Model Name: Nature Based Tourism

Functional Area: Ecosystem Service

Model Proponents: Coastal Protection and Restoration Authority

Model Developer(s): Denise Reed, University of New Orleans

Please note this is a working-draft document currently undergoing review and revision. The final version will be posted in March 2012 along with the final version of the 2012 Coastal Master Plan.

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1. *Background*

a. Purpose of Model

The Nature Based Tourism model was based on the concept of habitat suitability index (HSI) models. Through internal discussion among the model developers, modeling efforts were focused on areas that are near tourist areas such as major population centers or other points of interest across the coast.

b. Model Description and Depiction

The Nature Based Tourism Suitability Index (SI) is intended to consider the potential effect of a project in providing habitat suitable for nature based tourism. It is based on 500 x 500m model grid cells and is calculated on a 10 year time step. The model combines distance from major population centers (areas with populations > 50,000), distance from points of interest, land cover type, distance to beaches, barrier island percent land, type of beach polygon, and quantity and quality of alligator, river otter, muskrat, roseate spoonbill, gadwall, green-winged teal, mottled duck, and neotropical migrant habitat inputs to produce a suitability index for nature based tourism ranging from 0.0 to 1.0.

c. Contribution to Planning Effort

The model provides a 50-year prediction of habitat suitable for coastal species associated with nature based tourism in Louisiana.

d. Description of Input Data

Data used as input are distance from major population centers (mi), distance from points of interest (mi), land cover type, distance to beaches (mi), barrier island percent land, type of beach polygon, and quantity and quality of alligator, river otter, muskrat, roseate spoonbill, gadwall, green-winged teal, mottled duck, and neotropical migrant habitat. Barrier island percent land and all habitat quantity and quality inputs are output data from other 2012 Coastal Master Plan models. The land cover type, distance from major population centers, points of interest, and beaches, and type of beach polygon inputs are calculated using GIS shapefiles.

e. Description of Output Data

The output data is a suitability index ranging from 0.0 to 1.0 that represents the potential of a 500 x 500m model grid cell to provide suitable habitat for nature based tourism. A value of 1.0 indicates the greatest potential for nature based tourism.

f. Statement on the capabilities and limitations of the model

The model is capable of determining the potential of each 500mX500m model grid cell to provide suitable habitat for species associated with nature based tourism in order to evaluate the differences between proposed projects.

The model is limited by its focus on only a few animal species, and it does not account for communities with less than 50,000 people. The list of points of interest may not include all areas that would bring tourists to Louisiana. It is not intended to be a comprehensive quantitative model, but rather a broad planning-level model capable of predicting areas that have nature based tourism potential.

g. Description of model development process including documentation on testing conducted

The model focuses on nature based tourism in areas that are near tourist areas such as major population centers or other points of interest. Therefore, distance factors were included in the model with wetlands closer to populated areas or points of interest given higher scores. Since habitat type (e.g., swamps) can play a major role in nature based tourism, land cover type was also considered. Beach activity was also considered a type of nature based tourism, but in Louisiana, beaches are often small and remote, so distance, accessibility, and size factors were included. Wildlife habitat was also included for the charismatic fauna common in south Louisiana. Each of these factors was developed as an individual suitability index, and formed into coastal location, flora, beach access, and fauna component indices (CI) through arithmetic and geometric means. The component indices were combined arithmetically and geometrically to give a nature based tourism suitability index.

2. Technical Quality

a. Theory

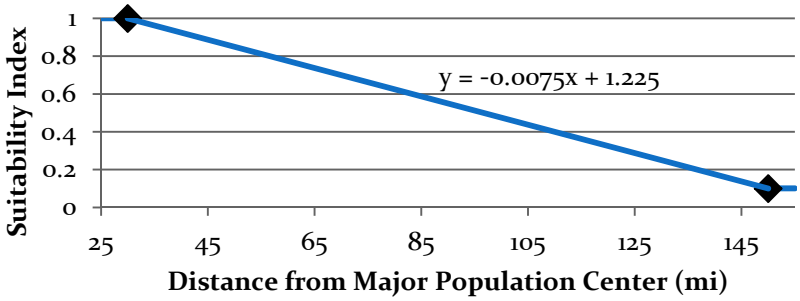
This model was developed in a similar style to habitat suitability indices. The following factors are included in the Nature Based Tourism SI Model:

SI_1 - Suitability Index for Distance from Major Population Center

Major population centers (MPC, communities with populations > 50,000) represent source areas for tourism, either due to the activities of the residents or as entry points for out of region tourists. The distance of areas of nature based tourism from these MPCs can directly influence their use. Areas of nature based tourism less than 30 mi from an MPC get an SI of 1.0. Those that are more than 150 mi receive an SI of 0.1. SI values for nature based tourism regions that are located between 30 and 150 mi are scaled linearly by the equation $SI_1 = (-0.0075 * V_1) + 1.225$.

V_1 = Distance from a major population center (mi)

$$SI_1 = \begin{cases} 1.0 & \text{for } V_1 < 30 \\ (-0.0075 * V_1) + 1.225 & \text{for } 30 \le V_1 < 150 \\ 0.1 & \text{for } V_1 \ge 150 \end{cases}$$



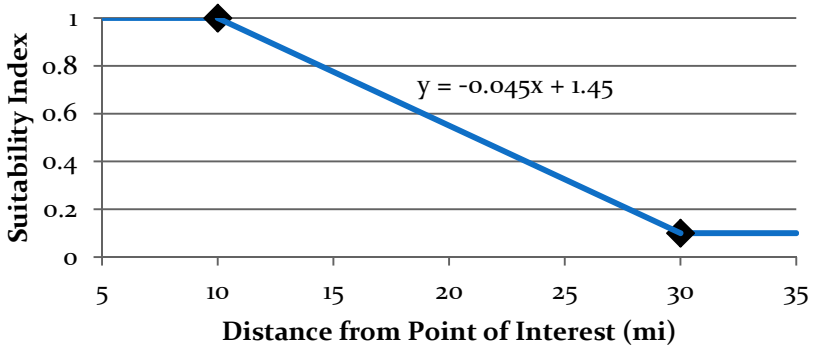
SI_2 - Suitability Index for Distance from Points of Interest

Points of Interest (POI) are other attractions which may bring tourists to the region. A few examples of POIs are Atchafalaya National Heritage Area, Thibodaux, Barataria Preserve, Chalmette Battlefield, Grand Isle State Park, Tickfaw State Park, Cameron Prairie National Wildlife Refuge, Mandalay National Wildlife Refuge, Rockefeller State Wildlife Refuge and Game

Preserve, Sabine National Wildlife Refuge, Bayou Segnette State Park, St. Bernard State Park, Big Branch National Wildlife Refuge, Fontainebleau State Park, Woodlands Trail and Park, Creole Nature Trail All-American Road, Pointe-Aux-Chenes Wildlife Management Area, and Wetlands Acadian Cultural Center. Similar to MPCs, the proximity of an area of nature based tourism to POI directly affects its use. Nature based tourism areas within 10 mi of POI are given an SI of 1.0. Those further than 30 mi receive an SI of 0.1. Areas between 10 and 30 mi are scaled linearly with the equation $SI_2 = (-0.045 * V_2) + 1.45$.

V_2 = Distance from points of interest (mi)

$SI_2 =$	1.0	for $V_2 \leq 10$
	$(-0.045 * V_2) + 1.45$	for $10 < V_2 \leq 30$
	0.1	for $V_2 > 30$



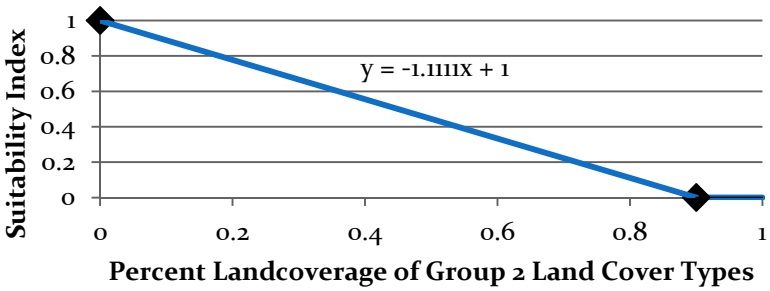
SI_3 - Suitability Index for Land Cover Type

The nature based tourism industry is dependent on the natural environment therefore some consideration of the land cover is essential. This variable uses percent cover information from the vegetation model land cover types. The types are grouped according to their value for nature based tourism. Values assume developed lands, uplands, spoil banks, and non-beach bare ground (default habitat type if total land cover < 100% for all other classes) have no ecotourism value (Group 2). All other land cover types are assumed to be desirable (Group 1). Calculations are based on percent land coverage of undesirable Group 2 land cover types. If Group 2 land cover types make up 0.0% of a 500 X 500 m model grid cell, then an SI of 1.0 is assigned. When Group 2 makes up 90% or more of a cell then it receives an SI of 0.0. All other conditions are calculated linearly with the equation $SI_3 = (-1.1111 * V_3) + 1.0$.

$SI_3 =$	1.0	for $V_3 = 0.0$
	$(-1.1111 * V_3) + 1.0$	for $0.0 < V_3 \leq 0.90$
	0.0	for $V_3 > 0.90$

Group 1	Group 2
• Wax Myrtle (*Morella cerifera*) • Cut-grass (*Zizaniopsis miliacea*) • Maidencane (*Panicum hemitomon*) • Cattail (*Typha domingensis*) • Sawgrass (*Cladium jamaicense*) • Bulltongue (*Sagittaria lancifolia*)	• Spoil Bank • Agriculture • Developed • Non-Beach Bare Ground

• Roseau cane (*Phragmites australis*) • Bullwhip (*Schoenoplectus californicus*) • Wiregrass (*Spartina patens*) • Paspalum (*Paspalum vaginatum*) • Needlegrass (*Juncus roemerianus*) • Oystergrass (*Spartina alterniflora*) • Black Mangrove (*Avicennia germinans*) • Delta Splay (composed of *Sagittaria latifolia*, *Schoenoplectus deltarum* and *Colocasia esculenta*) • Thin-mat (composed of *Eleocharis baldwinii*, *Hydrocotyle umbellata*, *Bidens laevis*) • Swamp Forest (composed of *Taxodium distichum* and *Nyssa aquatica*) • Shrub-scrub (composed of *Iva frutescens* and *Baccharis halmifolia*) • Brackish Marsh (composed of *Spartina patens*, *Distichlis spicata* and *Spartina alterniflora*) • SAV (Open water with SAV) • Open Water (Open water without SAV) • Non-Swamp Forested	

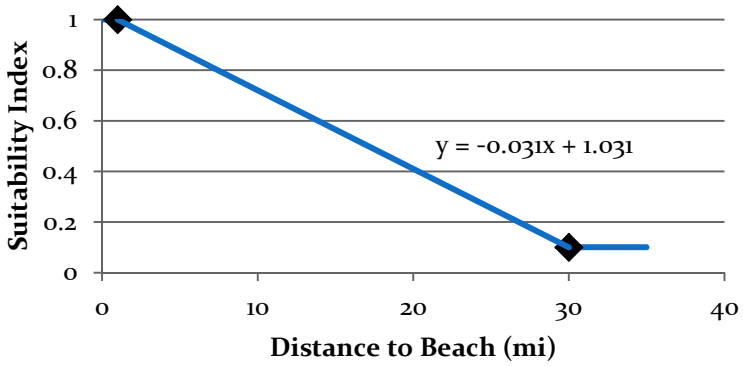


SI_4 - Suitability Index for Distance to Beaches

Beach activities were also included in the nature based tourism ecosystem service. While much of Louisiana's coast is wetlands, it does include some sandy beach habitat. Just as with other nature based tourism operations, the location of Louisiana beaches in relation to MPCs or POI can directly affect their utilization. The location of a beach is designated according to "polygons" within which barrier shorelines migrate during the period of analysis. Beach polygons that are within 1.0 mi of MPCs or POI are given an SI of 1.0. Those that are more than 30 mi from MPCs or POI receive an SI of 0.1. Polygons between 1.0 and 30 mi are calculated on a linear line with the equation $SI_4 = (-0.031 * V_4) + 1.031$.

V_4 = Distance to beaches (mi)

SI_4 =	1.0	for $V_4 < 1.0$
	$(-0.031 * V_4) + 1.031$	for $1.0 \leq V_4 \leq 30$
	0.1	for $V_4 > 30$

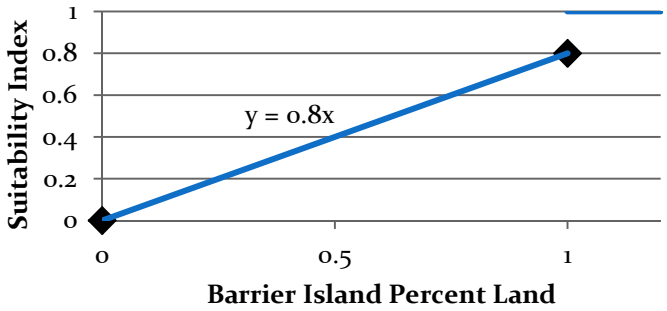


SI_5 - Suitability Index for Barrier Island Percent Land

Beach size is considered in the Master Plan modeling effort since it can be directly related to its usefulness for recreation. Since many of Louisiana's beaches occur on barrier islands and no direct measurements of beach size exists, the percent land of barrier islands is used as a proxy. This variable compares barrier island percent land to that of model year 0. Increases in barrier island percent land are optimal (SI = 1.0). If percent land shows no change it receives an SI of 0.8. Decreases in barrier island percent land follows the linear formula $SI_5 = (0.8 * V_5)$. If no land exists it is assigned an SI of 0.0. Changes in percent land are expressed as a decimal.

V_5 = Barrier island percent land (change from year 0)

SI_5 =	1.0	for $V_5 > 1.0$
	0.8	for $V_5 = 1.0$
	$(0.8 * V_5)$	for $0.0 < V_5 < 1.0$
	0.0	for $V_5 = 0.0$

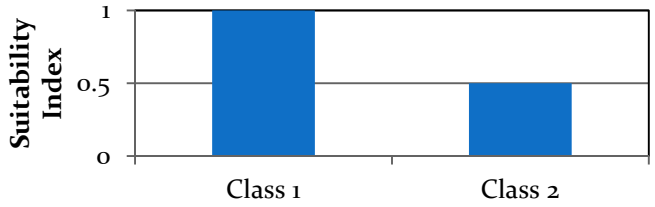


SI_6 - Suitability Index for Type of Beach Polygon

In Louisiana, the accessibility of beaches is an important issue in determining its usefulness for nature based tourism. Much of Louisiana's coast is remote and only accessible by boat. Therefore, consideration of this fact is achieved by classifying beach polygons according to the type of access currently available. Type of beach polygon: Class 1 (road access), Class 2 (boat access only).

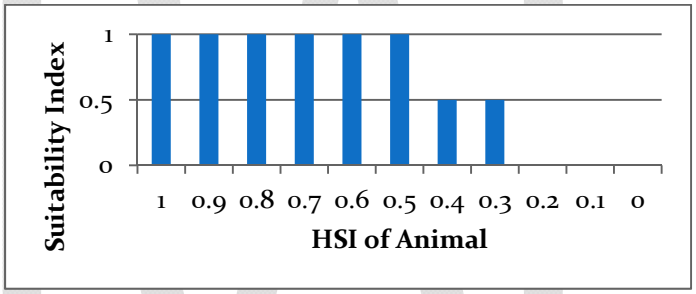
V_6 = Type of beach polygon

SI_6 =	1.0	for V_6 = Class 1
	0.5	for V_6 = Class 2



Suitability Indices for Quantity and Quality of Habitat (HSI) Factors SI_7 to SI_{14}

The fauna found within Louisiana coastal zones are vital to the nature based tourism industry. For many tour operations, the animals are the main attraction. Therefore suitability indices SI_7 to SI_{14} address the suitability of habitat for charismatic species throughout the coast. Animal species were selected from the available upper trophic level suitability index models. For all of the animal species, an HSI of 0.5 or greater (assigned by the species-specific ecosystem service models) is assumed to be quality habitat and receives an SI of 1.0. For HSIs between 0.5 and 0.25, an SI of 0.5 is assigned. An SI of 0.0 is given to HSI scores less than 0.25. The relationship of the species' HSI scores to the SI is illustrated here for all of these species.



SI_7 - Suitability Index for Quantity and Quality of Alligator Habitat

V_7 = Alligator HSI

SI_7 = 1.0 for $V_7 \geq 0.5$
0.5 for $0.25 \leq V_7 < 0.5$
0.0 for $V_7 < 0.25$

SI_8 – Suitability Index for Quantity and Quality of River Otter Habitat

V_8 = River Otter HSI

SI_8 = 1.0 for $V_8 \geq 0.5$
0.5 for $0.25 \leq V_8 < 0.5$
0.0 for $V_8 < 0.25$

SI_9 – Suitability Index for Quantity and Quality of Muskrat Habitat

V_9 = Muskrat HSI

SI_9 = 1.0 for $V_9 \geq 0.5$
0.5 for $0.25 \leq V_9 < 0.5$
0.0 for $V_9 < 0.25$

SI_{10} – Suitability Index for Quantity and Quality of Roseate Spoonbill Habitat

V_{10} = Roseate Spoonbill HSI

SI_{10} = 1.0 for $V_{10} \geq 0.5$
0.5 for $0.25 \leq V_{10} < 0.5$
0.0 for $V_{10} < 0.25$

SI_{11} - Suitability Index for Quantity and Quality of Gadwall Habitat (HSI)

V_{11} = Gadwall HSI

SI_{11} = 1.0 for $V_{11} \geq 0.5$
0.5 for $0.25 \leq V_{11} < 0.5$
0.0 for $V_{11} < 0.25$

SI_{12} - Suitability Index for Quantity and Quality of Green-Winged Teal Habitat

V_{12} = Green-Winged Teal HSI

SI_{12} = 1.0 for $V_{12} \geq 0.5$
0.5 for $0.25 \leq V_{12} < 0.5$
0.0 for $V_{12} < 0.25$

SI_{13} - Suitability Index for Quantity and Quality of Mottled Duck Habitat

V_{13} = Mottled Duck HSI

SI_{13} = 1.0 for $V_{13} \geq 0.5$
0.5 for $0.25 \leq V_{13} < 0.5$
0.0 for $V_{13} < 0.25$

SI_{14} - Suitability Index for Quantity and Quality of Neotropical Migrant Habitat

V_{14} = Neotropical Migrant HSI

SI_{14} = 1.0 for $V_{14} \geq 0.5$
0.5 for $0.25 \leq V_{14} < 0.5$
0.0 for $V_{14} < 0.25$

Component Equations for Nature Based Tourism SI

The calculation of the nature based tourism SI is based on the combination of several component indices (CIs), Coastal Location, Flora, Beach Access, and Fauna. The CI for Coastal Location is an arithmetic mean since the distance from either an MPC or POI is important. The CI for Flora is based on the type of land cover. The Beach Access CI is a geometric mean of its distance from an MPC or POI, barrier island percent land, and the type of polygon. Since any combination of fauna may be important for nature based tourism, the CI for Fauna is an arithmetic mean of all species.

1. Coastal Location
   $CI_{Location} = (SI_1 + SI_2) / 2$
2. Flora
   $CI_{Flora} = SI_3$
3. Beach Access

$CI_{Beach} = (SI_4 \times SI_5 \times SI_6)^{1/3}$

4. Fauna

$CI_{Fauna} = (SI_7 + SI_8 + SI_9 + SI_{10} + SI_{11} + SI_{12} + SI_{13} + SI_{14}) / 8$

Nature Based Tourism SI

The suitability index for nature based tourism is calculated for two different conditions, with or without beaches. The With-Beach Nature Based Tourism SI is a geometric mean of the Coastal Location CI, and the arithmetic mean of the Flora, Beach, and Fauna CIs. The Non-Beach Nature Based Tourism SI is the geometric mean of the Coastal Location CI and the arithmetic mean of the Flora and Fauna CIs.

With-Beach Nature Based Tourism SI = $(CI_{Location} * ((CI_{Flora} + CI_{Beach} + CI_{Fauna}) / 3))^{1/2}$
Non-Beach Nature Based Tourism SI = $(CI_{Location} * ((CI_{Flora} + CI_{Fauna}) / 2))^{1/2}$

b. Description of system being represented by the model

Nature based tourism is one of the most economically important and publically visible services that the Louisiana coastal ecosystem provides the state. In Louisiana, nature based tourism is a part of a $4.7 billion outdoor recreation industry and employs 48,000 people (Dearmon, 2010). In 2010, Lieutenant Governor Scott Angelle recognized its importance by establishing an NBT program in the Louisiana Office of Tourism (Dearmon, 2010). Known throughout the country as the "Sportsman's Paradise," there are many opportunities for nature based tourism such as hunting, fishing, hiking, biking, wildlife viewing, camping, beach activities, national and state parks, water sports and boating, golf, photography, and visiting historic places and cultural attractions (Louisiana Sea Grant, 2006). Many visitors to Louisiana engage in some form of NBT during their trip. Of those visitors that do engage in nature based tourism, 60.8% reported it as the primary reason for their visit (Louisiana Sea Grant, 2006). This suitability index is calculated for each 500m cell within the master plan analytical area. A total number of Nature Based Tourism Units is calculated based on the sum of SI values for all cells within each vision region.

This model simulates the effects of distance, flora, fauna, and beach activity on the ability of coastal Louisiana to support nature based tourism operations. Each factor is defined as its own suitability index and all of the factors are combined as coastal location, flora, beach access, and fauna component indices through arithmetic and geometric means. The component indices were combined as a nature based tourism suitability index also through arithmetic and geometric means.

c. Analytical requirements

In order to adequately investigate nature based tourism potential of south Louisiana, several key factors were identified: location, land cover type, beach area, beach accessibility, and faunal habitat. These key factors were all included in the modeling effort, and combined depending on their importance to nature based tourism potential. The suitability index for nature based tourism is calculated for two different conditions, with or without beaches. The With-Beach Nature Based Tourism SI is a geometric mean of the Coastal Location CI, and the arithmetic mean of the Flora, Beach, and Fauna CIs. The Non-Beach Nature Based Tourism SI is the geometric mean of the Coastal Location CI and the arithmetic mean of the Flora and Fauna CIs.

d. Assumptions

It is based on the assumption that the service provided is greater for habitats that are closer to population centers (as compared to more distant) or points of interest. It is assumed that the few animal species are representative for those that are important to nature based tourism operations. Additionally, the Nature Based Tourism Suitability Index assumes flora and fauna and beach activity are compensatory.

e. Identification of formulas used in the model and proof that the computations are appropriate and done correctly

The model decision rules that were coded are provided in section 2.a. above. Quality review was performed by both the model coders and CPRA to ensure formulas and computations were correct.

3. System Quality

a. Description and rationale for selection of supporting software tool/programming language and hardware platform

Building on the ecological modeling application development performed for the Everglades modeling community, Java was used as the programming language inside the Eclipse RCP environment which supports plug-in software development. This approach facilitated the construction of software suites which execute the specific decision rules provided by subject matter experts allowing an end-user to choose which of the ecosystem services models to run.

b. Proof that the programming was done correctly

All software products are the result of multiple programmers working in concert. As part of the code development process, code classes are either team developed which ensures multiple individuals real-time code review or when individually coded are spot checked prior to production builds and exports.

c. Availability of software and hardware required by model

The choice of Java as the development platform ensures the broadest execution platform. These software suites can run on desktops with the following operating systems: Windows XP, 7 (32 and 64 bit), Apple OSX (32 and 64 bit), Linux. Furthermore, these Java executables could be easily re-compiled to run on Windows or Linux Application Servers.

d. Description of process used to test and validate model

These models were tested prior to production release with fabricated data built according to the data descriptions provided by the various teams. The absence of “real” data made pre-production testing far less effective than it could have been had there been high quality test data.

Ideally, model outputs would be validated by comparing the model predictions to observations made in the field but that is not possible with this model. The second best validation is based upon comparison of modeled predictions to what is expected given the known inputs. The latter approach was followed and known spatial patterns and temporal patterns were used to predict patterns in nature based tourism potential.

e. Discussion of the ability to import data into other software analysis tools (interoperability issue)

Being standards compliant with international modeling data standards ensures rather broad interoperability. Unidata actively supports netCDF read/write libraries for C++, Java, C# and Fortran programming languages across multiple operating systems. Additionally, netCDF is natively consumable by commercial software product such as ESRI ArcMAP and MatLab. Furthermore, the Everglades Joint Ecologic Modeling community has backed a USGS software development effort resulting in EverVIEW which brings an open-source visualization platform solution to the complex realm of binary modeling data.

4. Usability

a. Availability of input data necessary to support the model

The input files required to run this model are available through the CPRA.

b. Formatting of output in an understandable manner

The output data is a suitability index ranging from 0.0 to 1.0 that represents the nature based tourism of a 500 x 500m model grid cell. The output files are in netCDF format and can be viewed using EverVIEW or ArcGIS.

c. Usefulness of results to support project analysis

In general, this model responds to projects which would result in increases or decreases in habitat suitable for the species that make up the Nature Based Tourism SI as well as projects that are within a certain distance of points of interest and major population centers. Therefore, projects such as barrier island restoration that would increase available beach habitat or marsh creation projects that would increase available habitat for the species in this model would drive changes in model results for a particular area.

d. Ability to export results into project reports

The model output is in netCDF format, which provides both a graphical and tabular representation of the model results that can be incorporated into reports. Model outputs can also be imported into ESRI ArcMap.

e. Training availability

Training for model usage can be provided through CPRA.

f. Users documentation availability and whether it is user friendly and complete

There are currently no user's guides or technical manuals to support the model; however, the model does have a help screen that explains how to convert model inputs into the necessary format as well as which files are necessary to run the model.

g. Technical support availability

Access to technical support can be provided through CPRA.

h. Software/hardware platform availability to all or most users

The ecosystem services modeling suite, being coded in Java, will run on most operating systems.

i. Accessibility of the model
Access to model and associated installation and execution files can be provided through CPRA.

j. Transparency of model and how it allows for easy verification of calculations and outputs
Model decision rules are documented in section 2a. Model HSI values must be between zero and one.

5. Sources of model uncertainty
All relationships in this model are sources of potential uncertainty.

6. Suggested model improvements
The model could be improved by performing additional research or data collection on the relationship of the variables in the suitability indices. In addition, the model could potentially be improved by the adding other contributing variables or additional animal species.

7. Quality review
Specific QR procedures for Nature Based Tourism Model to support the 2012 Coastal Master Plan included comparing modeled predictions with expected outcomes given the known inputs. The modeling team used known spatial patterns and temporal patterns in input to predict patterns in habitat suitable for nature based tourism.

8. Uncertainty analysis
No uncertainty analysis was performed for this model.

9. References
Dearmon, A. 2010. Lieutenant Governor Angelle presents LTCC recovery plan and nature-based tourism program. Louisiana Office of the Lieutenant Governor: 2 pp.

Louisiana Sea Grant. 2006. Louisiana nature-based tourism: an overview. Louisiana Sea Grant College Program: 28 pp.