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2017 Coastal Master Plan

Attachment C3-9: Brown Pelican, *Pelecanus occidentalis,* Habitat Suitability Index Model

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Coastal Protection and Restoration Authority

This document was prepared in support of the 2017 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 five years) and annual plans. CPRA's mandate is to develop, implement and enforce a comprehensive coastal protection and restoration master plan.

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Executive Summary

The 2012 Coastal Master Plan utilized Habitat Suitability Indices (HSIs) to evaluate potential project effects on wildlife species. Even though HSIs quantify habitat condition, which may not directly correlate to species abundance, they remain a practical and tractable way to assess changes in habitat quality from various restoration actions. As part of the legislatively mandated five year update to the 2012 plan, the wildlife habitat suitability indices were updated and revised using literature and existing field data where available. The outcome of these efforts resulted in improved, or in some cases entirely new suitability indices. This report describes the development of the habitat suitability indices for brown pelican, *Pelecanus occidentalis,* for use in the 2017 Coastal Master Plan modeling effort.

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List of Abbreviations

CPRA	Coastal Protection and Restoration Authority
ha	Hectares
HSI	Habitat Suitability Index
ICM	Integrated Compartment Model
LDWF	Louisiana Department of Wildlife and Fisheries
SI	Suitability Index
USFWS	United States Fish and Wildlife Service

1.0 Species Profile

Brown pelicans occupy an upper trophic level in coastal ecosystems and are of major cultural importance as Louisiana's state bird. The population experienced a major decline in abundance in the 1950s and 1960s (Nesbitt et al., 1978) leading to extirpation of breeding populations from state waters and listing of the populations in the northern Gulf of Mexico as endangered by the federal government. This decline is generally considered to be associated with the widespread use of DDT and other related pesticides (King et al., 1977; Blus, 1982). Banning of those chemicals in 1972 was associated with the recovery of this species (Holm et al., 2003). Breeding populations in the state were re-established via translocations of young birds from Florida (Nesbitt et al., 1978; McNease et al., 1984). The species was delisted by the federal government in 2009 (United States Fish and Wildlife Service [USFWS], 2009).

Today, one of the biggest threats to the species is loss of barrier islands, which the species uses as nesting habitat. The species is highly philopatric (Walter et al., 2013a), so colonization of new nesting habitats tends to be slow. Hurricanes and associated coastal erosion can accelerate loss of nesting areas (Walter et al., 2013b). A second threat to the species is environmental contamination from oil spills or other pollutants (Selman et al., 2012; Walter et al., 2014a). If the species encounters oil during foraging, adults can die or contaminate chicks (King et al., 1977; Parnell et al., 1984; USFWS, 2011). With its position at the top of the coastal food chains, the species is also sensitive to environmental contaminants such as metals or pesticides that are prone to bioaccumulation. Most of the state's nesting population of pelicans occurs on a small number of islands. These nesting islands tend to be clustered in a few sections of the coast, which can expose a large portion of the state's nesting habitats to a single major contamination or storm event (Raynor et al., 2013; Walter et al., 2013c; Walter et al., 2014a).

Brown pelicans nest on Louisiana's coastal islands in early spring (Figure 1). A smaller number of birds nest in early summer, but little is known about the success of those efforts. Typically, pelicans lay 1-3 eggs per nest (Shields, 2002), and the average number of chicks fledged per nest varies between 1.7 and 2.6 in Louisiana (Walter et al., 2013b). Incubation is about 4.5 weeks and young are fed for up to 12 weeks (Shields, 2002). Care of young continues after fledging from nests, at which time young assemble in large groups called crèches. Flight occurs at about 75 days of age (Shields, 2002). Individuals take 3-5 years to reach sexual maturity (Shields, 2002). Outside of the nesting season, pelican use of the northern gulf coast decreases slightly and birds are known to forage widely (King et al., 2013).

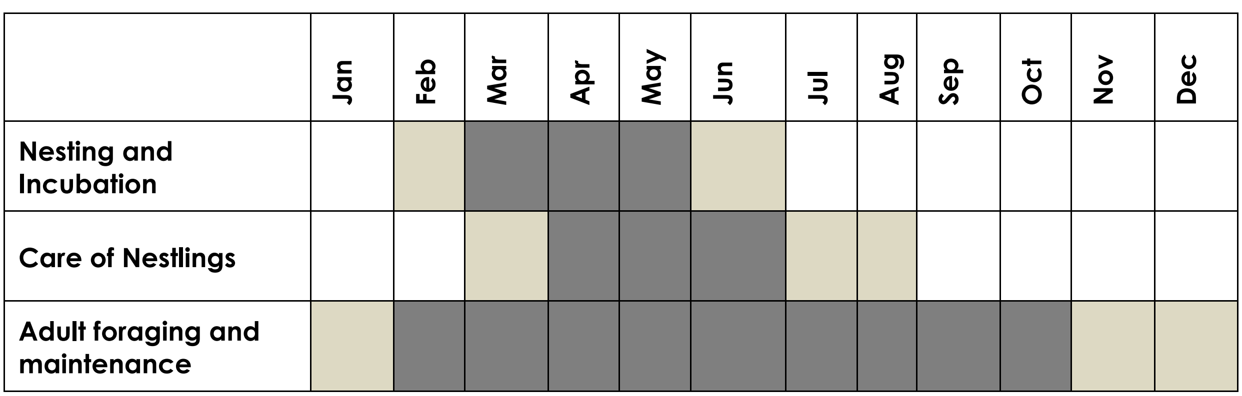

Figure 1: Seasonal Activities of the Brown Pelican in Coastal Louisiana. White cells indicate the life stage/activity is generally not present, light grey cells indicate the life stage is at moderate abundance, dark grey cells indicate high abundance.

The habitat suitability index (HSI) model was developed through identification of variables important to pelican nest site use (Table 1). Sources include the literature reviews of Hingtgen et al. (1985) and Shields (2002), referencing more recent literature focused on the Louisiana coast and surrounding areas as appropriate.

All pelican nest sites in Louisiana occur on islands that are largely surrounded by brackish to saline conditions (Visser et al., 2005). No islands surrounded by water with lower salinities are reported to be used by the species (Louisiana Department of Wildlife and Fisheries [LDWF], Natural Heritage Database).

As island area and proximity to the mainland increases, populations of mammalian predators increase (Hingtgen et al., 1985). Islands with mammalian predators are not likely to be used by pelicans as nesting habitat, so small isolated islands are the most common sites for pelican colonies (Visser et al., 2005). Although brown pelicans frequently forage in the vicinity of marinas and fishing boats, they seek nesting sites with little or no human disturbance (Hingtgen et al., 1985).

Nests that are placed 2-2.5 meters high in shrubs and woody vegetation have greater success than nests closer to the ground, which are more likely to flood (Walter et al., 2013b). Islands where the primary nesting habitat is black mangrove are more resilient to the effects of hurricanes than islands with other vegetative cover (Walter et al., 2013b). Nest site choice and nest survival is influence by elevation above mean high tide (Hingtgen et al., 1985; Visser et al., 2005; Walter et al., 2013b). On islands that are greater than 2 meters above high tide, bare ground with little vegetation can be a preferred nest site (Robinson & Dindo, 2011).

Proximity to productive foraging grounds is also important to nesting success. In Louisiana and Texas, over 90% of the pelican's diet is menhaden (*Brevoortia* spp.), although mullet (*Mugil* spp.) can also be important (Shields, 2002). In California, foraging during nesting season mostly occurs within 20 km of nest sites, although distances as great as 45 km have been reported (Hingtgen et al., 1985). Recently, Walter et al. (2014b) used GPS transmitters to obtain detailed information on movements of adult pelicans during the nesting season. This information should provide better estimates of foraging patterns than previously available.

Table 1: Habitat Requirements for Brown Pelican Nesting Sites Used in the HSI Model.

Characteristic	Optimum	Suboptimum
Island area[1]	25 to 180 ha	<25 or >180 ha
Island distance from larger areas of land[1]	>0.4 km	< 0.4 km
Vegetation[1]	Black Mangrove	Other vegetation
Distance from human activity center[1]	>0.4 km	0.1 to 0.4 km
Distance from concentrations of Menhaden and mullet[2]	<20 km	20 km to 45 km
Dominant habitat type[3]	Saline emergent Marsh type	Other habitats

[1] Optimum and suboptimum habitats are generally based on Hingtgen et al., 1985. These estimates can be improved upon using data from Visser et al., 2005; Robinson and Dindo, 2011; Walter et al., 2013a, b, c, and data from the LDWF Natural Heritage Database.

[2] Based on summaries of diets and flight distances of foraging pelicans in Hingtgen et al., 1985 (based on California data).

[3] Visser et al., 2005; King et al., 2013

2.0 Approach

This is a new HSI model developed for use in the 2017 Coastal Master Plan. There is an existing HSI model for the species (Hingtgen et al., 1985); however, many of the required inputs do not align well with those available from the master plan models. There are six variables in the current model.

Variables were selected as a result of a literature review. In addition, unpublished data collected by the author's students and collaborators were used to refine the model. Standard approaches for designing HSI models were used.

Habitat characteristics were assigned suitability index (SI) values between 0 and 1; with a value of 1 being assigned to the most preferred habitat state (USFWS, 1981). Quantitative measures of habitat use for an environmental variable were divided by the value for the variable state that had the highest value. This placed all the values of the variable on a scale from 0 to 1. Additional procedures are discussed for the individual variables. The HSI index values were obtained by taking the geometric means of the suitability indices of the individual variables (USFWS, 1981).

To validate the model, outputs from the 2012 Coastal Master Plan models, generated with the software EverView, were obtained for sites where the author has made field observations suggesting the species was common, uncommon, or absent. Outputs were applied to the habitat suitability model, and the HSI estimates were compared to the authors' field observations. In general, there was strong correspondence between observations of pelican nesting activity and the HSI estimates.

3.0 Habitat Suitability Index Model for Brown Pelican

The overall equation for the brown pelican HSI model is the geometric mean of six suitability variables, each scaled from 0–1, where 1 is the most suitable (Table 1). Solving the HSI equation produces a value that is between 0 and 1 that represents the total suitability of a model cell.

$HSI = (SI_1 \times SI_2 \times SI_3 \times SI_4 \times SI_5 \times SI_6)^{1/6}$

Where:
SI_1 = Island area (V_1)

SI_2 = Island distance to the mainland or large islands (V_2)

SI_3 = Abundance of the shrubs black mangrove and marsh elder (V_3)

SI_4 = Distance from any center of human activity (V_4)

SI_5 = Availability of high quality, nearby menhaden habitat (V_5).

SI_6 = Dominant (most common) vegetation (V_6).

3.1 Applicability of the Model

This model applies to adult brown pelicans nesting in coastal Louisiana. Chick survival is, of course, directly associated with adult nest success. The model focuses on nesting habitat, because although pelicans forage throughout much of coastal Louisiana (Walter et al., 2014b), nesting habitat is restricted to relatively few sites (Visser et al., 2005; Walter et al., 2013b) and thus likely to limit the population (Hingtgen et al., 1985).

3.2 Response and Input Variables

V_1: Area of island including the cell of interest

Variable 1 (V_1) is the total land area, in hectares (ha), of small islands to which the focal cell (the cell to which a value is being assigned) is contiguous and contributes to the total land area of the island (Figure 2). To be classified as a small island, the total land area in the contiguous cells must be ≤200 ha, and the cells comprising the land area of the island must be surrounded on all edges by cells that are 100% open water. This variable should be calculated yearly.

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

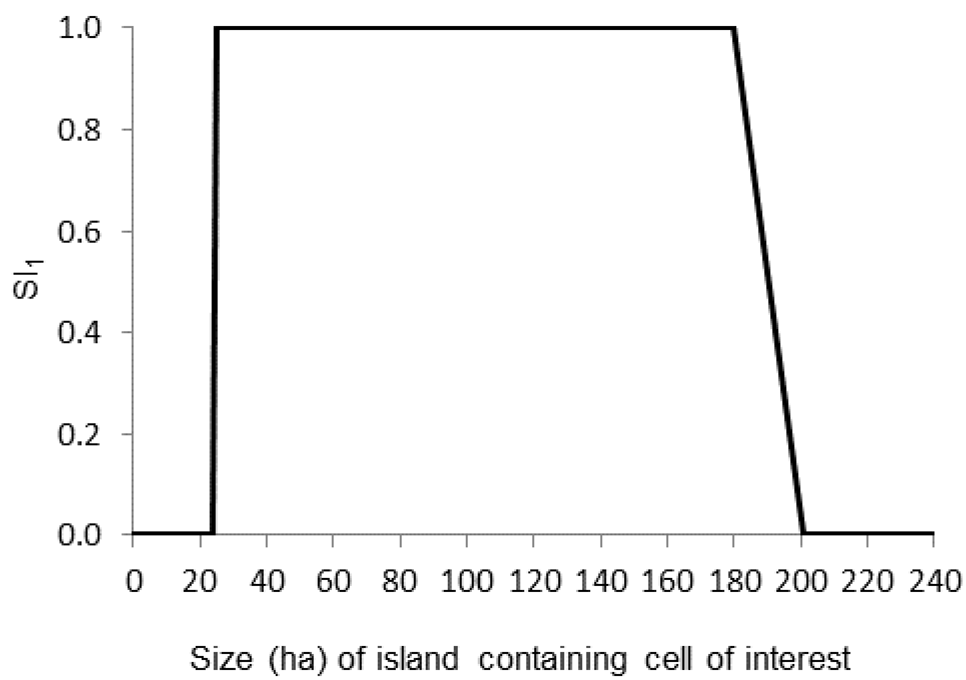

Figure 2: Relationship of Island Size with its Value as Pelican Nesting Habitat (SI_1).

Rationale: Brown pelicans nest on coastal islands (Visser et al., 2005, Walter et al., 2013a, b). Hingtgen et al. (1985), based on a survey of literature from across the Southeast, proposed that to be optimal pelican habitat, islands had to be smaller than 8 ha as larger islands were likely to have predators. Furthermore, Hingtgen et al. (1985) reasoned that islands smaller than 2 ha could not support enough nests for this social species to successfully nest. Visser et al. (2005) documented nesting colonies on islands between 10 and 70 ha in Louisiana. More recently, pelicans have been observed nesting on islands in Louisiana between 0.5 ha and 89 ha (Selman et al., 2012; Leberg, unpublished data). Based on these studies and the results from the first version of the brown pelican HSI model (see Section 4.0 - Model Verification and Future Improvements), the range of island area considered to be useful as a nesting colony was set to 25-180 ha = optimal habitat, with declining habitat value of islands up to 200 ha (Figure 2).

V_2: Minimum distance of an island to the mainland or a large island

Variable 2 (V_2) is the minimum distance from the center of any of the contiguous cells comprising the small island, including the focal cell, to the center of any cell containing land that does not meet the definition of a small island established in the description of V_1 (Figure 3).

SI_2 =	0.0	for $V_2 < 1.0$ km
	$(0.5 * V_2) – 0.5$	for $1.0 \leq V_2 < 3.0$
	1.0	for $V_2 \geq 3.0$ km

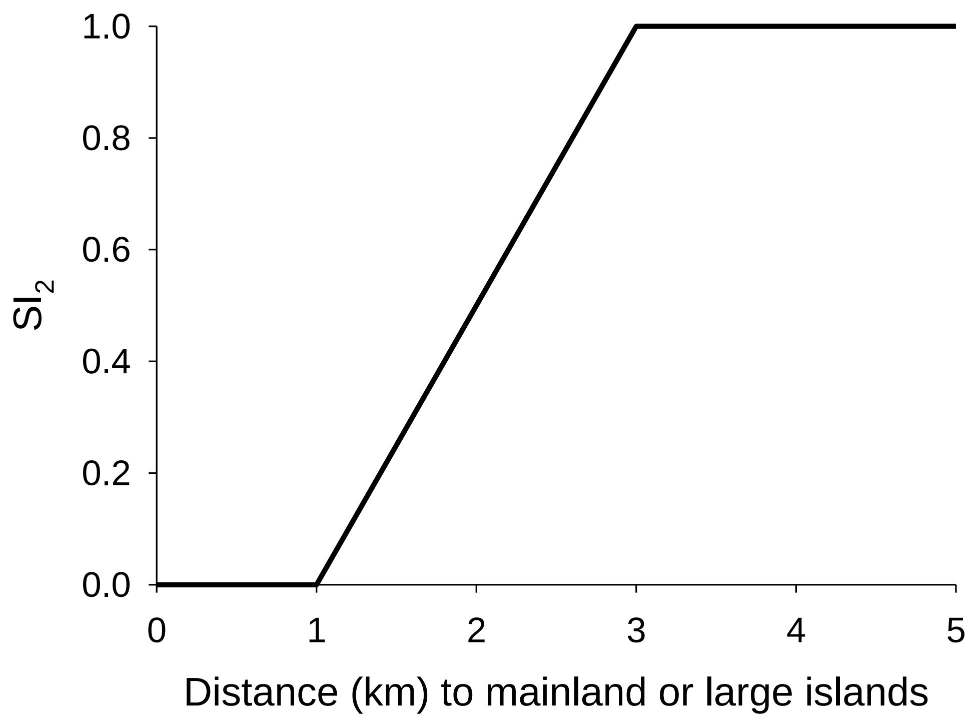

Figure 3: Relationship Between a Cell's Suitably as Potential Pelican Nesting Habitat with Distance from the Mainland or Large Islands.

Rationale: Islands used by nesting brown pelicans tend to be isolated from the mainland and other coastal islands (Visser et al., 2005). Clearly the closer islands are to mainland or large islands capable of supporting predator populations, the more likely the colony sites will be colonized by predators. Hingtgen et al. (1985), based on a review of the literature from throughout the Southeast, proposed that to be optimal pelican habitat islands should be at least 0.4 km from the mainland with decreasing habitat value at shorter distances, but provided no empirical justifications for those choices of values. Visser et al. (2005), studying Louisiana colonies, found that pelican colonies did not nest on islands closer than 7 km from the mainland and 0.3 km from other islands (but did not provide information on the size of those islands). The author is aware of at least two breeding colonies occurring as close as 1.3-1.5 km to the mainland or a much larger island in Louisiana, so pelicans can sometimes nest on such islands. The author and colleagues also have observed predators being able to recolonize islands < 2-3 km from the mainland relatively rapidly after being removed by hurricanes. Based on these observations, small islands occurring at distances beyond 3 km to the mainland or large islands were assigned values of 1 = optimal habitat (Figure 3). A linear function of decreasing habitat value was established for small islands located 1 to 3 km from larger islands or the mainland. A value of 0 was assigned to small islands located within 1 km of mainland or large islands.

V_3: Proportion of a cell containing high quality nesting habitat with the shrubs black mangrove *Avicennia germinans*, and marsh elder, *Iva frutescens*.

Variable 3 (V_3) is the proportion of the cell that is composed of the combination of black mangrove and marsh elder. This variable should be calculated yearly (Figure 4).

$$SI_3 = \begin{cases} 0.2 & \text{for } V_3 = 0.0 \\ (1.6 * V_3) + 0.2 & \text{for } 0.0 < V_3 < 0.5 \\ 1.0 & \text{for } V_3 \geq 0.5 \end{cases}$$

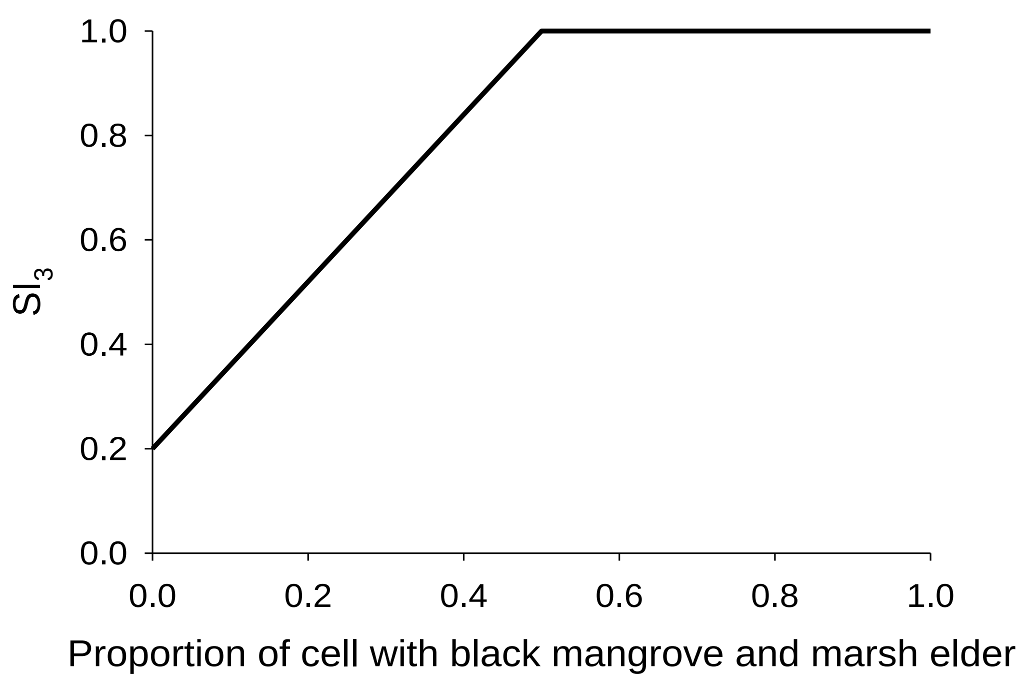

Figure 4: Relationship of a Site's Suitability as Potential Pelican Nesting Habitat with the Availability of the Shrubs Black Mangrove and Marsh Elder.

Rationale: Brown pelicans studied in Louisiana prefer nesting in mangrove and marsh elder, and nest success in these shrubs is higher than in grassy vegetation or on bare ground (Walter et al., 2013b). It is believed that nesting in shrubs is preferred as it minimizes loss of nests during over-wash events. Hingtgen et al. (1985), based on a review of the literature from throughout the Southeast, proposed that optimal pelican habitat had shrub coverage of greater than 50%, with decreasing habitat value for lower percentages of shrub coverage. Although Walter et al. (2013b) documented decreasing nest success with proximity to the ground, they did document some successful nesting on the ground. Furthermore, there are sites in Louisiana where pelicans nested in the absence of woody vegetation and at least some nests produced chicks (Walter et al., 2013b; Leberg, unpublished data). Therefore, the Hingtgen model was modified to include marsh elder, and allow for sites without woody vegetation to have small, but positive contributions as pelican nesting habitat (Figure 4).

V_4: Straight-line distance (in km) from any center of human activity (homes, businesses, oil field production facilities, roads, piers, etc.)

Variable 4 (V_4) is the minimum straight-line distance (in km) from the edge of any center of human activity to the edge of any of the cells forming the island that contains the cell of interest (Figure 5). This variable should be calculated yearly.

SI_4 =	0.0	for $V_4 < 0.1$ km
	$(3.33 * V_4) - 0.33$	for $0.1 \leq V_4 < 0.4$
	1.0	for $V_4 \geq 0.4$ km

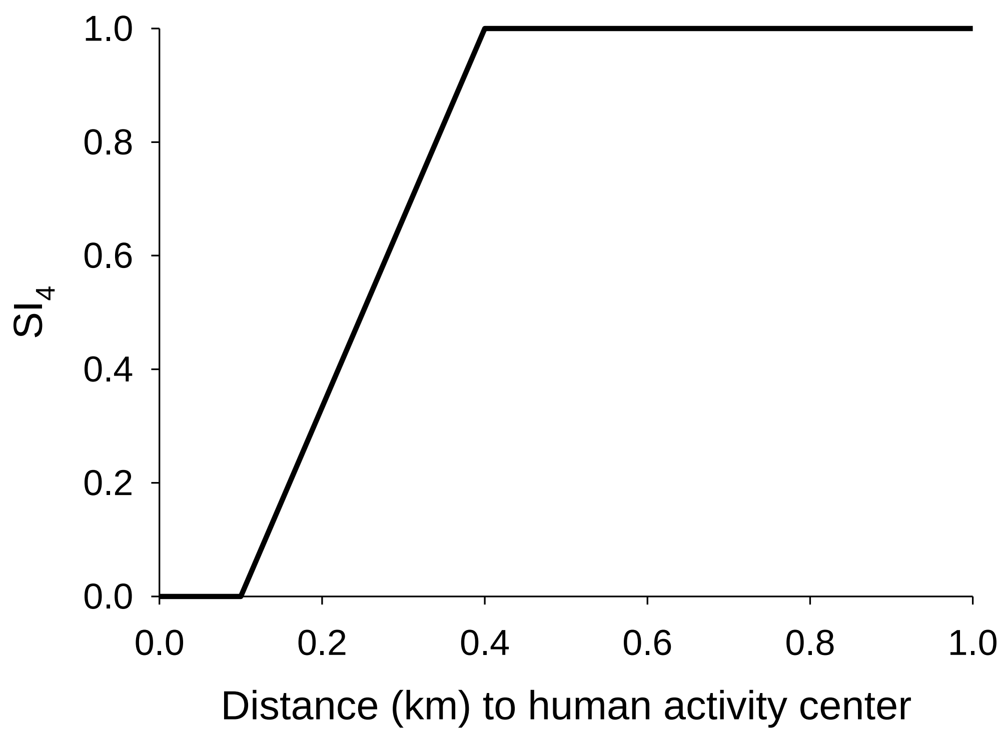

Figure 5: Relationship Between Pelican Habitat Suitability (SI_4) and the Minimum Distance to Human Activity.

Rationale: Pelican nest success and use of colony sites decreases with proximity to humans (Hingtgen et al., 1985); much of this relationship appears to be due to human disturbance of nesting birds. Based on a review of the literature from Florida and California, Hingtgen et al. (1985) proposed that optimal pelican nesting habitat is greater than 0.4 km from human activity centers and that sites less than 0.1 km from humans would not be used (Figure 5). None of the studies conducted in Louisiana have examined human activity on nesting; however, none of the known pelican colonies are near centers of human activity.

There is probably some variation in the relationship proposed by Hingtgen et al. (1985), based upon the level of human activity. Pelicans in Louisiana are known to tolerate some human activity, such as the presence of researchers and fishermen. Thus, a measure of relative human activity would improve the model. Furthermore, available measures of human activity are also relatively static, as the master plan makes no attempt at modeling the relocation of piers, roads, and oil production activities.

V_5: Average menhaden habitat suitability index of the cells within a 20 km radius of a cell where $V_1 > 0$

Variable 5 (V_5) is the average adult Gulf menhaden habitat suitability index of the cells within a 20 km radius of a cell where $V_1 > 0$ (Figure 6). This variable should be calculated yearly.

$SI_5 =$	$1.667*V_5$	for $V_5 < 0.60$
	1.0	for $V_5 \geq 0.60$

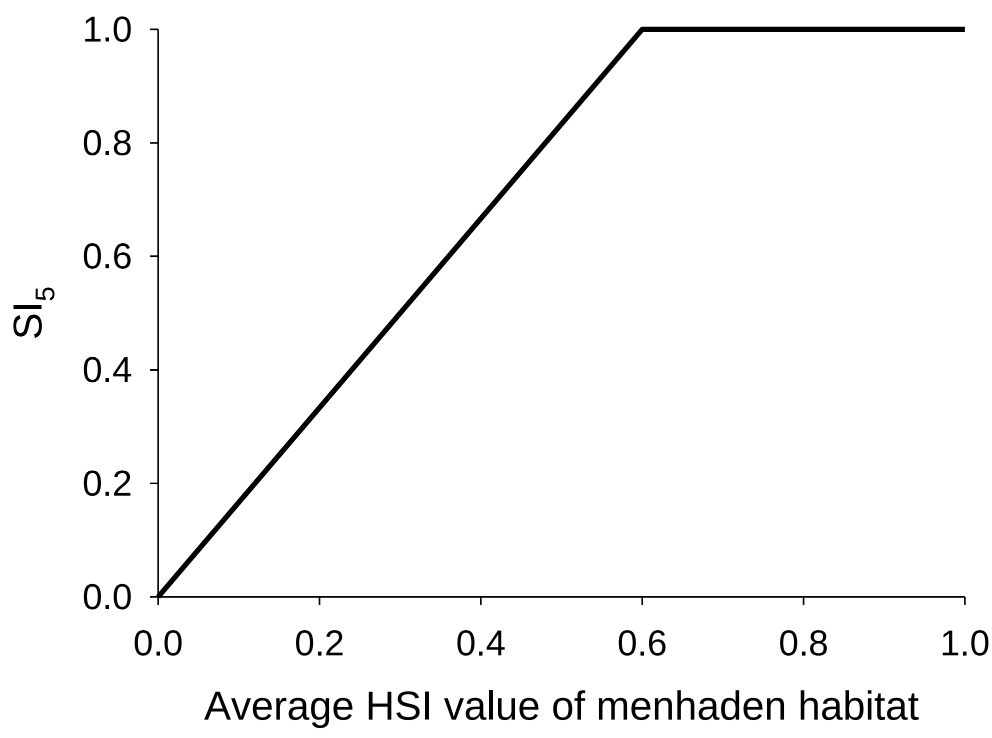

Figure 6: Suitability (SI_5) of Nesting Habitat for Pelicans Based on the Availability of Habitat for Menhaden.

Rationale: Brown pelicans in Louisiana and Texas forage almost entirely on menhaden (Shields, 2002). Although pelicans will forage at great distances from nest sites (Hingtgen et al., 1985), most birds forage within 20 km of nesting habitat. Furthermore, using GPS telemetry in Louisiana and Alabama, Walter et al. (2014b) found that birds in reduced body condition are more likely than birds in good condition to fly great distances from nest site. This result is suggestive of competition for food near colonies, with birds in poorer condition being forced to forage at less desirable sites. Given these studies, it is reasonable that areas with high average values of menhaden habitat will be most likely to provide the resources necessary to support a large pelican colony. As a first approximation of this relationship, when the average HSI for menhaden for cells in 20 km radius of a cell is $\geq$ 0.6, SI_5 is set at 1.0 = optimal foraging habitat. The value of SI_5 decreases to 0 with reduced availability of menhaden habitat.

V_6: Dominant emergent wetland vegetation type in cell

Variable 6 (V_6) is the dominant (most common) vegetation type in the cell (Figure 7). This variable should be calculated yearly.

SI_6 = 1.00 for V_6 = Saline Marsh
0.00 for V_6 = Any other habitat

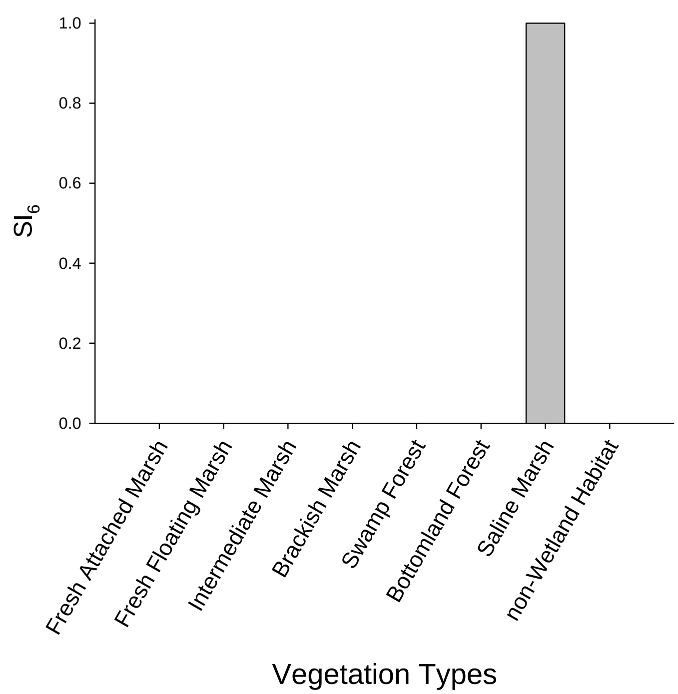

Figure 7: Relative Values (SI_6) of Different Dominant Emergent Vegetation Types as Nesting Habitat for Brown Pelicans.

Rationale: The strong affinity of pelicans for nesting in coastal habitats is well established (Hingtgen et al., 1985; Shields, 2002). Based on the LDWF Natural Heritage dataset and personal observations by the author and his collaborators, all of the pelican colonies located in Louisiana and the rest of the northern gulf coast are located on islands with saline marsh plant associations. Therefore, saline marsh was assigned a value of 1.0 = optimal habitat with other wetland plant associations assigned values of 0.0 (Figure 7).

4.0 Model Verification and Future Improvements

To help ensure the distributions and patterns of HSI scores across were realistic relative to current knowledge of the distribution of brown pelicans, a verification exercise was conducted. In order to generate HSI scores across the coast, the HSI models were run using calibrated and validated Integrated Compartment Model (ICM) spin-up data to produce a single value per ICM grid cell. Given the nature of a coast wide model, the ICM spin-up data may not reflect 'real-world' conditions in all areas of the coast. For example, some areas known to have wetland vegetation were classified as non-wetland habitat resulting in low HSI scores when high scores would otherwise be expected. In these instances, no improvements could be made to the HSI as these issues reside in other ICM subroutines (i.e., vegetation). As a result, the accuracy of the verification exercise is contingent on these inconsistencies.

In general, cells on islands that either currently serve as pelican nest colonies, or which could serve as colonies based on their habitat structure, had high HSI values in the verification exercise. As expected, inland sites typically had HSI values of zero. However, a number of cells near the land-water interface along the gulf unexpectedly had intermediate HSI values, when such sites do not usually support pelican nesting colonies. The first version of the pelican HSI model, which was used for the verification exercise and for subsequent project-level analyses, was programmed such that islands were defined as ICM grid cells surrounded on all sides by open water based on the 30 m x 30 m resolution of the Wetland Morphology subroutine. Because of this, many small groups of cells near the land-water interface received a higher value for SI_1 than was justified and the amount of suitable pelican habitat was overestimated. To address this concern, the equation for SI_1 was adjusted to exclude islands smaller than 25 ha (i.e., the 500 m x 500 m resolution of the Vegetation subroutine). The SI_1 equation was also adjusted to increase the maximum island area considered to be optimum for pelican nesting to 180 ha (rather than the previous maximum of 80 ha), to better match the model's ability to identify suitable pelican nesting habitat with field observations of pelican nesting colonies. The resulting second version of the pelican HSI model was then used for alternative-level analyses.

The model may be further improved by additional information on the factors affecting selection of nesting habitats. Although pelicans always nest on small islands in coastal Louisiana there is a nearby case where a successful pelican colony is located on a much larger island (Gaillard Island, Alabama = 526 ha). It is possible that given specific conditions such as those on Gaillard, other larger islands might be successful. However, Gaillard Island is so different from any island in Louisiana (a large, rocky structure with only small patches of vegetation) it might be uninformative to the situation in Louisiana. From the perspective of pelicans and their mammalian predators, Gaillard Island might not provide any more habitat than its small areas covered with vegetation (< 100 ha in total). However, this hypothesis needs to be investigated.

With data available for only a small number of islands used by pelicans, and almost no assessment of islands not used by them, it is not yet possible to design a function related to island distance from the mainland with a high degree of confidence. It is also likely that island size interacts with distance in determining predator colonization dynamics (island biogeographical theory predicts large islands may be colonized from greater distances than smaller islands); however, currently there is insufficient understanding to build that relationship into an SI.

Although the importance of Gulf menhaden as a food source for pelicans is well established, how the spatial distribution of menhaden abundance affects the success of nearby nesting colonies is not known. Therefore, studies of the effects of food resources are recommended, especially in relation to the hypoxic areas in coastal Louisiana.

Additional studies of the influence of vegetation type on nest success are also recommended. Estimates of the effects of vegetation height and type on pelican nest success are limited to only two barrier islands in Louisiana. It is likely that these relationships are affected in unknown ways by the presence of nest predators, something that cannot be included directly into the current model.

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