ≤ 56
V_{3h} = the proportion of cell with mean water depth >56

<u>SI_4 = Mean salinity during brood rearing, April through July.</u>

SI_4 = 1.0, when $V_4 \leq 9$ ppt
(-0.11*V_4) + 1.98, when $9 < V_4 \leq 18$
0.0, when $V_4 > 18$

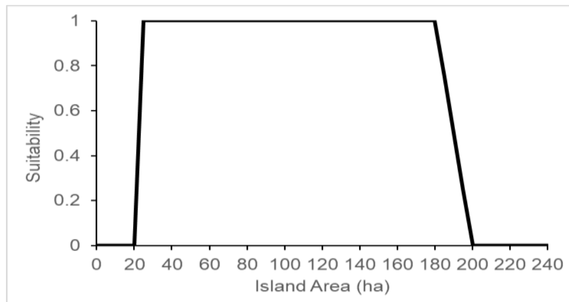


7.0 BROWN PELICAN

The brown pelican (*Pelecanus occidentalis*) is an upper trophic level coastal seabird and is a species of conservation need in Louisiana. The brown pelican HSI model is used to calculate the annual habitat suitability score of a model cell for nesting brown pelicans in Louisiana. The model includes six suitability indices (SIs) that define the optimal size, location, and vegetation coverage of coastal islands for successful nesting and brood rearing. These SIs are then used in the following equation: $HSI = (SI_1 \times SI_2 \times SI_3 \times SI_4 \times SI_5 \times SI_6)^{1/6}$.

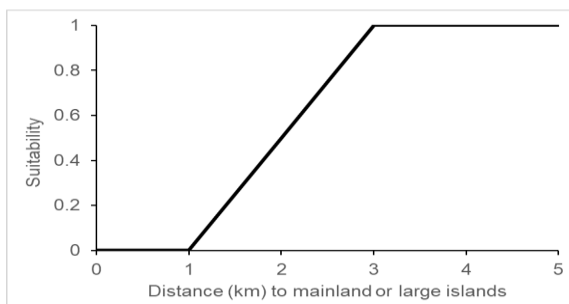
<u>SI_1 = Area of island including the cell of interest (V_1).</u> This SI only considers small islands to be suitable for nesting pelicans. Small islands are defined as contiguous model cells comprising a land mass less than 200 hectares in area that is surrounded by cells that are 100% open water.

SI_1 = 0.0, when $V_1 < 25$ or >200 hectares
1.0, when $25 \leq V_1 \leq 180$
$10 - (0.05*V_1)$, when $180 < V_1 \leq 200$



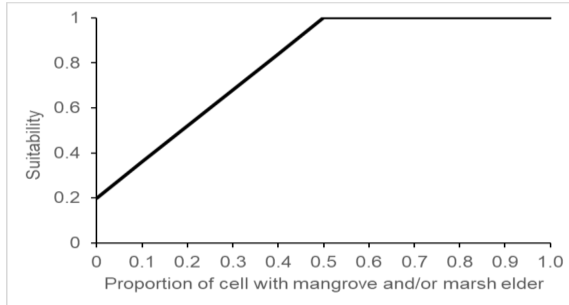
<u>SI_2 = Distance to the mainland or large island (V_2).</u> This SI is the minimum distance from the center of the contiguous cells comprising a small island, including the focal cell, to the center of any cell containing land that does not meet the definition of a small island as described for SI_1.

SI_2 = 0.0, when $V_2 < 1.0$ km
$(0.5*V_2) - 0.5$, when $1.0 \leq V_2 < 3.0$
1.0, when $V_2 \geq 3.0$



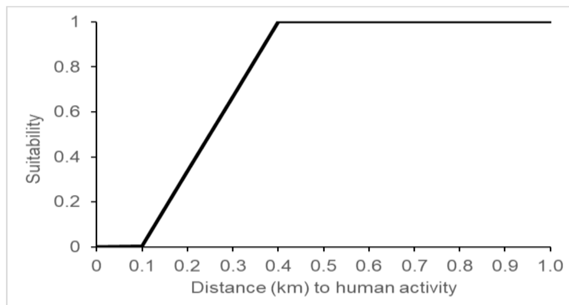
<u>SI_3 = Proportion of cell with black mangrove, *Avicennia germinans*, and/or marsh elder, *Iva frutescens* (V_3).</u>

SI_3 = 0.2, when V_3 = 0.0
($1.6*V_3$) + 0.2, when 0.0< V_3 <0.5
1.0, when $V_3 \geq 0.5$



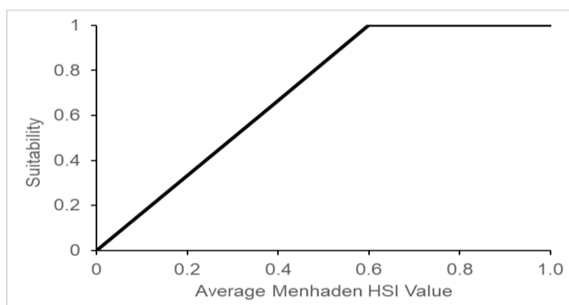
<u>SI_4 = Distance to human activity (V_4).</u> This SI is the minimum distance from the edge of a human activity area to the edge of the contiguous cells forming the island containing the focal cell.

SI_4 = 0.0, when V_4 <0.1 km
($3.33*V_4$) – 0.33, when $0.1 \leq V_4$ <0.4
1.0, when $V_4 \geq 0.4$



<u>SI_5 = Mean gulf menhaden HSI score (V_5).</u> This SI is the mean adult menhaden HSI score of cells within a 20 km radius of a cell where SI_1 >0.0.

SI_5 = $1.667*V_5$, when V_5 <0.60
1.0, when $V_5 \geq 0.60$



<u>SI_6 = Dominant habitat type in cell.</u> Saline marsh receives a score of 1.0, whereas other habitat types receive a score of 0.0.

8.0 SEASIDE SPARROW

The seaside sparrow (*Ammospiza maritima fisheri*) is a year-round resident of vegetated marsh habitats, and is a species of conservation need in Louisiana. The seaside sparrow HSI model is used to calculate the annual habitat suitability score of a model cell for nesting seaside sparrows in coastal Louisiana. The model includes three suitability indices (SIs) that describe habitat conditions needed to reduce predation and flooding impacts on nests. These SIs are then used in the following equation: $HSI = (SI_1 \times SI_2 \times SI_3)^{1/3}$.

<u>SI_1 = Proportion of model cell covered by habitat types (V_1).</u> Habitat types other than intermediate marsh, brackish marsh, and saline marsh are given a suitability score of 0.0.

$SI_1 = [(1.0 \times V_{1a}) + (0.7 \times V_{1b}) + (0.3 \times V_{1c})]$

Where: V_{1a} = the proportion of a model cell that is saline marsh

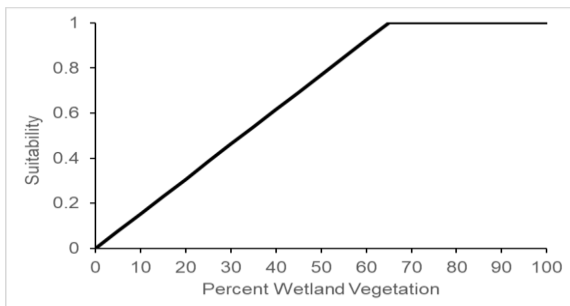
V_{1b} = the proportion of a model cell that is brackish marsh

V_{1c} = the proportion of a model cell that is intermediate marsh

<u>SI_2 = Percent of model cell covered by wetland vegetation (V_2).</u> This SI is the ratio of vegetated marsh to non-vegetated habitat (i.e., open water, bare ground, etc.) in a model cell.

$SI_2 = 0.0154 * V_2$, when $V_2 < 65\%$

1.0, when $V_2 \geq 65$

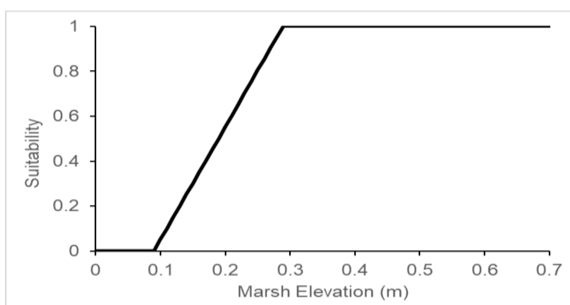


<u>SI_3 = Mean elevation of marsh relative to mean annual water level (V_3).</u>

$SI_3 = 0.0$, when $V_3 \leq 0.09$ m

$(5.025 * V_3) - 0.452$, when $0.09 < V_3 < 0.285$

1.0, when $V_3 \geq 0.285$



9.0 BALD EAGLE

The bald eagle (*Haliaeetus leucocephalus leucocephalus*) is an upper trophic level raptor that nests primarily in wooded, freshwater habitats, and is a species of conservation need in Louisiana. The bald eagle HSI model is used to calculate the annual habitat suitability score of a 36 km^2 cell for bald eagle nesting in coastal Louisiana. The model includes six suitability indices (SIs) that are based on statistical relationships between nest probability of occurrence and the proportion of different land cover classes in the 36 km^2 cell. These SIs are then used in the following equation: HSI = $((SI_1)^{0.0104}$ x $(SI_2)^{0.3715}$ x $(SI_3)^{0.4743}$ x $(SI_4)^{0.0330}$ x $(SI_5)^{0.0353}$ x $(SI_6)^{0.0669})^{0.991}$.

<u>SI_1 = Percent of cell covered by developed and upland (V_1).</u> If there is no developed land or upland in a cell, an SI_1 score of 0.01 is assigned. Otherwise, the SI is calculated using the following function:

$$\mathrm{SI}_1 = 0.408 + 0.142\mathrm{x} \ln \mathrm{V}_1$$

<u>SI_2 = Percent of cell covered by flotant marsh (V_2).</u>

$$\mathrm{SI}_2 = 0.282 + 0.047\mathrm{xV}_2 - 1.105\mathrm{e}^{-3}\mathrm{xV}_2{}^2 + 1.101\mathrm{e}^{-5}\mathrm{xV}_2{}^3 - 3.967\mathrm{e}^{-8}\mathrm{xV}_2{}^4$$

<u>SI_3 = Percent of cell covered by forested wetland (V_3).</u>

$$\mathrm{SI}_3 = 0.015 + 0.048\mathrm{xV}_3 - 1.178\mathrm{e}^{-3}\mathrm{xV}_3{}^2 + 1.366\mathrm{e}^{-5}\mathrm{xV}_3{}^3 - 5.673\mathrm{e}^{-8}\mathrm{xV}_3{}^4$$

<u>SI_4 = Percent of cell covered by fresh marsh (V_4).</u>

$$\mathrm{SI}_4 = 0.370 + 0.070\mathrm{xV}_4 - 2.655\mathrm{e}^{-3}\mathrm{xV}_4{}^2 + 3.691\mathrm{e}^{-5}\mathrm{xV}_4{}^3 - 1.701\mathrm{e}^{-7}\mathrm{xV}_4{}^4$$

<u>SI_5 = Percent of cell covered by intermediate marsh (V_5).</u>

$$\mathrm{SI}_5 = 0.263 - 9.406\mathrm{e}^{-3}\mathrm{xV}_5 + 5.432\mathrm{e}^{-4}\mathrm{xV}_5{}^2 - 3.817\mathrm{e}^{-6}\mathrm{xV}_5{}^3$$

<u>SI_6 = Percent of cell covered by open water (V_6).</u> If there is no open water in a cell, an SI_6 score of 0.01 is assigned. If a cell is covered by >95% open water, the cell is given an HSI score of zero. Otherwise, the SI is calculated using the following function:

$$\mathrm{SI}_6 = 0.985 - 0.105\mathrm{x}\left({}^{1}\!/\!_{\mathrm{V}_6}\right)$$

10.0 SMALL JUVENILE BROWN SHRIMP

Brown shrimp (*Farfantepenaeus aztecus*) are benthic crustaceans that use estuaries as nursery habitat, and support an important commercial fishery in Louisiana. The small juvenile brown shrimp HSI model is used to calculate the annual habitat suitability score of a model cell for brown shrimp (median total length = 53 mm) that have recently settled to Louisiana estuaries and are most common between April and July. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2)^{1/2}$.

<u>SI_1 = Mean salinity and water temperature from April through July.</u>

$$SI_1 = \frac{e^{1.97+1.23(S_{SI})+1.66(T_{SI})-1.07(S_{SI}{}^2)-1.53(T_{SI}{}^2)-0.12(S_{SI}*T_{SI})} - 1}{12.50}$$

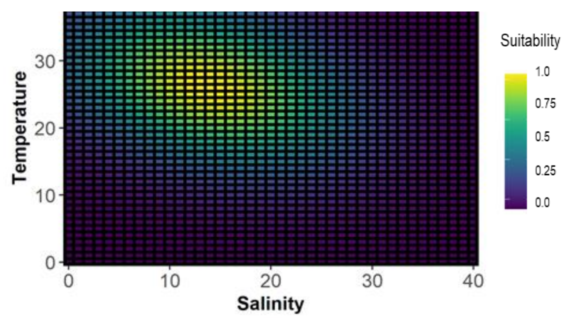
Where,

$$S_{SI} = \frac{\text{Salinity} \ - 7.94}{7.07}$$

$$T_{SI} = \frac{\text{Temperature} \ - 26.87}{3.73}$$

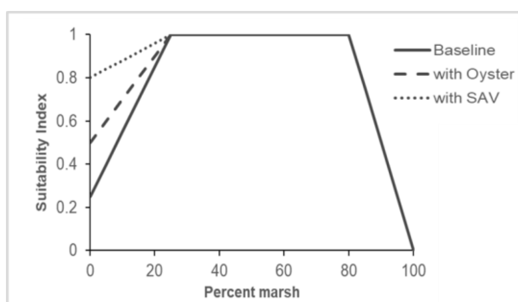
$$S_{SI}{}^2 = \frac{(\text{Salinity} * \text{Salinity}) - 112.91}{165.81}$$

$$T_{SI}{}^2 = \frac{(\text{Temperature} * \text{Temperature}) - 735.69}{191.54}$$



<u>SI_2 = Percent of cell covered by emergent vegetation (V_2).</u>

$SI_2 = (0.03*V_2) + 0.25$, when V_2 <25%
1.0, when $25 \le V_2 \le 80$
$5.0 - (0.05*V_2)$, when V_2 >80



If the model cell has extensive oyster reef coverage (e.g., average oyster HSI score >0.5), then:

$SI_2 = (0.02*V_2) + 0.5$, when V_2 <25%
1.0, when $25 \le V_2 \le 80$
$5.0 - (0.05*V_2)$, when V_2 >80

If the model cell has extensive SAV coverage (e.g., coverage >20% of the cell), then:

SI_2 = $(0.008*V_2) + 0.8$, when $V_2 < 25\%$

1.0, when $25 \leq V_2 \leq 80$

$5.0 - (0.05*V_2)$, when $V_2 > 80$

11.0 LARGE JUVENILE BROWN SHRIMP

The large juvenile brown shrimp HSI model is used to calculate the annual habitat suitability score of a model cell for brown shrimp (median total length = 72 mm) that occur in the deeper parts of the estuarine basins prior to their emigration offshore. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2)^{1/2}$.

<u>SI_1 = Mean salinity and water temperature from April through July.</u>

$$SI_1 = \frac{e^{2.68+1.54(S_{SI})+0.86(T_{SI})-1.51(S_{SI}{}^2)-0.72(T_{SI}{}^2)-0.18(S_{SI}*T_{SI})} - 1}{24.61}$$

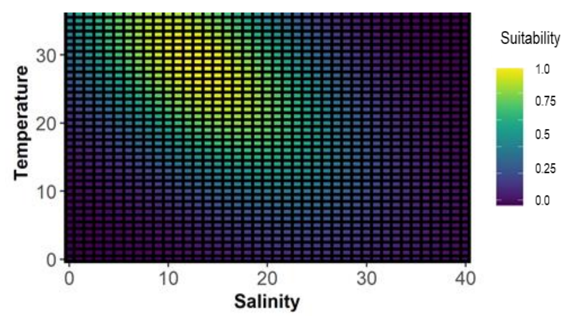
Where,

$$S_{SI} = \frac{\text{Salinity} \; -10.97}{8.03}$$

$$T_{SI} = \frac{\text{Temperature} \; -26.64}{3.73}$$

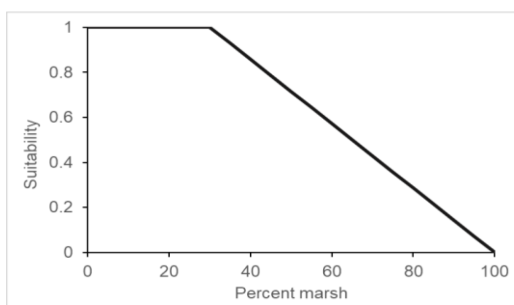
$$S_{SI}{}^2 = \frac{(\text{Salinity} * \text{Salinity}) - 184.85}{216.00}$$

$$T_{SI}{}^2 = \frac{(\text{Temperature} * \text{Temperature}) - 723.40}{189.05}$$



<u>SI_2 = Percent of cell covered by emergent vegetation (V_2).</u>

SI_2 = 1.0, when $V_2 \leq 30$
1.43 - ($0.0143*V_2$), when $V_2 > 30$



12.0 SMALL JUVENILE WHITE SHRIMP

White shrimp (*Litopenaeus setiferus*) are benthic crustaceans that use estuaries as nursery habitat, and support an important commercial fishery in Louisiana. The small juvenile white shrimp HSI model is used to calculate the annual habitat suitability score of a model cell for white shrimp (median total length = 43 mm) that have recently settled to Louisiana estuaries and are most common between June and December. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2)^{1/2}$.

<u>SI_1 = Mean salinity and water temperature from June through December.</u>

$$SI_1 = \frac{e^{1.63+0.61(S_{SI})+1.69(T_{SI})-0.54(S_{SI}{}^2)-2.02(T_{SI}{}^2)-0.08(S_{SI}*T_{SI})} - 1}{10.05}$$

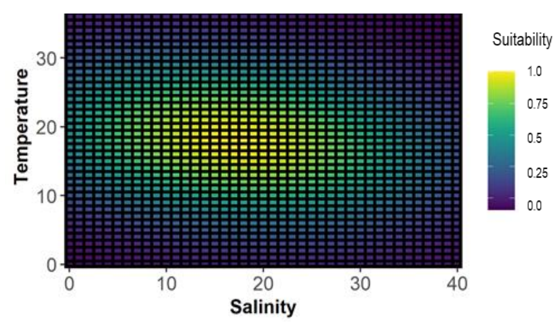
Where,

$$S_{SI} = \frac{\text{Salinity } - 10.69}{7.72}$$

$$T_{SI} = \frac{\text{Temperature } - 24.39}{6.33}$$

$$S_{SI}{}^2 = \frac{(\text{Salinity} * \text{Salinity}) - 173.92}{208.18}$$

$$T_{SI}{}^2 = \frac{(\text{Temperature} * \text{Temperature}) - 635.09}{283.81}$$

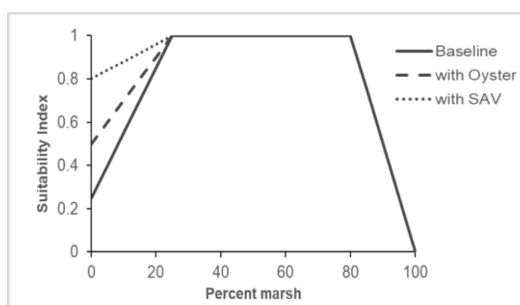


<u>SI_2 = Percent of cell covered by emergent vegetation (V_2).</u>

SI_2 = $(0.03*V_2) + 0.25$, when $V_2 < 25\%$
1.0, when $25 \leq V_2 \leq 80$
$5.0 - (0.05*V_2)$, when $V_2 > 80$

If the model cell has extensive oyster reef coverage (e.g., average oyster HSI score >0.5), then:

SI_2 = $(0.02*V_2) + 0.5$, when $V_2 < 25\%$
1.0, when $25 \leq V_2 \leq 80$
$5.0 - (0.05*V_2)$, when $V_2 > 80$



If the model cell has extensive SAV coverage (e.g., coverage >20% of the cell), then:

$SI_2 = (0.008*V_2) + 0.8$, when $V_2 < 25\%$
1.0, when $25 \leq V_2 \leq 80$
$5.0 - (0.05*V_2)$, when $V_2 > 80$

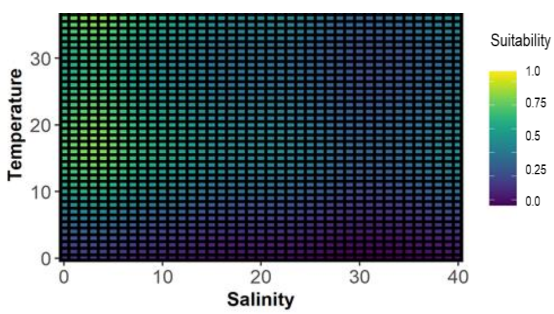
13.0 LARGE JUVENILE WHITE SHRIMP

The large juvenile white shrimp HSI model that was developed for the 2023 Coastal Master Plan produced unreasonable results. The model is not recommended for use and is not provided here.

14.0 JUVENILE BLUE CRAB

Blue crab (*Callinectes sapidus*) are benthic crustaceans that reside in estuarine habitats throughout most of its life cycle, and support an important commercial fishery in Louisiana. The juvenile blue crab HSI model is used to calculate the annual habitat suitability score of a model cell for blue crab (carapace width <60 mm) that have recently settled to Louisiana estuaries and are common throughout the year. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2)^{1/2}$.

<u>SI_1 = Mean salinity and water temperature from the entire year.</u> This SI is based on a generalized additive mixed model, the results of which are depicted below. Because the model equations are long and complex, they are not provided here. However, a look-up table has been created that provides the suitability score (indicated in the "*cpue_scaled*" column of the table) for combinations of salinity ("*sal_m*") and water temperature ("*wtemp_m*"). The table is available at: github.com/CPRA-MP.

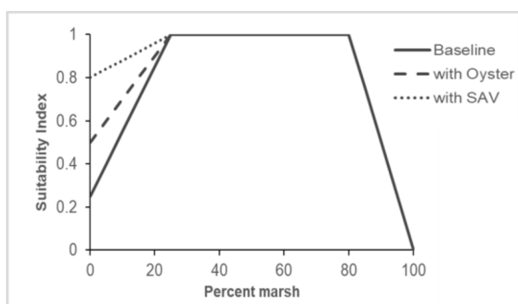


<u>SI_2 = Percent of cell covered by emergent vegetation (V_2).</u>

$SI_2 = (0.03 \cdot V_2) + 0.25$, when V_2 <25%
1.0, when $25 \leq V_2 \leq 80$
$5.0 - (0.05 \cdot V_2)$, when V_2 >80

If the model cell has extensive oyster reef coverage (e.g., average oyster HSI score >0.5), then:

$SI_2 = (0.02 \cdot V_2) + 0.5$, when V_2 <25%
1.0, when $25 \leq V_2 \leq 80$
$5.0 - (0.05 \cdot V_2)$, when V_2 >80



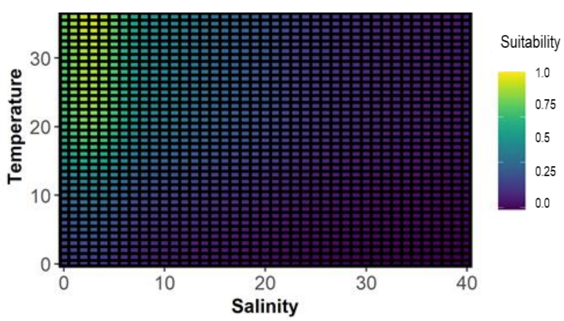
If the model cell has extensive SAV coverage (e.g., coverage >20% of the cell), then:

$SI_2 = (0.008*V_2) + 0.8$, when $V_2 < 25\%$
    1.0, when $25 \leq V_2 \leq 80$
    $5.0 - (0.05*V_2)$, when $V_2 > 80$

15.0 JUVENILE GULF MENHADEN

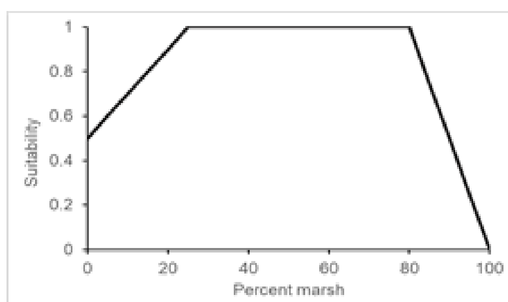
Gulf menhaden (*Brevoortia patronus*) are planktivorous fish that primarily use estuaries as nursery habitat, but also may forage in estuaries as adults. Menhaden support an important commercial fishery in Louisiana. The juvenile gulf menhaden HSI model is used to calculate the annual habitat suitability score of a model cell for menhaden (median total length = 35 mm) that have recently settled to Louisiana estuaries and are most common between January and August. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2)^{1/2}$.

<u>SI_1 = Mean salinity and water temperature from January through August.</u> This SI is based on a generalized additive mixed model, the results of which are depicted below. Because the model equations are long and complex, they are not provided here. However, a look-up table has been created that provides the suitability score (indicated in the "*cpue_scaled*" column of the table) for combinations of salinity ("*sal_m*") and water temperature ("*wtemp_m*"). The table is available at: github.com/CPRA-MP.



<u>SI_2 = Percent of cell covered by emergent vegetation (V_2).</u>

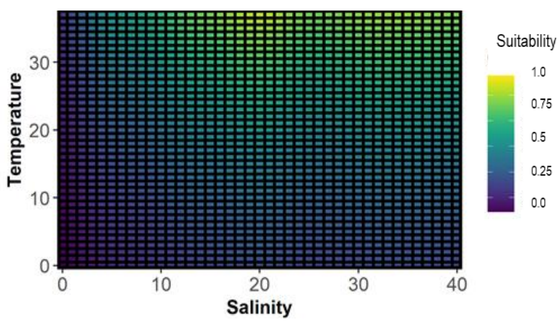
$SI_2 = (0.02*V_2) + 0.5$, when $V_2 < 25\%$
1.0, when $25 \leq V_2 \leq 80$
$5.0 - (0.05*V_2)$, when $V_2 > 80$



16.0 ADULT GULF MENHADEN

The adult gulf menhaden HSI model is used to calculate the annual habitat suitability score of a model cell for menhaden (median total length = 175 mm) that occur in the open waters of estuarine basins primarily between March and November. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2)^{1/2}$.

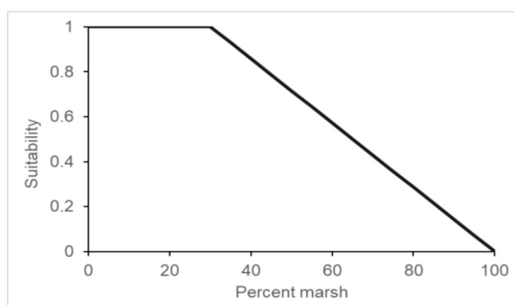
<u>SI_1 = Mean salinity and water temperature from March through November.</u> This SI is based on a generalized additive mixed model, the results of which are depicted below. Because the model equations are long and complex, they are not provided here. However, a look-up table has been created that provides the suitability score (indicated in the "*cpue_scaled*" column of the table) for combinations of salinity ("*sal_m*") and water temperature ("*wtemp_m*"). The table is available at: <u>github.com/CPRA-MP</u>.



<u>SI_2 = Percent of cell covered by emergent vegetation (V_2).</u>

SI_2 = 1.0, when $V_2 \leq 30$

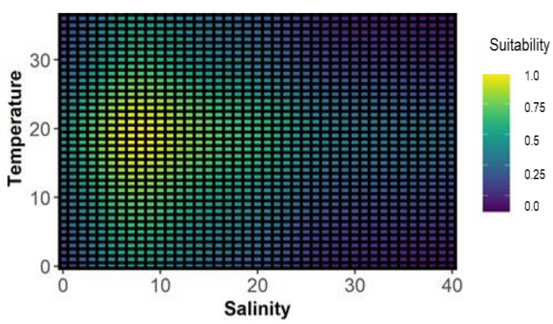
1.43 - $(0.0143 * V_2)$, when $V_2 > 30$



17.0 JUVENILE SPOTTED SEATROUT

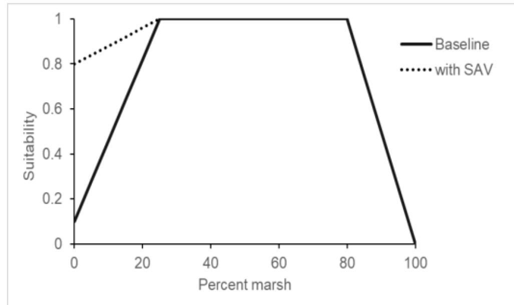
Spotted seatrout (*Cynoscion nebulosus*) are predatory fish that reside in estuarine habitats throughout most of its life cycle, and support an important recreational fishery in Louisiana. The juvenile spotted seatrout HSI model is used to calculate the annual habitat suitability score of a model cell for spotted seatrout (median total length = 60 mm) that have recently settled to Louisiana estuaries and are most common between September and November. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: $HSI = (SI_1 \times SI_2)^{1/2}$.

SI_1 = Mean salinity and water temperature from September through November. This SI is based on a generalized additive mixed model, the results of which are depicted below. Because the model equations are long and complex, they are not provided here. However, a look-up table has been created that provides the suitability score (indicated in the "*cpue_scaled*" column of the table) for combinations of salinity ("*sal_m*") and water temperature ("*wtemp_m*"). The table is available at: github.com/CPRA-MP.



SI_2 = Percent of cell covered by emergent vegetation (V_2).

$SI_2 = (0.036*V_2) + 0.1$, when $V_2 < 25\%$
1.0, when $25 \leq V_2 \leq 80$
$5.0 - (0.05*V_2)$, when $V_2 > 80$



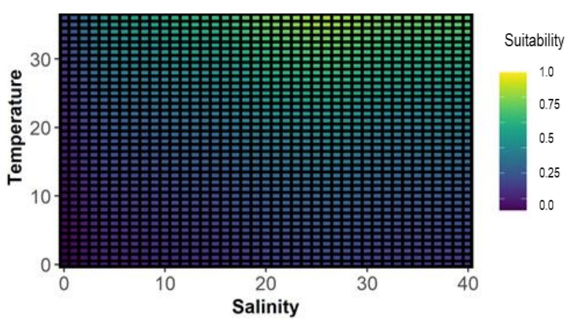
If the model cell has extensive SAV coverage (e.g., coverage >20% of the cell), then:

$SI_2 = (0.008*V_2) + 0.8$, when $V_2 < 25\%$
1.0, when $25 \leq V_2 \leq 80$
$5.0 - (0.05*V_2)$, when $V_2 > 80$

18.0 ADULT SPOTTED SEATROUT

The adult spotted seatrout HSI model is used to calculate the annual habitat suitability score of a model cell for spotted seatrout (median total length >200 mm) that occur in Louisiana's estuarine basins throughout the year. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2)^{1/2}$.

<u>SI_1 = Mean salinity and water temperature from the entire year.</u> This SI is based on a generalized additive mixed model, the results of which are depicted below. Because the model equations are long and complex, they are not provided here. However, a look-up table has been created that provides the suitability score (indicated in the "*cpue_scaled*" column of the table) for combinations of salinity ("*sal_m*") and water temperature ("*wtemp_m*"). The table is available at: <u>github.com/CPRA-MP</u>.

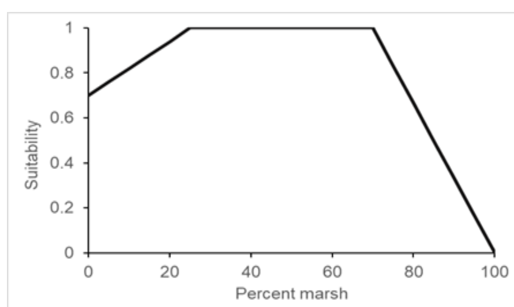


<u>SI_2 = Percent of cell covered by emergent vegetation (V_2).</u>

$SI_2 = (0.012 * V_2) + 0.7$, when $V_2 < 25\%$

1.0, when $25 \leq V_2 \leq 70$

$3.33 - (0.0333 * V_2)$, when $V_2 > 70$



19.0 LARGEMOUTH BASS

Largemouth bass (*Micropterus salmoides*) are predatory fish that are primarily associated with freshwater habitats, and are a popular recreational fishery species. The largemouth bass HSI model is used to calculate the annual habitat suitability score of a model cell for juvenile and adult bass (median TL = 200 mm) that occur in Louisiana's estuarine basins throughout the year. The model includes two suitability indices (SIs), a water quality SI, which describes the suitability of varying salinity and water temperature; and a structural habitat SI, which describes the suitability of aquatic habitat composition. These SIs are then used in the following equation: HSI = $(SI_1 \times SI_2)^{1/2}$.

<u>SI_1 = Mean salinity and water temperature from the entire year.</u>

$$SI_1 = \frac{\exp(2.50 - 0.25(S_{SI}) + 0.30(T_{SI}) - 0.04({S_{SI}}^2) - 0.33({T_{SI}}^2) - 0.05(S_{SI} * T_{SI}))}{14.30}$$

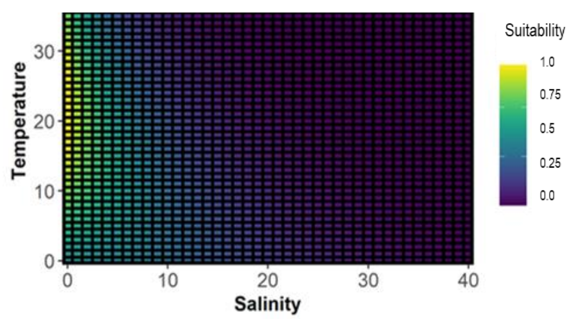
Where,

$$S_{SI} = \frac{\text{Salinity} \ - 0.84}{1.84}$$

$$T_{SI} = \frac{\text{Temperature} \ - 22.68}{4.64}$$

$${S_{SI}}^2 = \frac{(\text{Salinity} * \text{Salinity}) - 4.08}{24.91}$$

$${T_{SI}}^2 = \frac{(\text{Temperature} * \text{Temperature}) - 535.99}{206.16}$$



<u>SI_2 = Percent of cell covered by emergent vegetation (V_2).</u>

SI_2 = 0.01, when $V_2 < 20$
- $(0.099*V_2) - 1.997$, when $20 \leq V_2 < 30$
- 1.0, when $30 \leq V_2 < 50$
- $(-0.0283*V_2) + 2.414$, when $50 \leq V_2 < 85$
- 0.01, when $85 \leq V_2 < 100$
- 0.0, when $V_2 = 100$