CHAPTER C.10
HABITAT USE MODULE

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10.1 Introduction

The Habitat Use module provides a methodology for estimating how various restoration scenarios will affect habitat capacity for key life stages of representative species of fish, shellfish, and wildlife. Habitat capacity will be determined by first rating individual factors (e.g., water temperature) from zero to one (quality value) in spatial cells, then the ratings of multiple factors in each spatial cell will be combined to obtain a single value for each cell, and then the combined values will be summed over spatial cells to obtain an overall quality-weighted habitat area for the system. The relationship between an individual factor and quality will be based on published research and published Habitat Suitability Index (HSI) models.

Analyses will be applied to the 0.3 mi^2 (1-km^2) grid for each basin. The information available for each 0.3 mi^2 (1-km^2) cell is listed in Table C.10-1. Factors to be used in calculating habitat capacity include habitat type (bottomland hardwood forest, swamp, fresh marsh, intermediate marsh, brackish marsh, saline marsh, open water, barrier island, and maritime forest ridge), average monthly water salinity (ppt), average monthly water temperature (oC), average water depth (m), and the percent of cell that is land. The out from the hydrodynamic models will be used to predict the monthly salinity, monthly temperature, and average water depth for spatial cells that represent water flow within the basin (*i.e.*, channels and lakes, not land cells). The 0.3 mi^2 (1-km^2) grid will cover the entire basin, including water and land. Hydrodynamic model cells will be mapped to the appropriate 0.3 mi^2 (1-km^2) cells, and values of salinity, temperature, and depth will be area-averaged (based on the areas of the hydrodynamic cells) to obtain single values for each 0.3 mi^2 (1-km^2) cell. the percent of the 0.3 mi^2 (1-km^2) cell that is water and the percentages of the land that are each of the ten possible land types will also be known.

Table C.10-1 Factors and Variables Available for the Habitat Suitability Analysis for each of the 0.3 mi^2 (1km^2) Cells

1-km^2 cell	Hydro-dynamic model cell	Area of Hydro-Dynamic model cell	Monthly Salinity J F D	Monthly Temperature J F … D	Monthly Depth J F … D	Percent of cell that is water	Of the land, the dominant habitat type (hardwood, marsh, barrier island, *etc.*)
1	A						
	A						
	A						
	A						
	None – land						
2	B						
	B						
	None - land						
3	None - land						

Quality-weighted habitat will be computed for each 0.3mi^2 (1-km^2) cell, and then summed to obtain a single value for the entire basin for each of the fish, shellfish, and wildlife species. The same calculations will be repeated for the alternative restoration scenarios. The final product is a single table that shows the habitat capacity for each of the twelve species for each basin across the alternative restoration scenarios.

Habitat capacity models have a long history of use in fisheries and wildlife (see Anderson and Gutzwiller 1996). The 1996 reauthorization of the Magnuson-Stevens Act, which governs fisheries management in US coastal waters, specifically requires that fish habitat be considered in fishery management plans. The Instream Incremental Flow Methodology (IFIM) uses the habitat suitability approach to quantify how changes in river flow will affect fish habitat (Bovee *et al.* 1998). An approach very similar to the approach used here was recently used to quantify water quality effects on spotted seatrout in Pensacola Bay and Tampa Bay, Florida (Clark *et al.* 2003).

Species will be analyzed that represent the major ways coastal environments are used by fish and wildlife, and for which adequate data are readily available. Habitat capacity models will be applied to 12 *taxa*: white shrimp, brown shrimp, oyster, gulf menhaden, spotted seatrout, Atlantic croaker, largemouth bass, American alligator, muskrat, mink, otter, and dabbling ducks. For some of these species, specific lifestages (e.g., juvenile spotted seatrout) will be analyzed because habitat use varies with life stage. These species are representative of the diverse habitat preferences of organisms that use the estuarine system as habitat.

10.2 Limitations of the Module

One of the limitations of the proposed analyses is the lack of information on interspersion (*i.e.*, spatial arrangement of the land within the spatial cells). Interspersion, and the related quantity of edge between emergent vegetation and open water, is critical to some of the species.

Species for which the value of edge effect has been demonstrated include muskrats, dabbling ducks, juvenile red drum, juvenile brown shrimp, juvenile white shrimp, and other fish and decapod crustaceans (Weller 1978, Kaminski and Prince 1981, Prolux and Gilbert 1983, Zimmerman and Minello 1984, Minello *et al.* 1994, Peterson and Turner 1994, Rozas and Zimmerman 2000, Stunz *et al.* 2002). The relationship between the amount of land in an area and the corresponding amount of edge is complicated, and dependent upon how the land is arranged within the spatial area. Therefore, for some species, the analyses are missing an important factor in determining habitat capacity.

In addition to the amount of edge, several other key factors for some of the species are also missing. For example, turbidity is an important characteristic of Louisiana estuaries, often used as an indicator of cover (Chesney *et al.* 2000). Largemouth bass are considered intolerant of suspended solids (turbidity) and sediment (Muncy *et al.* 1979, Stuber *et al.* 1982). Buck (1956a; 1956b) reported optimum suspended solid levels are between 5 and 25 parts per million (ppm), and levels less than 5 ppm indicate low productivity.

The major caveat of using quality-weighted habitat is that predicted changes in habitat area may or may not translate into actual changes in numbers of individuals in the population. Many factors affect the annual numbers of individuals of fish, shellfish, and wildlife populations. Quality-weighted habitat is best thought of as the capacity of the system to support individuals. Whether all habitat cells can be accessed by individuals and how other factors may limit population numbers are ignored in the analyses. It is assumed that increasing the capacity of the system to support individuals is beneficial.

10.3 Fish and Shellfish Models

10.3.1 General Methods

the focus is on the juvenile life stage for the fish species analyzed. Fish exhibit ontogenetic (life stage-dependent) changes in how they use the estuarine environment. The habitat needs and preferences of young-of-the-year juveniles are taken into account because many species are highly dependent on the estuary for growth and survival. Furthermore, annual recruitment (survival to adulthood) of many estuarine-dependent fish and shellfish are generally thought to be established by, or during, the early juvenile life stage.

Published HSI models for each of the species of interest was the starting point. These HSI models were developed by the US Fish and Wildlife Service and have been peer-reviewed. The published models were modified in three possible ways. One way was to reduce the number of factors included. The published models often included factors or variables that are not available for the 0.3 mi^2 ($1\text{-}km^2$) grid overlain on coastal Louisiana. In these cases, the published model was simplified by removing the unavailable factors from the model. This is equivalent to assuming that the removed factor is uniform across the different restoration scenarios.

The second way of modifying the published models was to change some of the habitat suitability functions. The habitat suitability functions are the specified relationships (often piece-wise linear) that assign numerical values between 0 and 1 to values of the factors. The habitat requirements and preferences specified by each suitability function was compared to the environmental conditions associated with field samples of fish and shellfish species for coastal Louisiana. The primary sources for the field-associations were Baltz *et al.* (1993; 1998; 2003), Jones *et al.* (2002), Minello and Rozas (2002). The suitability functions relying on expert opinion and interpretation of the published field data results were changed.

The third way of modifying the published HSI models was to change how the different factors were combined into the single measures of habitat quality for a cell. There are a variety of ways suitability values of the different factors can be combined (*e.g.*, minimum of the values, arithmetic mean, geometric mean). These alternative ways to combine factors are often used in various combinations in HSI models. For example, one could take the arithmetic average of summer and winter temperature suitability values and the arithmetic average of summer and winter salinity suitability values, and then the geometric mean of the two arithmetic averages. The final model then might use the minimum between the geometric average of the salinity and temperature effects and the suitability value of annual average salinity. There is a biological basis for using the minimum, arithmetic, or geometric averages. Because of the coarse spatial scale of the analyses 0.3 mi^2 (1-km^2) is coarse for fish and shellfish), averages over minimums were used to smooth results and to avoid unrealistically large changes in suitability due to small changes in a single factor.

The habitat suitability models for each of the fish and shellfish species are described below. The same notation that was used in the published models which refers back to the variables included in the published models is used so the reader can easily cross-reference these models with the published models and see which factors were removed for the analyses. Some of the suitability functions were also modified to reflect the conditions of coastal Louisiana and the preferences and tolerances of juveniles. The general approach is to combine factors into one of three categories (water quality, food, cover), and then to combine the three categories into a single index. The suitability functions would be applied to each 0.3 mi^2 (1-km^2) cell.

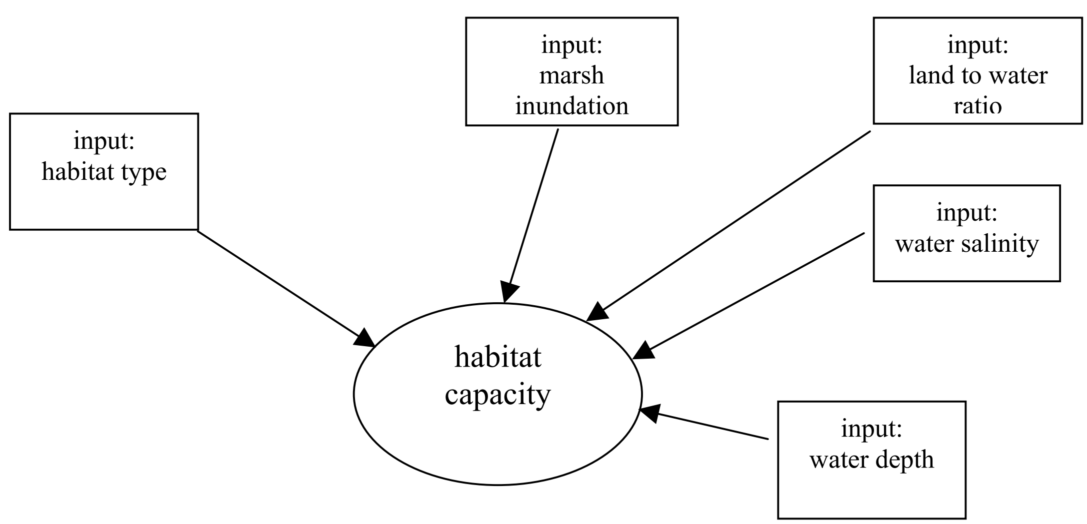


Figure C.10-1 Conceptual Model

10.3.2 Juvenile Gulf Menhaden

The following factors were included in the published HSI model (Christmas *et al.* 1982). The factors shown in bold are the ones used.

V3 - average annual salinity

V5 - substrate composition (mud; sandy mud; sand and shell)

V8 - lowest monthly average winter (Dec-Feb) water temperature

V9 - lowest monthly average winter (Dec-Feb) salinity

V10 - lowest weekly average DO concentration

V11 - marsh acreage (>1000; 500-1000; 50-500, <50)

V12 - water color (brown, clear; green)

V13 - highest monthly average summer (June-August) water temperature

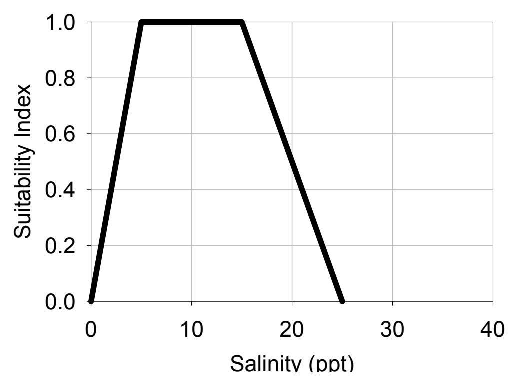
V14 - same as V3

Substrate composition (V5), dissolved oxygen (V10), and water color (V12) factors from the published suitability model were removed. marsh acreage (V11) was modified to be the percent of the 0.3 mi^2 (1-km^2) cell that is marsh (sum of fresh, intermediate, brackish, and saline marsh habitat types).

Suitability function for V3

(Juvenile Gulf Menhaden)

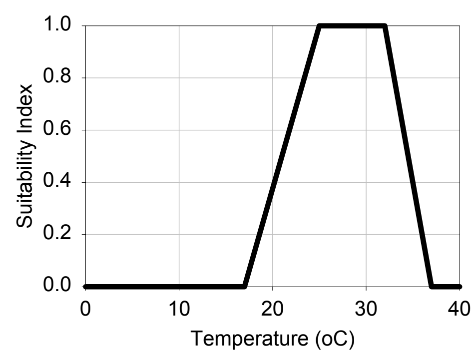
$$SI_3 = \begin{cases} 0.2 \bullet V3 & \text{for } 0 < V3 \le 5 \\ 1.0 & \text{for } 5 < V3 \le 15 \\ 2.5 - 0.1 \bullet V3 & \text{for } 15 < V3 \le 25 \\ 0 & \text{for } V3 > 25 \end{cases}$$



Suitability function for V8

(Juvenile Gulf Menhaden)

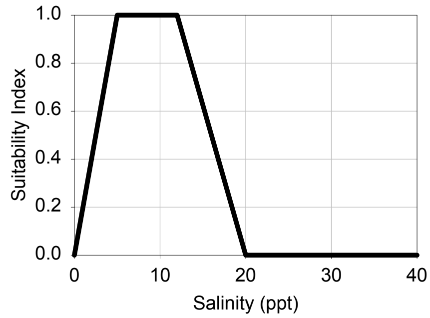
$$SI_8 = \begin{cases} 0 & \text{for } V8 \le 2 \\ 0.33 \bullet V8 - 0.65 & \text{for } 2 < V8 \le 5 \\ 1.0 & \text{for } 5 < V8 \le 20 \\ 5.0 - 0.2 \bullet V8 & \text{for } 20 < V8 \le 25 \\ 0 & \text{for } V8 > 25 \end{cases}$$



Suitability function for V9

(Juvenile Gulf Menhaden)

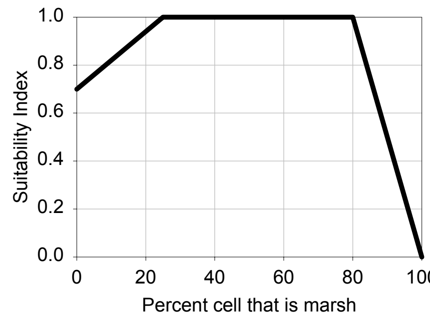
$$SI_9 = \begin{cases} 0.2 \bullet V9 & \text{for } V9 \le 5 \\ 1.0 & \text{for } 5 < V9 \le 12 \\ 2.5 - 0.125 \bullet V9 & \text{for } 12 < V9 \le 20 \\ 0.0 & \text{for } V9 > 20 \end{cases}$$



Suitability function for V11

(Juvenile Gulf Menhaden)

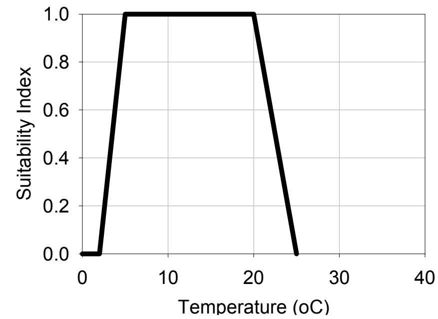
$$SI_{11} = \begin{cases} 0.012 \bullet V11 + 0.7 & \text{for } 0 < V11 \le 25 \\ 1.0 & \text{for } 25 < V11 \le 80 \\ 5.0 - 0.05 \bullet V11 & \text{for } 80 < V11 \le 100 \end{cases}$$



Suitability function for V13

(Juvenile Gulf Menhaden)

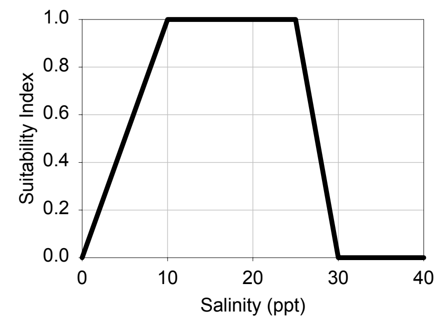
$$SI_{13} = \begin{cases} 0 & \text{for } V13 \le 17 \\ 0.125 \bullet V13 - 2.125 & \text{for } 17 < V13 \le 25 \\ 1.0 & \text{for } 25 < V13 \le 32 \\ 7.4 - 0.2 \bullet V13 & \text{for } 32 < V13 \le 37 \\ 0 & \text{for } V13 > 37 \end{cases}$$



Suitability function for V14

(Juvenile Gulf Menhaden)

$$SI_{14} = \begin{cases} 0.1 \bullet V14 & \text{for } 0 < V14 \le 10 \\ 1.0 & \text{for } 10 < V14 \le 25 \\ 6.0 - 0.2 \bullet V14 & \text{for } 25 < V14 \le 30 \\ 0 & \text{for } V14 > 30 \end{cases}$$



The water quality effect (CI_{wq}) is computed as the arithmetic average of two geometric averages. The geometric average of the two salinity-related factors and the geometric average of the two temperature-related factors were computed first, and then the arithmetic average of these two geometric averages was computed.

$$CI_{wq} = [(SI_8 \times SI_{13})^{1/2} + (SI_9 \times SI_{14})^{1/2}]/2$$

The food effect (CI_{food}) and cover effect (CI_{cover}) reduce to the suitability values of single factors.

$$CI_{food} = SI_3$$

$$CI_{cover} = SI_{11}$$

Finally, the water quality, food, and cover effects were combined into a single measure of habitat suitability (HIS) by computing the geometric average of the three effects:

$$HSI = (CI_{wq} \times CI_{food} \times CI_{cover})^{1/3}$$

10.3.3 Juvenile Spotted Seatrout

The following factors were included in the published HSI model (Kostecki 1984). The factors shown in bold are the ones used.

V1 - lowest monthly mean winter and spring salinity

V2 - highest monthly mean summer (June-Sept) salinity

V3 - **lowest monthly mean winter (Dec-Feb) water temperature**

V4 - **highest monthly mean summer (June-Sept) water temperature**

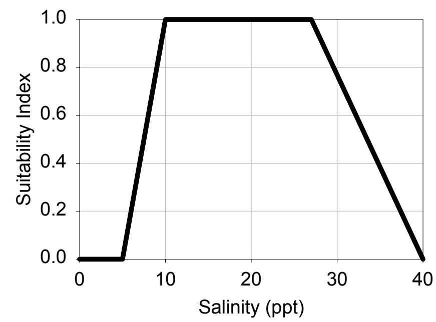
V5- **percentage of area with submerged or emergent vegetation, submerged islands, shell reefs, or oyster beds**

The winter salinity (V1) was removed because its inclusion was based on spawning, and the focus was on the juvenile life stage. Winter temperature was kept because it relates to over winter stress on juveniles. The percentage of area with submerged or emergent vegetation, submerged islands, shell reefs, or oyster beds (V11) were modified to be the percent of the 0.3 mi^2 ($1km^2$) cell that is marsh (sum of fresh, intermediate, brackish, and saline marsh habitat types).

Suitability function for V2

(Juvenile Spotted Seatrout)

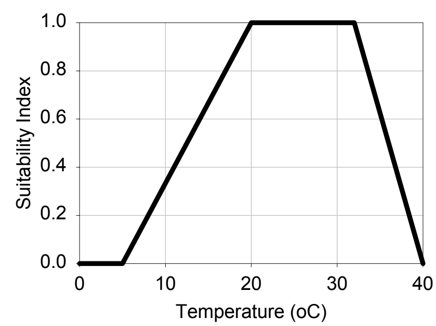
$$SI_2 = \begin{cases} 0.0 & \text{for } V2 \le 5 \\ 0.2 \bullet V2 - 1.0 & \text{for } 5 < V2 \le 10 \\ 1.0 & \text{for } 10 < V2 \le 27 \\ 3.08 - 0.077 \bullet V2 & \text{for } 27 < V2 < 40 \end{cases}$$



Suitability function for V3

(Juvenile Spotted Seatrout)

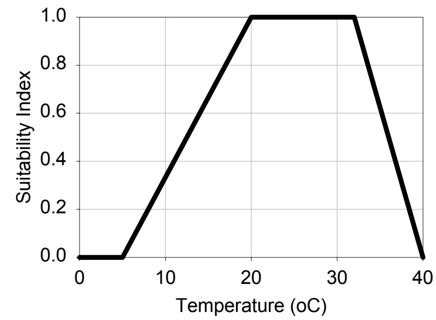
$$SI_3 = \begin{cases} 0.0 & \text{for } V3 \le 5 \\ 0.067 \bullet V3 - 0.34 & \text{for } 5 < V3 \le 20 \\ 1.0 & \text{for } 20 < V3 \le 32 \\ 5.0 - 0.125 \bullet V3 & \text{for } 32 \le V3 < 40 \end{cases}$$



Suitability function for V4

(Juvenile Spotted Seatrout)

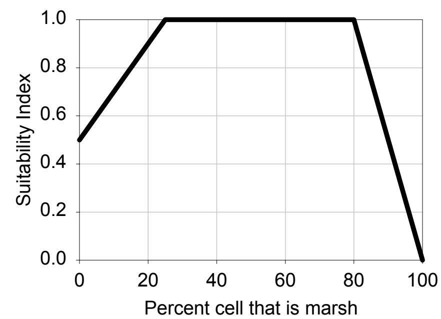
$$SI_4 = \begin{cases} 0.0 & \text{for } V4 \le 5 \\ 0.067 \bullet V4 - 0.35 & \text{for } 5 < V4 \le 20 \\ 1.0 & \text{for } 20 < V4 \le 32 \\ 5.0 - 0.125 \bullet V4 & \text{for } 32 \le V4 < 40 \end{cases}$$



Suitability function for V5

(Juvenile Spotted Seatrout)

$$SI_5 = \begin{cases} 0.02 \bullet V5 + 0.7 & \text{for } 0 < V5 \le 25 \\ 1.0 & \text{for } 25 < V5 \le 80 \\ 5.0 - 0.05 \bullet V5 & \text{for } 80 < V5 \le 100 \end{cases}$$



The salinity factor and the two temperature factors relate to water quality effects, while the percent that is marsh factor relates to cover. The habitat value is the geometric average of the suitability values of the four factors.

$$HSI = (SI_2 \text{ x } SI_3 \text{ x } SI_4 \text{ x } SI_5)^{1/4}$$

10.3.4 Juvenile Atlantic Croaker

The published HSI model (Diaz and Onuf 1985) included the following factors. The factors shown in bold are the ones used.

V1 - mean turbidity (FTU or mg/L) during March though September

V2 - minimum DO concentration during July through September

V3 - mean salinity during March through May (used dotted line for LA)

V4 - mean salinity during June through September (not used for LA)

V5 - depth category (shallow close to marsh; open water <2 m deep; open water >2 m deep)

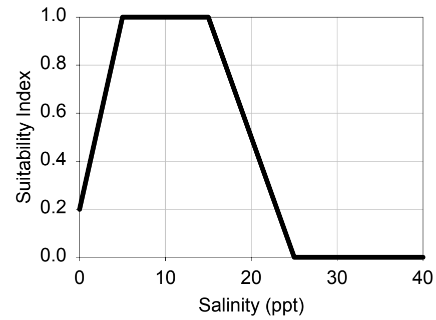
V6 - dominant substrate type (>75% mud; 25-75% mud; >75% sand/shell; seagrass or mostly rock *i.e.*, no soft material)

The turbidity factor (V1), DO-related factor (V2), and substrate type factor (V6) were removed. The predicted values of turbidity or DO were not used, and substrate type can be assumed to be mud. The depth suitability function was modified to be dependent on the three categories of <1 m deep, 1-2 m deep, and >2 m deep.

Suitability function for V3

(Juvenile Atlantic Croaker)

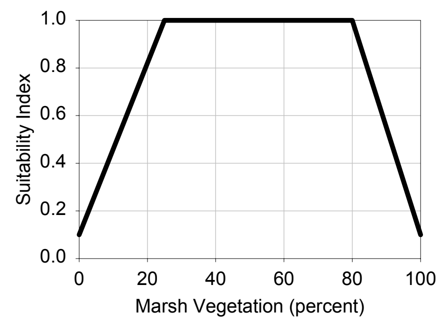
$$SI_{13} = \begin{cases} 0.16 \bullet V3 + 0.2 & \text{for } 0 < V3 \le 5 \\ 1.0 & \text{for } 5 < V3 \le 15 \\ 2.5 - 0.1 \bullet V3 & \text{for } 15 < V3 \le 25 \\ 0 & \text{for } V3 > 25 \end{cases}$$



Suitability function for V5

(Juvenile Atlantic Croaker)

$$SI_5 = \begin{cases} 1.0 & \text{for } V5 \le 1 \text{ m deep} \\ 0.7 & \text{for } 1 < V5 \le 2 \text{ m deep} \\ 0.3 & \text{for } V3 > 2 \text{ m deep} \end{cases}$$



The water quality effect reduces to mean salinity during March through May, and the combined effects of food and cover effects reduce to the depth-related factor. The final HSI is the geometric mean of the two suitability values of the two factors:

$$HSI = (SI_3 \text{ x } SI_5)^{1/2}$$

10.3.5 Largemouth Bass

The following factors were included from the published HSI model (Stuber et al 1982).

V1 - Percent emergent vegetation per $1km^2$ (modified from Percent bottom cover, V3)

V2 - average water temperature for April to August (V8 in original model)

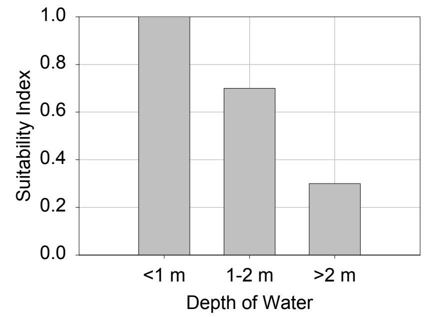
V3 - Maximum salinity for June to August (V12 in original model)

The published HSI model included two versions of the model (riverine versus lake), and many factors in each of the versions. The model had to be reduced to the three factors because the other factors were not available. Specifically, the original variables denoted V1 V4, V5, V6, V7, V11, V15, V16, V19, and V22 from the riverine version of the published HSI model were eliminated. The suitability function for maximum salinity (SI_3) was also modified from the published HSI model based on relationships between nekton populations and marsh-water patterns shown by Minello and Rozas (2002). It is assumed that the salinity and temperature values from the hydrodynamic models represent near-bottom values.

Suitability function for V1

(Largemouth Bass)

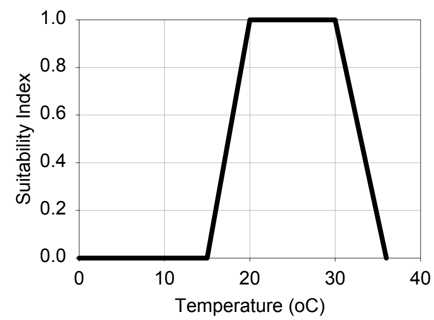
$$SI_1 = \begin{cases} 0.036 \bullet V1 + 0.1 & \text{for } 0 < V1 \le 25 \\ 1.0 & \text{for } 25 < V1 \le 80 \\ 4.582 - 0.0448 \bullet V1 & \text{for } 80 < V1 \le 100 \end{cases}$$



Suitability function for V2

$$SI_2 = \begin{cases} 0.0 & \text{for } V2 \le 15 \\ 0.067 \bullet V2 - 1.6719 & \text{for } 15 < V2 \le 20 \\ 1.0 & \text{for } 20 < V2 \le 30 \\ 6.002 - 0.1665 \bullet V2 & \text{for } 30 \le V2 < 36 \\ 0.0 & \text{for } V2 > 36 \end{cases}$$

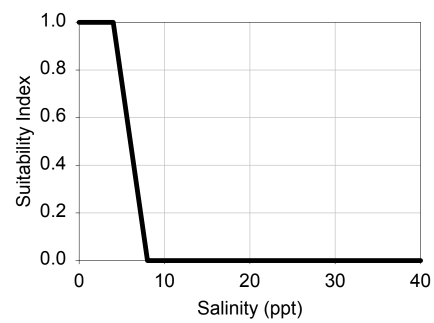
(Largemouth Bass)



Suitability function for V3

$$SI_3 = \begin{cases} 1.0 & \text{for } 0 < V3 \le 4 \\ 2.0 - 0.25 \bullet V3 & \text{for } 4 < V3 \le 8 \\ 0.0 & \text{for } V3 > 8 \end{cases}$$

(Largemouth Bass)



The food effect (CI_{food}) is simple the suitability value of V1 ($CI_{food} = SI_1$). The cover effect (CI_{cover}) is the geometric mean of V1 and the salinity-related factor (V3):

$CI_{cover} = (V_1 \text{ x } V_3)^{1/2}$

The water quality effect (CI_{wq}) depends on the water temperature (V2) and salinity (V3) factors:

Finally, the food, cover, water quality, and other effects were combined by computing the geometric mean.

$$CI_{wq} = \begin{cases} SI_2 & \text{if } V3 = 1.0 \\ \dfrac{SI_2 + SI_3}{2} & \text{if } V3 < 1.0 \end{cases}$$

$HSI = (CI_{food} \text{ X } CI_{cover} \text{ X } CI_{wq})^{1/3}$

10.3.6 Brown Shrimp

The following factors were used from the published HSI model (Turner and Brody 1983). The original factors from the published model have been renumbered.

V1 - percentage of km^2 covered by marsh vegetation

V2 - mean salinity for spring (March, April, and May)

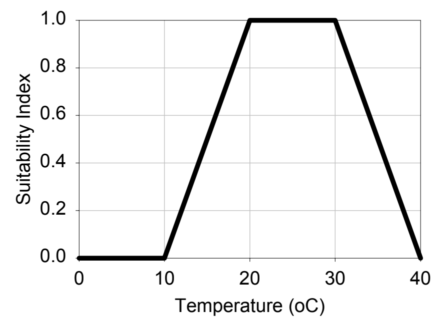
V3 - mean water temperature for spring (March, April, and May)

The factor related to substrate was eliminated. The suitability function for V1 from that used in the published HSI model based on relationships between nekton populations and marsh-water patterns shown by Minello and Rozas (2002) was also modified.

Suitability function for V1

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

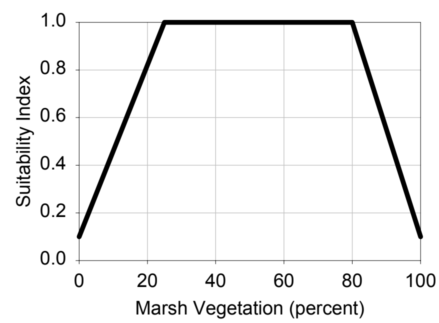
(Brown Shrimp)



Suitability function for V2

$$SI_2 = \begin{cases} 0.1 \bullet V2 & \text{for } V2 \leq 10 \\ 1.0 & \text{for } 10 < V2 \leq 20 \\ 1.4 - 0.02 \bullet V2 & \text{for } 20 < V2 < 30 \\ 2.4 - 0.0533 \bullet V2 & \text{for} 30 < V2 < 45 \end{cases}$$

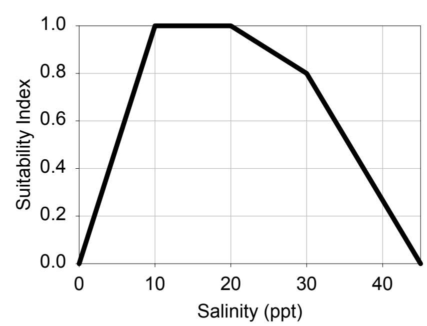
(Brown Shrimp)



Suitability function for V3

$$SI_3 = \begin{cases} 0.0 & \text{for } V3 \leq 10 \\ 0.1 \bullet V3 - 1.0 & \text{for } 10 < V3 \leq 20 \\ 1.0 & \text{for } 20 < V3 \leq 30 \\ 4.0 - 0.1 \bullet V3 & \text{for } 30 \leq V3 < 40 \end{cases}$$

(Brown Shrimp)



The final equation for computing the HSI value also was modified from that presented in the published HSI model. the three suitability values were combined by taking the geometric mean of SI_1 squared and the other two variables. SI_1 is squared in the equation to give this variable twice the weight of the other variables.

$$HSI = (SI_1^2 \times SI_2 \times SI_3)^{1/4}$$

10.3.7 White Shrimp

The HSI model for white shrimp is analogous to the model used for brown shrimp, with the adjustment that the mean salinity (V2) and mean temperature (V3) factors are computed based on June, July, and August. The suitability functions for the marsh-related factor of V1 and temperature-related factor of V3 for brown shrimp are also used for white shrimp; the suitability function for the salinity-related factor of V2 differs between brown and white shrimp.

V1 - percentage of km^2 covered by marsh vegetation

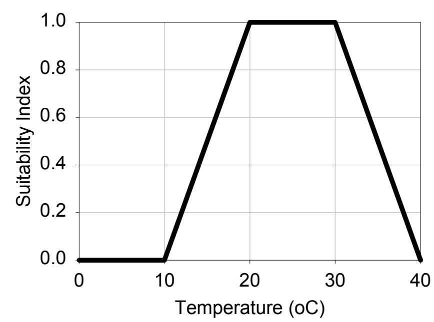
V2 - mean salinity for summer (June, July, and August)

V3 - mean water temperature for summer (June, July, and August)

Suitability function for V1

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

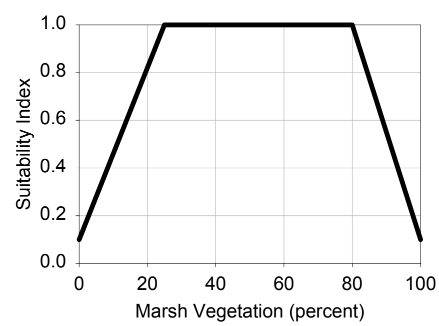
(White Shrimp)



Suitability function for V2

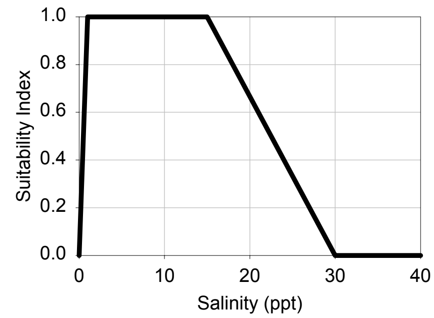
$$SI_2 = \begin{cases} V2 & \text{for } V2 \leq 1 \\ 1.0 & \text{for } 1 < V2 \leq 15 \\ 2.0 - 0.0667 \bullet V2 & \text{for } 15 < V2 < 30 \\ 0.0 & \text{for} V2 > 30 \end{cases}$$

(White Shrimp)



Suitability function for V3

$$SI_3 = \begin{cases} 0.0 & \text{for } V3 \le 10 \\ 0.1 \bullet V3 - 1.0 & \text{for } 10 < V3 \le 20 \\ 1.0 & \text{for } 20 < V3 \le 30 \\ 4.0 - 0.1 \bullet V3 & \text{for } 30 \le V3 < 40 \end{cases}$$



(White Shrimp)

As with brown shrimp, the suitability values for the three factors were combined using a geometric mean with the marsh-related factor (V1) squared to give it more weight.

$HSI = (SI_1^2 \text{ x } SI_2 \text{ x } SI_3)^{1/4}$

10.3.8 Oyster

The following factors were used from the published MHSI model (Soniat and Brody 1988). The original factors from the published model were renumbered. V3 was added to account for land to water in each cell.

V1 - mean summer salinity (June, July, August, September), V2 in MHSI

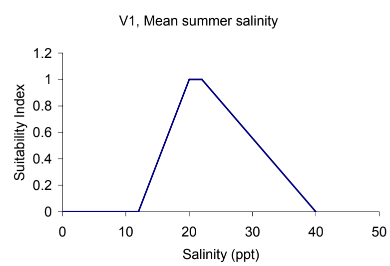
V2 - historic mean salinity, V4 in MHSI

V3 - % water in 0.3 mi^2 (1 km^2) grid

The published HSI model was reduced to three factors because the other factors were not available. Specifically, the original variables denoted V1, V3, V5, V6, V7, and V8 were eliminated from the published MHSI model. It was assumed that the salinity and temperature values from the hydrodynamic models represent near-bottom values.

Suitability function for V1

$$SI_1 = \begin{cases} 0.0 & for\, V1 \le 12 \\ 0.125 \bullet V1 - 1.5 & for\ 12 < V1 \le 15 \\ 1.0 & for\, 15 < V1 \le 22 \\ 2.222 - 0.0556 \bullet V1 & for\ 22 \le V1 < 40 \\ 0.0 & for\, V1 > 40 \end{cases}$$

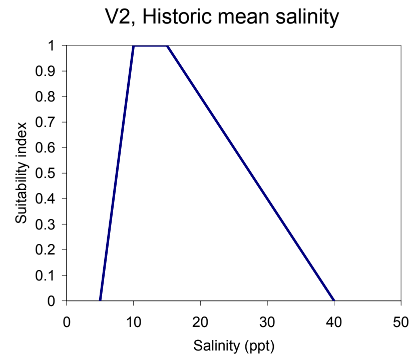


(Oyster)

Suitability function for V2

$$SI_2 = \begin{cases} 0.0 & for\ V2 < 5 \\ 0.2 \bullet V2 - 1.0 & for\ 5 < V2 \le 10 \\ 1.0 & for\ 10 < V2 \le 15 \\ 1.6 - 0.04 \bullet V2 & for\ 15 < V2 \le 40 \\ 0.0 & for\ V2 > 40 \end{cases}$$

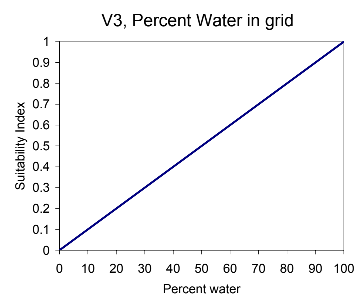
(Oyster)



Suitability function for V3

$$SI_3 = \left\{ 0.01 \bullet V3 \right. \qquad for\ 0 < V3 \le 100$$

(Oyster)



Finally, the summer salinity, historic salinity, and percent water were combined in the grid effects by computing the geometric mean.

$HSI = (SI_1 \text{ x } SI_2 \text{ x } SI_3)^{1/3}$

10.4 Wildlife Models

10.4.1 General Methods

HSI models were prepared for American alligator, otter, mink, muskrat, and dabbling ducks using methods similar to the ones used for fish and shellfish. Habitat capacity is determined by first rating individual factors (*e.g.*, percent land, percent flooding) from zero to one (quality value) in each spatial cell. Then, ratings of multiple factors in each spatial cell are combined to obtain a single value for each cell, and then the combined values are summed over spatial cells to obtain an overall quality-weighted habitat area for the system. The relationship between an individual factor and quality is based on published research and published Habitat Suitability Index (HSI) models.

A fundamental difference between the wildlife and fish/shellfish models is that the wildlife models are based on the habitat type of land within each 0.3 mi ^{2} (1-km ^{2}) cell. Recall the fish and shellfish models focused heavily on the environmental conditions of the water and, when they used information about the land it was the total percent of marsh.

Allwildlife HSI models were based on three factors:

V1 - habitat type of the land in the cell.

V2 - percent of the cell that is land; assumed to be land of the type defined by V1.

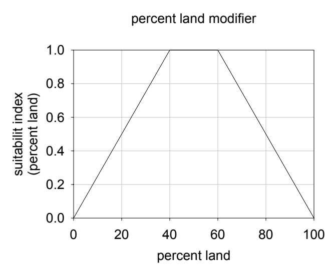
V3 - average water depth (m) relative to land surface in the cell.

If in the future, information on interspersion classes used by the WVA procedure becomes available, it is strongly recommended that interspersion is incorporated into the models.

The habitat type of the land (V1) was one variable influencing wildlife habitat capacity of a cell. The relationship between habitat type and suitability is *taxa*-specific and described below for each of the wildlife *taxa*.

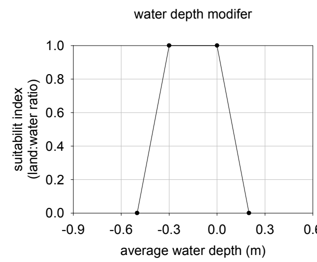
The percent of land in a cell (V2) was another factor influencing wildlife habitat capacity of a cell. Wildlife habitat capacity is based on the widely assumed relationship between wildlife and the interspersion of vegetated marsh and open water. Species for which the value of edge effect has been demonstrated include muskrats, dabbling ducks, juvenile red drum, juvenile brown shrimp, juvenile white shrimp, and other fish and decapod crustaceans (Kaminski and Prince 1981, Minello *et al.* 1994, Peterson and Turner 1994, Prolux and Gilbert 1983, Rozas and Zimmerman 2000, Stunz *et al.* 2002, Weller 1978, Zimmerman and Minello 1984). A general relationship between suitability and percent land for otter and mink was used, but species-specific relationships for were used for the American alligator, dabbling ducks, and muskrats. The general suitability function for percent land is based on assuming that the optimal situation is a cell with one half land and one half water:

$$SI_2 = \begin{Bmatrix} 0.025 \bullet V2 & for\ 0 \le V2 \langle 40 \\ 1 & for\ 40 \le V2 \le 60 \\ 2.5 - (V2 \bullet (-0.025)) & for\ V2 > 60 \end{Bmatrix}$$



The third factor of marsh flooding (V3) is widely believed to affect wildlife habitat capacity of marsh. When flooding is low, disease and predation may increase as wildlife concentrate near deep water where larger alligators are common; feeding activity may be reduced and wildlife may drown when flooding is high (Kinler *et al.* 1990). Despite a widespread recognition that extreme flooding or lack of flooding reduces wildlife habitat capacity, there are no species specific data upon which to base a relationship. Therefore, the same relationship between suitability and flooding for all wildlife *taxa* was used. Also used was the average water depth as a surrogate for marsh flooding. The assumed relationship between average water depth and marsh flooding is based on average water depth of -0.3 m being optimum because analyses of 422,756 hours of water-level data at Marsh Island showed that water levels average 0.98 ft (0.3 m) (std = 1.97 ft (0.6 m)) during the late 1990s (J.A. Nyman, unpublished data), and because wildlife habitat capacity is assumed to be high there. The models therefore assumed the following relationship between percent of the year a cell was flooded and wildlife habitat capacity.

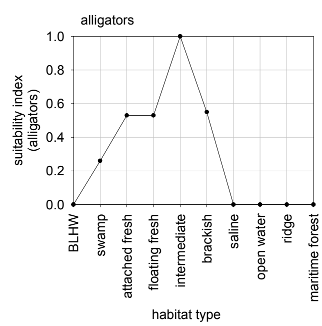
$$SI_3 = \begin{cases} 0 & for\, V3 \le -0.5 \\ 2.5 + (V3 \bullet 5) & for - 0.5 < V3 \le -0.3 \\ 1 & for\, 0.3 < V3 \le 0 \\ 1 - (V3 \bullet 5) & for\, 0 < V3 \le 0.2 \\ 0 & for\, V3 > 0.2 \end{cases}$$



10.4.2 American Alligator

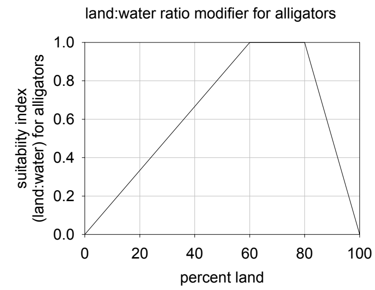
Habitat capacity for American alligator is based on data reported by McNease and Joanen (1978), the HSI model by Newsom *et al.* (1987), and unpublished data from J.A. Nyman (School of Renewable Natural Resources, LSU). The ratios of alligators among the habitat types are based on table 2 from McNease and Joanen (1978): 0.73 mi^2 (1.9 km^2), 1.4 mi^2 (3.6 km^2), and 0.77 mi^2 (2.0 km^2) gators/mi^2 in fresh, intermediate, and brackish marsh respectively. The swamp gator density is a guess by J.A. Nyman. Alligator density reported by McNease and Joanen are much lower than current because alligator populations were still recovering from decades of illegal harvest that ended in 1963. Maximum density in fresh marsh is assumed to be 23/km^2 in fresh marsh based on more recent data from Lacassine Pool, NWR (J.A. Nyman unpublished). Maximum density in other habitat types was estimated from that density and the ratios observed by McNease and Joanen (1987). The relationship between habitat type and alligator habitat suitability can be represented by:

$$SI_1 = \begin{cases} 0 \;\; when\, V1 = BLHW, open\ water, \\ \;\; maritime\ forest, saline, and\ ridge. \\ 0.26\ when\, V1 = swamp \\ 0.55\ when\ \ V1 = attached\ \ fresh\ and \\ floating\ \ fresh \\ 1.0\ when\, V1 = \mathrm{int}\, ermediate \\ 0.55\ when\, V1 = brackish \end{cases}$$



The general relationship between "percent marsh" and habitat quality used for other wildlife species was not used for American alligator because a relationship between those parameters was previously presented in the HSI model by Newsom *et al.* (1987). The relationship presented by Newson *et al.* (1987) was therefore used in this model and is represented by:

$$SI_3 = \begin{Bmatrix} V3 \bullet 0.0167 & for\ 0 \leq V2 < 60 \\ 1 & for\ 60 \leq V3 \leq 80 \\ 5 - (V3 \bullet 0.05) & for\ 80 < V3 \leq 100 \end{Bmatrix}$$



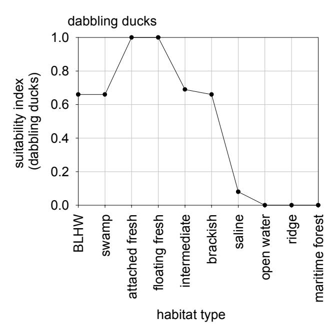
HSI for alligator is computed as the geometric mean of the three factors:

$HSI = (SI_1 \times SI_2 \times SI_3)^{1/3}$

10.4.3 Dabbling Ducks

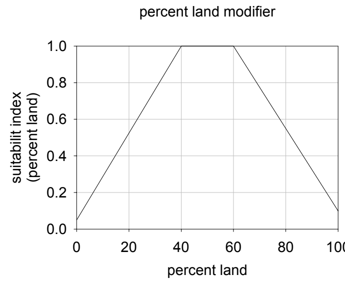
Habitat capacity for dabbling ducks was based on data reported by Palmisano (1973). Data from tables 2, 7, and 8 were used to generate relative abundances of dabbling ducks among the marsh types of 214.7 mi^2 (556/km^2), 140.5 mi^2 (364/km^2), 134.7 mi^2 (349/km^2), and 15.4mi^2 (40/km^2) in fresh, intermediate, brackish, and saline marshes, respectively. Palmisano (1973) did not report numbers for bottomland hardwood or swamp. This model assumed that dabbling duck use of bottomland hardwood and swamp was similar to that in brackish marsh (personal communication, Barry Wilson, Ducks Unlimited, Lafayette, Louisiana).

$$SI_1 = \begin{Bmatrix} 0\ \ when\ V1 = open\ water, maritime \\ forest, and\ ridge. \\ 0.66\ when\ V1 = BLHW\ and\ swamp \\ 1.00\ when\ V1 = attached\ fresh\ and \\ floating\ fresh \\ 0.69\ when\ V1 = intermediate \\ 0.66\ when\ V1 = brackish \\ 0.08\ when\ V1 = saline \end{Bmatrix}$$



Dabbling duck habitat capacity was assumed to vary with percent marsh in a 1 km^2 cell in a slightly different manner than the general relationship used as previously described. Areas having 0% marsh were assumed to provide some loafing habitat and possibly foraging habitat rather than no habitat. Areas having 100% marsh were assumed to provide some foraging habitat.

$$SI_2 = \begin{cases} 0.05 + (V2 \bullet 0.02375) & for\ 0 \le V2 < 40 \\ 1 & for\ 40 \le V2 \le 60 \\ 2.35 - (V2 \bullet 0.0225) & for\ V2 > 60 \end{cases}$$



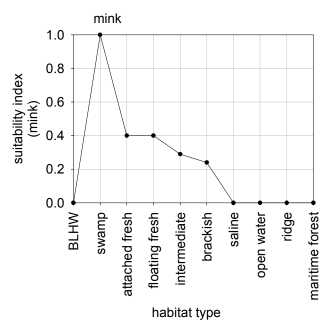
HSI for dabbling duck is computed as the geometric mean of the three factors:

HSI = $(SI_1 \times SI_2 \times SI_3)^{1/3}$

10.4.4 Mink

Habitat capacity for mink was based on data reported by Linscombe and Kinler (1985) who determined the mink harvest distribution using statewide trapping records from 1977 through 1983. They reported mink pelt harvest averaged 3.07/km^2, 1.23/km^2, 0.90/km^2, and 0.72/km^2 in swamp, fresh marsh, intermediate marsh, and brackish marsh respectively. Assuming that optimum mink habitat occurs in swamps, then the relationship between habitat type and mink habitat capacity can be represented by:

$$SI_1 = \begin{cases} 0\ when\ V1 = BLHW, saline, \\ open\ water, maritime\ forest, \\ \ and\ ridge. \\ 1.00\ when\ V1 = swamp \\ 0.40\ when\ V1 = attached\ fresh\ and \\ floating\ fresh \\ 0.29\ when\ V1 = intermediate \\ 0.24\ when\ V1 = brackish \end{cases}$$



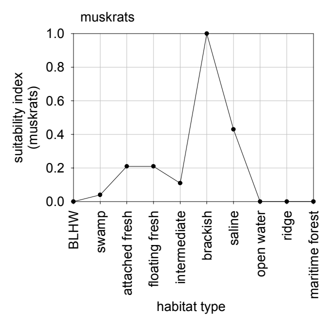
HSI for mink is computed as the geometric mean of the three factors:

HSI = $(SI_1 \times SI_2 \times SI_3)^{1/3}$

10.4.5 Muskrat

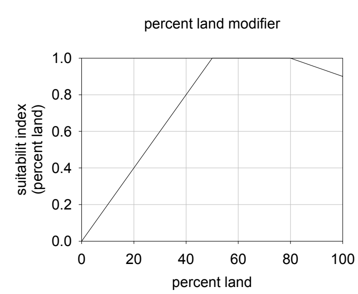
Habitat capacity for muskrat was based on data reported by Linscombe and Kinler (1985) who determined the muskrat harvest distribution using statewide trapping records from 1977 through 1983. They reported muskrat pelt harvest averaged 2.0/km^2, 9.4/km^2, 4.7/km^2, and 44.1/km^2 in swamp, fresh marsh, intermediate marsh, and brackish marsh respectively. Those data indicate that optimum muskrat habitat occurs in brackish marsh. Muskrats also inhabit saline marshes. The value of saline marsh relative to brackish was estimated from the ratio of muskrat house density in brackish and saline marsh, which was calculated from house count data in Palmisaano (1973:table 4) that were adjusted for the amounts of the marsh types in their survey relative to the amounts of the marsh types in the coastal marshes (see tables 2 and 3 in Palmisano 1973). Assuming that optimum muskrat habitat occurs in brackish marsh, the relationship between habitat type and muskrat habitat capacity can be represented by:

$$SI_1 = \left\{ \begin{array}{l} 0 \;\; when\, V1 = BLHW, open\ water, \\ maritime\ forest, and\ ridge. \\ 0.04\, when\, V1 = swamp \\ 0.21\, when\;\; V1 = attached\ fresh\ and \\ floating\ fresh \\ 0.11\, when\, V1 = intermediate \\ 1.00\, when\, V1 = brackish \\ 0.43\, when\, V1 = saline \end{array} \right\}$$



The effect of percent marsh on habitat capacity for muskrat differed from that used for other wildlife. Unlike other wetland wildlife that were modeled, muskrats prefer marsh farthest from ponds (Nyman *et al.* 1993) and the HSI model for muskrats indicates optimal habitat occurs when percent land exceeds 50% (Allen and Hoffman 1984). Thus, the effect of percent marsh on muskrat habitat capacity was the same as that described by Allen and Hoffman (1984):

$$SI_2 = \left\{ \begin{array}{ll} 0.02 \bullet V2 & for\ V2 \langle 50 \\ 1 & for\ 50 \le V2 \le 80 \\ 1.4 + (-0.005 * V2) & for\ V2 \ge 80 \end{array} \right\}$$



HSI for muskrat is computed as the geometric mean of the three factors:

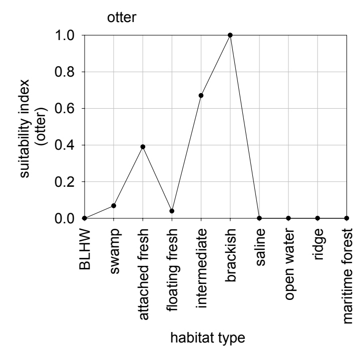
HSI = $(SI_1 \times SI_2 \times SI_3)^{1/3}$

10.4.6 Otter

Habitat capacity for otter was based on data reported by Linscombe and Kinler (1985) who determined the otter harvest distribution using statewide trapping records from 1977 through

1983. They reported otter pelt harvest averaged 0.30/km^2, 0.17/km^2, 0.29/km^2, and 0.44/km^2 in swamp, fresh marsh, intermediate marsh, and brackish marsh respectively. Assuming that optimum otter habitat occurs in brackish marsh, the relationship between habitat type and otter habitat capacity can be represented by:

$$SI_1 = \left\{ \begin{array}{l} 0 \;\; when\; V1 = BLHW, open\; water, \\ maritime\;\; forest, saline, \\ and\;\; ridge. \\ 0.68\; when\;\; V1 = swamp \\ 0.39\; when\;\; V1 = attached\;\; fresh\; and \\ floating\;\; fresh \\ 0.67\; when\; V1 = \mathrm{int}\, ermediate \\ 1.0\; when\; V1 = brackish \end{array} \right\}$$



HSI for otter is computed as the geometric mean of the three factors:

$$HSI = (SI_1 \text{ x } SI_2 \text{ x } SI_3)^{1/3}$$

10.5 Implementation

The HSI models have been described assuming certain information will be available. The models described in this document will likely have to be modified and fine-tuned, as the exact nature of available information becomes clear. If some of the factors are available in some regions but not in others, care must be used in how these missing factors are treated in the HSI models. Comparisons of habitat capacity among *taxa* and among regions can be greatly affected by how missing factors are treated in the models. Also, the committee may determine that if certain factors are missing, *taxa* whose models use this factor may need to be dropped from the analysis.

In most cases, multiple hydrodynamic model cells map to each 0.3 mi^2 (1km^2) cell. The monthly salinity, temperature, and depth are the averages for the water in the 0.3 mi^2 (1km^2) cell, and are obtained from area-weighting the salinity, temperature, and depth predictions from the hydrodynamic model cells. The percent of the cell that is water is the sum of the areas of the hydrodynamic cells within the 0.3 mi^2 (1km^2) cell.

10.6 Results

The habitat use algorithms were used to predict the habitat suitability for all species at 10 year intervals under all different restoration alternatives within each subprovince. To illustrate these results year 50 in subprovince 1 is used as an example, but results from the other subprovinces and intermediate time periods are similar.

Largemouth bass is the only fish species that shows increased habitat suitability with restoration scenarios of increasing sediment load (Figure C.10-2). In contrast, juvenile Atlantic croaker, brown shrimp, juvenile spotted seatrout, and oysters show a declining habitat suitability trend with increased sediment load. This reflects the decreased salinity that is associated with increased sediment load. Since juvenile Atlantic croaker have a SI of 1 from 5 to 15 ppt, the decrease in this species is likely associated more with the loss of open water habitat than with decreases in salinity. Species with wide salinity tolerances such as white shrimp and juvenile gulf menhaden seem to be relatively unaffected by the different restoration scenarios in subprovince 1.

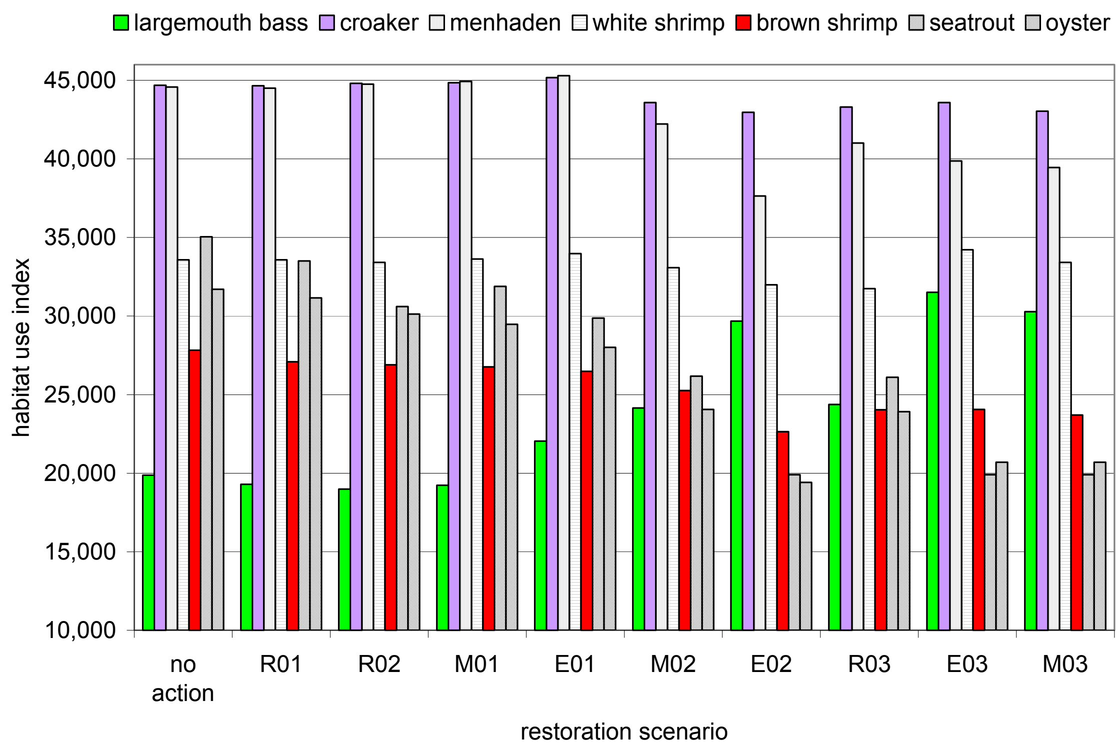


Figure C.10-2 Restoration Scenario Effects on Habitat Suitability for Fish and Shellfish Species in Subprovince 1

Restoration scenario order represents increasing sediment loads from diversions.

Wildlife species show a general increase with increasing sediment load and the resulting increase in fresh wetland area (Figure C.10-2)). This increasing trend is especially large for alligator and dabbling duck, two species that have high SI values for fresh and intermediate marshes.

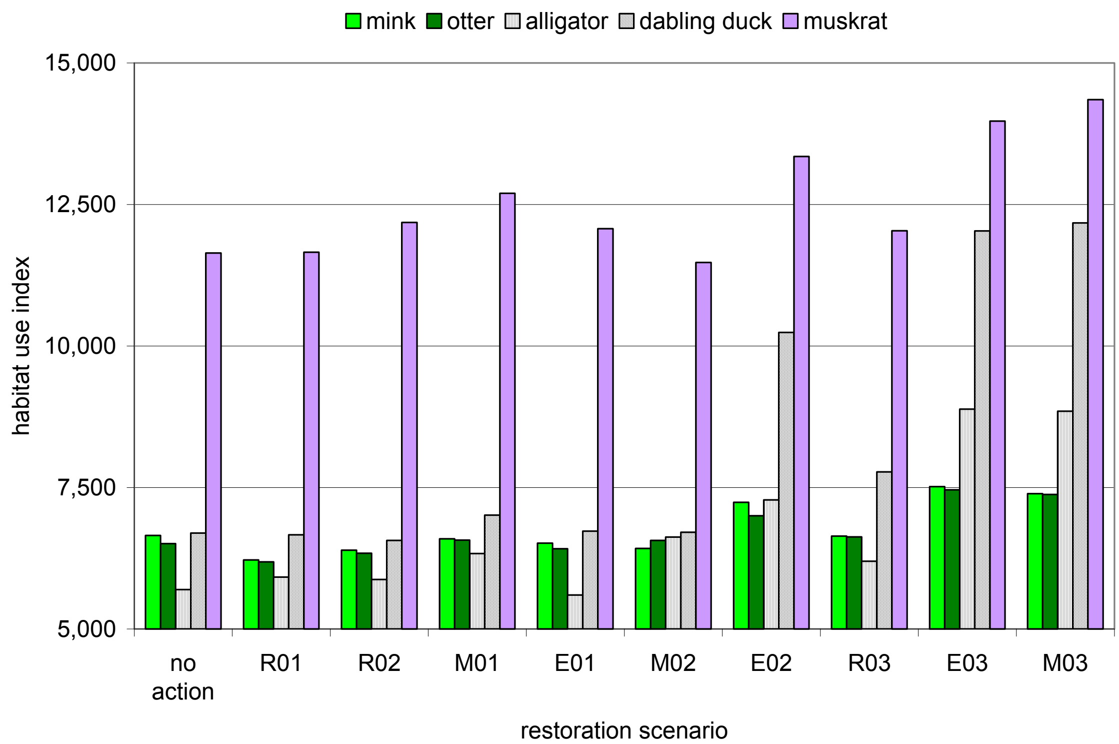


Figure C.10-3 Restoration Scenario Effects on Habitat Suitability for Wildlife Species

Restoration scenario order represents increasing sediment loads from diversions.