

**Model Name:** River Otter Habitat Suitability Index

**Functional Area:** Ecosystem Services / Upper Trophic Level

**Model Proponents:** Coastal Protection and Restoration Authority

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**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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**Table of Contents**

**1. Background**..... 4

**a. Purpose of Model** ..... 4

**b. Model Description and Depiction** ..... 4

**c. Contribution to Planning Effort** ..... 5

**d. Description of Input Data** ..... 5

**e. Description of Output Data**..... 5

**f. Statement on the capabilities and limitations of the model**..... 6

**g. Description of model development process including documentation on testing conducted (Alpha and Beta tests)**..... 6

**2. Technical Quality** ..... 6

**a. Theory** ..... 6

**b. Description of system being represented by the model**..... 10

**c. Analytical requirements**..... 10

**d. Assumptions** ..... 10

**e. Identification of formulas used in the model and proof that the computations are appropriate and done correctly** ..... 11

**3. System Quality**..... 11

**a. Description and rationale for selection of supporting software tool/programming language and hardware platform**..... 11

**b. Proof that the programming was done correctly**..... 11

**c. Availability of software and hardware required by model** ..... 11

**d. Description of process used to test and validate model**..... 11

**e. Discussion of the ability to import data into other software analysis tools (interoperability issue)**..... 11

**4. Usability**..... 12

**a. Availability of input data necessary to support the model** ..... 12

**b. Formatting of output in an understandable manner**..... 12

**c. Usefulness of results to support project analysis-** ..... 12

**d. Ability to export results into project reports** ..... 12

**e. Training availability** ..... 12

**f. Users documentation availability and whether it is user friendly and complete**..... 12

**g. Technical support availability** ..... 12

**h. Software/hardware platform availability to all or most users**..... 12

**i. Accessibility of the model** ..... 12

**j. Transparency of model and how it allows for easy verification of calculations and outputs**..... 13

5. *Sources of model uncertainty* ..... 13

6. *Suggested model improvements* ..... 13

7. *Quality review* ..... 13

8. *Uncertainty analysis*..... 13

9. *References* ..... 13

DRAFT

## 1. Background

### a. Purpose of Model

The purpose of this model is to compare the effects of various coastal protection and wetland restoration options on habitat quality for North American river otters (*Lontra Canadensis*) in coastal Louisiana. It was created to provide information to be considered by the State of Louisiana as it prepared the 2012 Coastal Master Plan.

### b. Model Description and Depiction

The North American river otter is a charismatic, fish-eating, fur-bearing, aquatic mammal that was eliminated in the early 1900s from much of the U.S. by over-harvest. In the late 1900's, river otter populations expanded throughout the U.S. partly because harvest was regulated and partly because of re-introductions with Louisiana providing otters to 15 of the 21 states that reintroduced them (Raesly 2001). Data from the Association of Fish and Wildlife Agencies (see [http://jjcdev.com/~fishwild/?section=furbearer\\_management\\_resources](http://jjcdev.com/~fishwild/?section=furbearer_management_resources)) show that harvest of river otter pelts averages 4,700 annually in Louisiana with much variation that appears tied to demand worldwide rather than otter abundance in Louisiana (Figure 1). Those data also show that Louisiana accounts for 22% of all otter pelts harvested in the nation and leads the nation in producing river otter pelts in most years but that could change if habitat quantity and/or quality in Louisiana declined. Throughout the United States, river otters historically were most abundant in coastal marshes but also occurred in interior, riverine habitats (Raesly 2001). In Louisiana, Shirley et al. (1988) estimated river otter density in brackish marshes at Rockefeller Refuge at one otter per 86 ha; direct estimates in other habitat types are unavailable but pelt harvest data indicate that river otters reach their greatest density in brackish marsh (Linscombe and Kinler 1988).

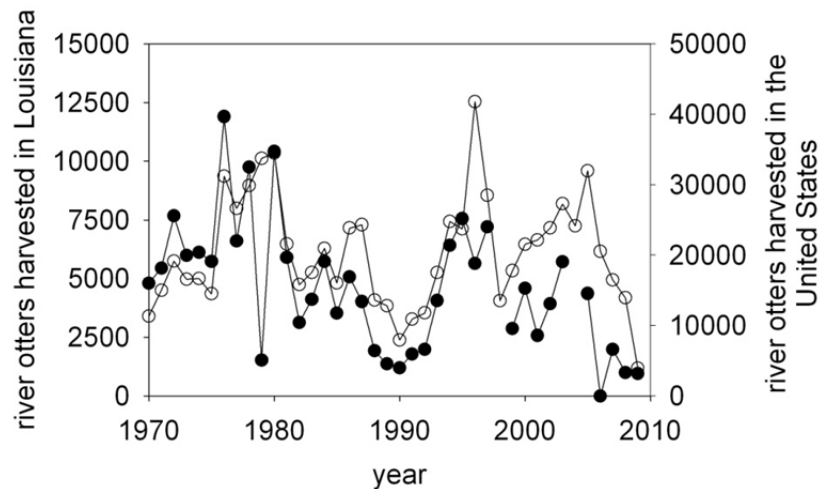


Figure 1. Annual harvest of river otter pelts in Louisiana and the United States. Black circles represent Louisiana harvest and white circles represent United State harvest. (Data are from the Association of Fish and Wildlife Agencies; see [http://jjcdev.com/~fishwild/?section=furbearer\\_management\\_resources](http://jjcdev.com/~fishwild/?section=furbearer_management_resources))

The North American river otter model prepared for Louisiana's 2012 Coastal Master Plan is a Habitat Suitability Index (HSI), which predicts habitat suitability rather than actual numbers of river otters in an area. Habitat Suitability Indices have a long history of use in wildlife management (see Anderson and Gutzwiller 1996). The major caveat of using HSI's is that

predicted changes in habitat area may or may not translate into actual changes in numbers of otters because factors other than habitat quality, such as harvest mortality, affect the numbers of river otters. There are numerous published models that predict habitat suitability for river otters in interior, riverine habitat but none for river otters in coastal marshes even though river otters reach greater density in coastal marshes than in interior, riverine habitat (Raesly 2001). A model of habitat suitability for river otters in coastal marshes was developed for the 2004 LCA study and also considered in the 2007 Louisiana Master Plan (Foret et al 2004). The model developed for the 2012 Coastal Master Plan was based in large part on the earlier models but was modified to account for better information regarding average hydrologic conditions and to account for wetland edge effects.

**c. Contribution to Planning Effort**

The model has potential application to any coastal planning activity that involves evaluation of projects that modify water depth, salinity, or the coastal landscape. The model can be used to evaluate effects on river otter habitat suitability for a variety of coastal protection and restoration projects, including river diversions, hydrological modifications, and marsh creation.

**d. Description of Input Data**

Data used as input are water depth relative to marsh surface, percent land, marsh edge, and habitat type. Water Depth (m) is calculated from outputs from both the Eco-Hydrology and Wetland Morphology models, percent land and marsh edge are provided by the Wetland Morphology model; and habitat type is provided by the Vegetation model. All of these input data sets are converted from their native format into netCDF format.

The inputs and outputs to the River Otter HSI model are in netCDF format. NetCDF (network Common Data Form) is a set of interfaces for array-oriented data access and a freely-distributed collection of data access libraries for C, Fortran, C++, Java, and other languages. The netCDF libraries support a machine-independent format for representing scientific data. Together, the interfaces, libraries, and format support the creation, access, and sharing of scientific data.

(<http://www.unidata.ucar.edu/software/netcdf/docs/faq.html#whatisit>)

**e. Description of Output Data**

The model output files are yearly HSI values for 50 years for the entire Louisiana coast. The HSI values range from 0 to 1, with 0 representing unsuitable habitat and 1 representing optimum habitat in each 500 x 500 m cell. The model outputs are produced in netCDF format, and therefore, the output can be displayed or viewed on a common desktop computer with the EverVIEW Data Viewer software (EverVIEW). EverVIEW, created by the U.S. Geological Survey for the Everglades Joint Ecologic Modeling community group (JEM) the for use in viewing Everglades ecosystem modeling data (Conzelmann and Romañach, 2010) was used to review master plan model inputs and outputs. EverVIEW allows a user to load a netCDF file and visually inspect and compare the graphical data outputs both spatially and temporally. Users can select points within the graphical data to identify model output values at that location, and model output values can also be viewed in tabular format within EverVIEW. EverVIEW can be obtained for free from the Joint Everglades Modeling website at <http://www.jem.gov/Modeling>.

**f. Statement on the capabilities and limitations of the model**

The model is more capable of detecting larger changes in habitat quality for otters than smaller changes. Thus, users should have more confidence in predicted differences among model runs than in predicted similarity among model runs.

The model is limited by the quality of the input data for the variables used. For instance, any artifacts in the model used to predict water depth will be transmitted through this model and create artifacts in the predictions of habitat quality for otters. Many such artifacts should not influence predicted effects of various coastal protection and restoration projects according to their effects on habitat quality for otters because such artifacts should be present in all model runs. The model also potentially is limited by the lack of other variables that are ecologically important but are unavailable because they are not modeled elsewhere in the master plan models.

**g. Description of model development process including documentation on testing conducted (Alpha and Beta tests)**

This model was based upon the otter model used in the 2003 LCA Plan (Foret et al. 2004). That model was updated to account for differences in habitat quality caused by distance from wetland edge habitats.

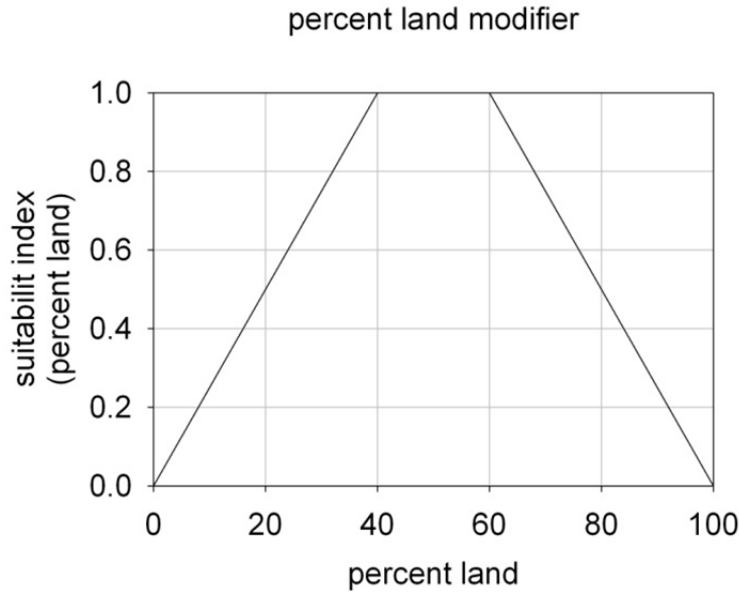
**2. Technical Quality****a. Theory**

Habitat quality for otter is based on data reported by (Linscombe and Kinler 1985). These data are based on fur harvest and are assumed to reflect otter density in the different habitat types because differences in animal abundance most likely cause some areas to produce more animals than other areas and because other possible causes for differences in harvest, such as trapper access, do not differ greatly among the habitat types. Zero habitat value was assigned habitat types that lack reports of river otter harvest such as open water, submersed aquatic vegetation, and saline marsh. River otters cannot complete their life cycle in such habitats even though adults use them extensively at some times. Inclusion of a variable accounting for marsh edge habitat; i.e., open water and open water with SAV that is adjacent to emergent vegetation, accounts for the value of such habitat without increasing habitat quality for extensive areas of open water. Habitat edge effects were incorporated because fish and crustacean are more abundant in water adjacent to emergent vegetation than in open water (La Peyre et al. 2007) and these items are important prey of river otters (Newsom et al. 1987).

***North American River Otter: land:water;  $SI_1$*** 

Habitat quality for otter is assumed to depend upon a combination of open water areas where otter can hunt and fish and emergent vegetation where otter can sleep, avoid adverse weather, and care for young. The suitability function for percent land was based on assuming that the optimal situation in a cell is one 40% land and 60% water:

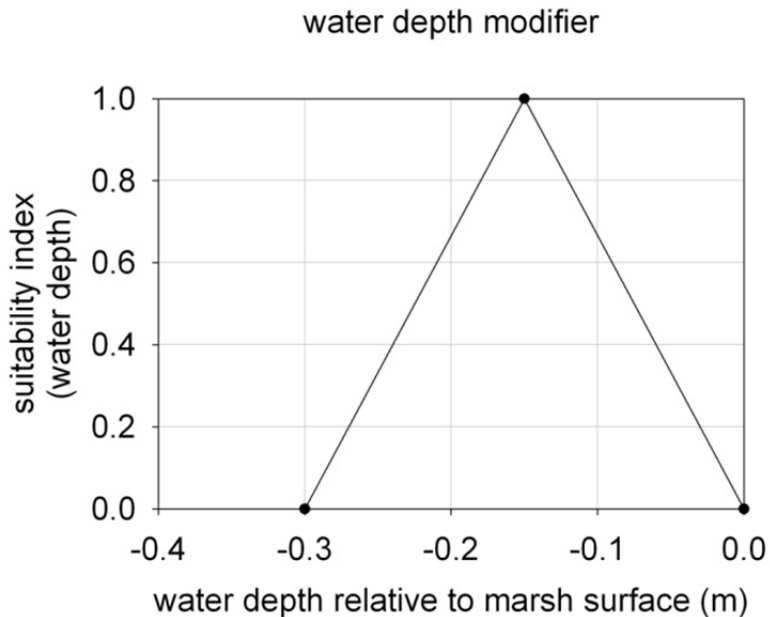
$$\begin{aligned}
 SI_1 &= (\text{percent land})/40 && \text{for } (\text{percent land}) < 40 \\
 SI_1 &= 1 && \text{for } 40 \leq (\text{percent land}) \leq 60 \\
 SI_1 &= 2.5 - ((\text{percent land}) * 0.025) && \text{for } 60 < (\text{percent land}) \leq 100
 \end{aligned}$$



North American River Otter: water level,  $SI_2$

When flooding is low, disease and predation may increase as animals concentrate near deep water; feeding activity may be reduced and river otters and/or their prey may drown when flooding is high (e.g., Kinler et al. 1990). Despite a widespread recognition that extreme flooding or lack of flooding reduces habitat quality for wildlife in general, there are no data that can be used to develop a relationship between water depth and habitat quality for river otters either across all those habitat types or within each of those habitats. Nor are there data sets that can be used to compare water depth among baldcypress swamp, fresh marsh, intermediate marsh, brackish marsh, and saline marsh. The best description of flooding in coastal Louisiana wetlands is limited to intermediate and brackish marshes (Nyman et al. 2009). This model therefore assumed that the average water depth in intermediate and brackish marshes on the central Louisiana coast represent ideal water depth for all habitat types. It is likely that ideal water depth conditions in fresh marsh and baldcypress swamp are different but there are no data to quantify how different. Likewise, it is possible that river otters have a narrower or broader tolerance to water depth than the tolerance assumed in this model but there are no data that can be used to estimate the actual tolerance. Habitat quality for river otters is assumed to be ideal when water depth averages 15 cm (0.15 m) below the elevation of the soil surface in emergent marsh. This assumption is based on the observation that water depths annually average 15 cm below marsh elevation on the central Louisiana coast (Nyman et al. 2009), where wildlife habitat quality is assumed to be high. The 2012 river otter model takes advantage of monthly water level estimates, which were unavailable for the LCA Study and 2007 Master Plan.

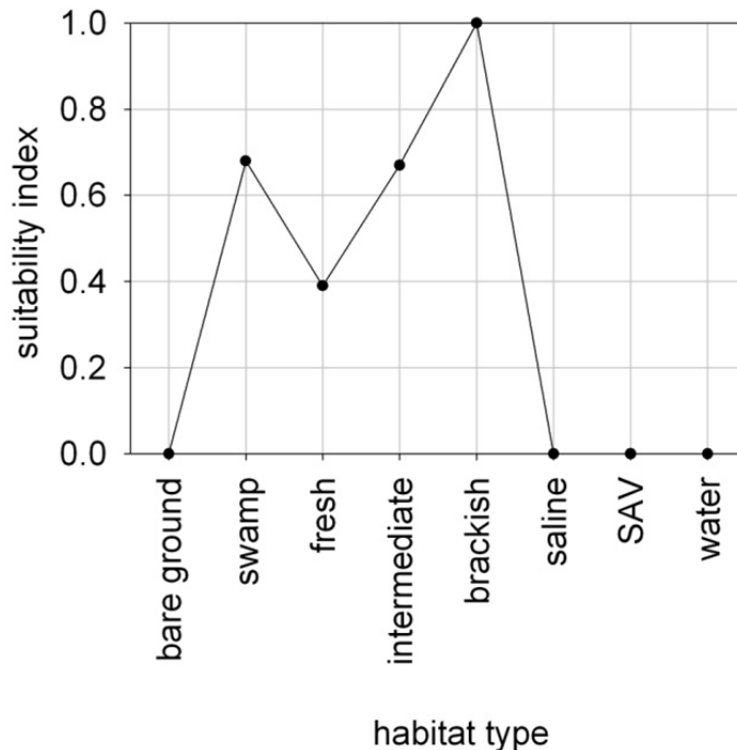
$$SI_2 = \left\{ \begin{array}{ll} 0 & \text{for depth during previous 12 months} \leq -0.3 \text{ m} \\ 2.0 + (\text{depth} \bullet 6.7) & \text{for } -0.3 \text{ m} < \text{depth during previous 12 months} < -0.15 \text{ m} \\ 1 & \text{depth during previous 12 months} = -0.15 \text{ m} \\ \text{depth} \bullet -6.7 & \text{for } -0.15 \text{ m} < \text{depth during previous 12 months} \leq 0.0 \text{ m} \\ 0 & \text{for depth during previous 12 months} > 0.0 \text{ m} \end{array} \right\}$$



*North American River Otter: habitat type,  $SI_3$*

Habitat preference 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 pelts/km<sup>2</sup>, 0.17 pelts/km<sup>2</sup>, 0.29 pelts/km<sup>2</sup>, and 0.44 pelts/km<sup>2</sup> in swamp, fresh marsh, intermediate marsh, and brackish marsh, respectively. Zero habitat value was assigned to saline marsh because no river otters were harvested there. Zero value also was assigned to other habitat types such as open water and open water with submersed aquatic vegetation (SAV) because no river otters were harvested there. Assuming that optimum otter habitat occurs in brackish marsh, the relationship between habitat type and otter habitat capacity can be represented by:

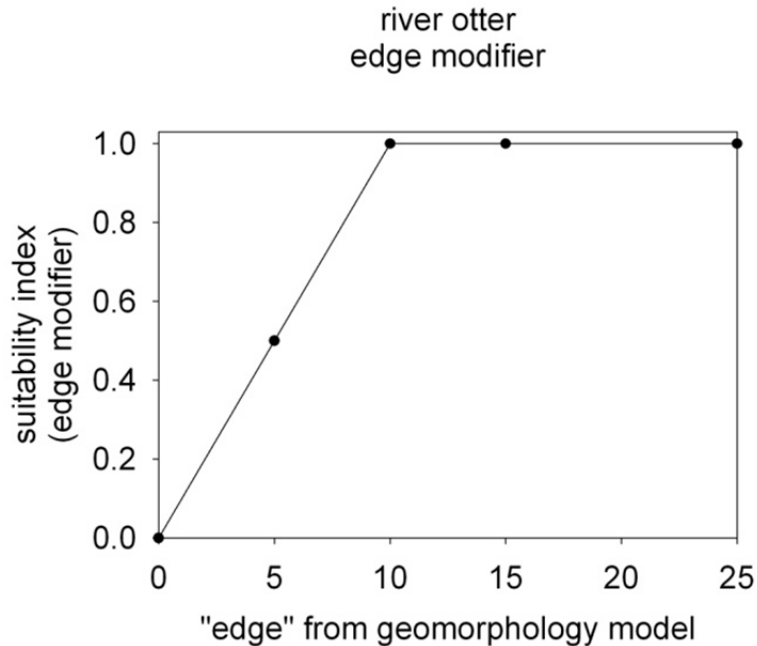
$$SI_3 = (0.68 * \text{portion swamp}) + (0.39 * \text{portion fresh marsh}) + (0.67 * \text{portion intermediate marsh}) + (1.0 * \text{portion brackish marsh})$$



North American River Otter: edge;  $SI_4$

Habitat quality for river otters is assumed to increase with the amount of edge habitat; i.e., open water that is within 10 meters of emergent vegetation, because prey items such as crustaceans and fish are more densely populated in edge habitat than in open water (La Peyre et al. 2007, O’Connell and Nyman 2010). The wetland edge input is simulated by the Wetland Morphology model used for the master plan; the distribution of its output was used to scale this relationship such that values less than the 50<sup>th</sup> percentile produce an index of approximately 0.5 and such that values greater than the 90<sup>th</sup> percentile produce an index of 1.0. The median of all nonzero values of EDGE input was 4.62 and the 90<sup>th</sup> percentile was 11.12; for simplicity, these values were divided by 10 to generate this modifier.

$$SI_4 = \begin{cases} \text{Edge}/10 & \text{for } 0 \leq \text{Edge} \leq 10.0 \\ 1.0 & \text{for } \text{Edge} > 10.0 \end{cases}$$



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

$$HSI = (SI_1 \times SI_2 \times SI_3 \times SI_4)^{1/4}$$

**b. Description of system being represented by the model**

This model simulates the effects of emergent wetland and open water, habitat type, water depth, and marsh edge effect on habitat suitability for the river otter within a 500 x 500 m cell per year.

**c. Analytical requirements**

The River Otter HSI has the following analytical requirements: percent land, water depth relative to marsh surface, habitat type, and edge within a 500 x 500 m cell per year. The geometric mean of these four variables provides the HSI for each cell.

**d. Assumptions**

Because differences in animal abundance most likely cause some areas to produce more animals than other areas and because other possible causes for differences in harvest, such as trapper access, do not differ greatly among habitat types discussed here, habitat quality for otter is based on reported fur harvest data and is assumed to reflect otter density in different habitat types.

Because there are no data that can be used to develop a relationship between water depth and habitat quality for river otters either across habitat types or within each of those habitats, this model assumed that the average water depth in intermediate and brackish marshes on the central Louisiana coast represent ideal water depth for all habitat types. Habitat quality for river otters is assumed to be ideal when water depth averages 15 cm below the elevation of the soil surface in emergent marsh. This assumption is based on the observation that water depths

annually average 15 cm below marsh elevation on the central Louisiana coast (Nyman et al. 2009), where wildlife habitat quality is assumed to be high.

**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. After final model coding was performed, an independent review was performed to ensure that the model code exactly matched the decision rules contained in the documentation provided to the model coder.

**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**

The model was 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 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 in input were used to predict output patterns for river otters. For example, habitat quality for river otters was projected to be low in areas modeled as saline marsh, and it was verified in model validation.

**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

All input data are simulated by other master plan models: percent land, habitat type, water depth, wetland edge. The input files that were produced by master plan modeling teams for use in 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 to 1 that represents the river otter habitat suitability of each 500 x 500 m model grid cell. The output files are in netCDF format and can be viewed using EverVIEW or ESRI ArcGIS.

##### c. Usefulness of results to support project analysis

In general, this model responds to projects which result in changes in river otter habitat suitability. Therefore, projects such as marsh creation, river diversions, or hydrologic restoration that change water depth, habitat type, or landscape configuration 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 for this model 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 the modeling software package can be made available 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**

Uncertainty is introduced into model projections by two factors. The first factor is the scientific rigor of the assumptions on how input variables affect habitat quality for the river otters. For instance, it is possible that important factors controlling habitat quality for the river otters were not included in the model. The second factor is the quality of the input data. For instance, it is possible that salinity data or habitat type data used as input are insensitive to some aspects of coastal protection and restoration projects.

**6. Suggested model improvements**

The model could be improved if the effects of water level on river otter density could be quantified in each of the major habitat types.

**7. Quality review**

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 in input were used to predict output patterns for river otters. Habitat quality for river otters was projected to be low in areas modeled as saline marsh, and it was verified in model validation.

**8. Uncertainty analysis**

No uncertainty analysis was conducted for this model.

**9. References**

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