Model Name: Muskrat Habitat Suitability Index

Functional Area: Ecosystem Services / Upper Trophic Levels

Model Proponents: Coastal Protection and Restoration Authority

Model Developer(s): J.A. Nyman, School of Renewable Natural Resources, LSU AgCenter, Baton Rouge, LA.

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 purpose of this model is to compare the effects of various coastal protection and wetland restoration projects on habitat quality for mukrats (*Ondatra zibethicus*) in coastal Louisiana. It was created to provide information to be considered by the State of Louisiana as it prepared its 2012 Coastal Master Plan.

b. Model Description and Depiction

The muskrat is a fur-bearing, aquatic mammal that eats mostly vegetation but also eats some fish, crustaceans, and snails; muskrats are consumed primarily by American alligators (O'Neil 1949). At one time, muskrats occurred throughout North American but they were eliminated in the early 1900s from much of their range by over-harvest. Beginning in the early 1900s, its harvest for use in fur garments drove economic activity and later scientific research in coastal Louisiana (Arthur 1928, Verlander 1941, O'Neil 1949, Palmisano 1968) but its fur has not been in demand since the 1980s. Data from the Association of Fish and Wildlife Agencies (see http://jjcdev.com/~fishwild/?section=furbearer_management_resources) show that muskrat harvest in Louisiana averaged 5,492,500 annually during the 1970s but declined to 390 annually during the 2000s. The decline in muskrat harvest in Louisiana appears tied to worldwide demand rather than muskrat abundance in Louisiana because nationwide harvest also has remained low since the 1990s (Figure 1). Harvest remains low partly because of low demand but partly because of low supply because, unlike nutria and otter trapping, muskrat trapping requires walking the marsh interior far from the edges of bayous that can be trapped via boat (personal communication, Edmund Mouton, Louisiana Department of Wildlife and Fisheries). Those data also show that Louisiana accounted for 9% of all muskrat pelts harvested in the nation when demand was high in the 1970s but has declined to less than tenth of one percent in the 2000s (Figure 1).

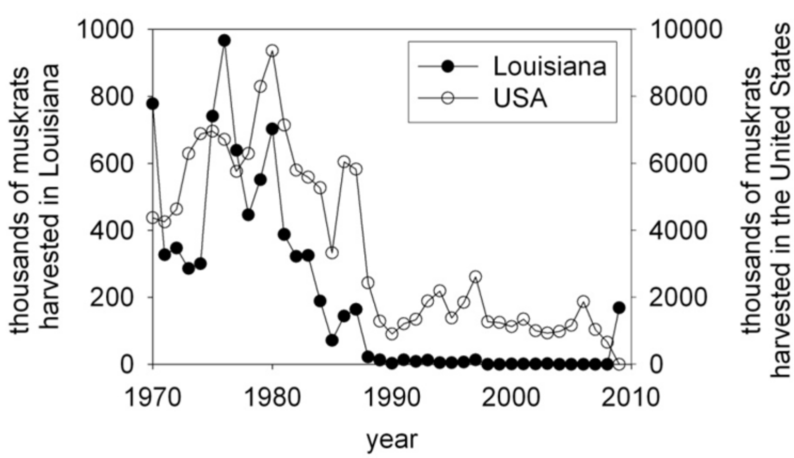


Figure 1. Annual harvest of muskrat pelts in Louisiana and the United States (data are from the Association of Fish and Wildlife Agencies; see http://jjcdev.com/~fishwild/?section=furbearer_management_resources)

Muskrat populations can be very dynamic and damage to marsh vegetation occurs when muskrat population levels are high (O'Neil 1949,Lynch et al. 1947). Keddy et al. (2009) hypothesized that muskrat populations in coastal Louisiana rose and fell as American alligators became less and more abundant, which explains why muskrat damage to marsh was much more common in the early and mid-1900s than in the late 1900s. Pelt harvest data indicate that muskrats in Louisiana consistently reach their greatest density in brackish marsh (Linscombe and Kinler 1988).

The muskrat model prepared for Louisiana's 2012 Coastal Master Plan is a Habitat Suitability Index (HSI), which predicts habitat suitability rather than actual numbers of muskrats 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 muskrats because factors other than habitat quality, such as harvest mortality, affect the numbers of muskrats. Allen and Hoffman (1984) prepared an HSI for muskrats, which served as a basis for a muskrat HSI model in coastal marshes that 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 on the earlier models but was modified to account for better information regarding average hydrologic conditions and hydrologic models capable of providing monthly, rather than annual, estimates of average water level.

c. Contribution to Planning Effort

The model has potential application to any coastal planning activity that involves evaluation of projects that modify water depth, habitat type, or the coastal landscape. The model can be used to evaluate effects on muskrat 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, and habitat type. Water Depth (m) is calculated from outputs from both the Eco-Hydrology and Wetland Morphology models, percent land is 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 Muskrat 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#whatisitare/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 muskrats 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 muskrats. Many such artifacts should not influence ranking the effects of various coastal protection and restoration projects according to their effects on habitat quality for muskrats 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)

Allen and Hoffman (1984) prepared an HSI for muskrats, which served as a basis for a muskrat HSI model in coastal marshes that 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 on the earlier model but was modified to account for better information regarding average hydrologic conditions and hydrologic models capable of providing monthly, rather than annual, estimates of average water level.

2. *Technical Quality*

a. Theory

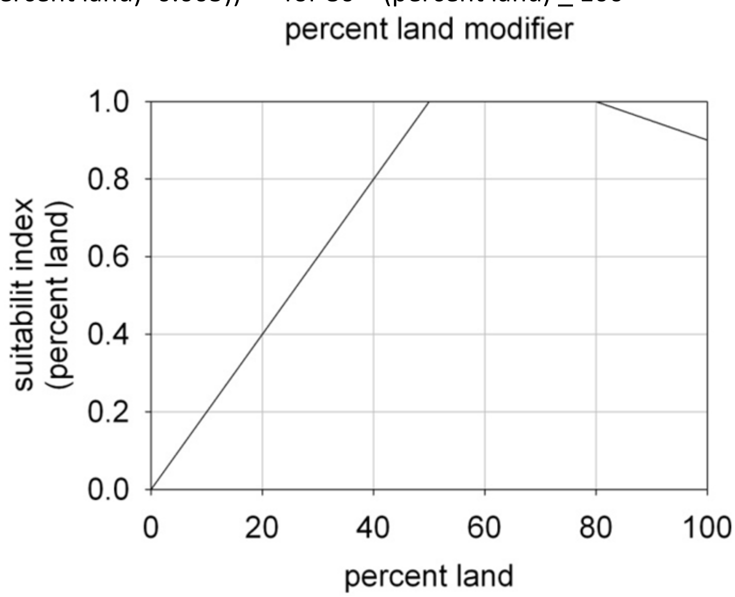
The muskrat model developed for the 2012 Coastal Master Plan is based on the muskrat HSI model prepared by Allen and Hoffman (1984), data reported by (Linscombe and Kinler 1985), data reported by Nyman et al. (2009), and best professional judgment. Allen and Hoffman (1984) based their model on four variables, percent vegetative cover, percent persistent vegetative cover, percent vegetative cover by the preferred food plant *Schoenoplectus americana*, and percent of open water supporting Submersed Aquatic Vegetation (SAV). Only two of those variables were available as input for the 2012 Master Plan: percent vegetative cover and percent of open water supporting SAV. Only percent vegetative cover was retained for the 2012 muskrat HSI model; SAV was not included in this model because data from coastal Louisiana (Linscombe and Kinler 1984) demonstrate that fresh marshes, which have the highest SAV coverage of the marsh types (Chabreck 1971), do not have the highest muskrat abundance. The fur harvest data reported by Linscome and Kinler (1985) are assumed to reflect differences in habitat quality for muskrat among 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 variation in harvest, such as trapper access and trap efficiency, do not differ greatly among habitat types. Zero habitat value was assigned to habitat types that lack reports of muskrat harvest such as open water and saline marsh. Habitat Edge effects were not incorporated in this muskrat HSI model because muskrats do not depend upon fish and crustaceans for food, which are more abundant near edge, and because Nyman et al. (1993)

observed that muskrats in Louisiana are more common in the marsh interior, far from open water than they are near marsh edge (Nyman et al. 1993).

Muskrat: land:water; SI_1

Habitat suitability is calculated annually. 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) in their HSI model:

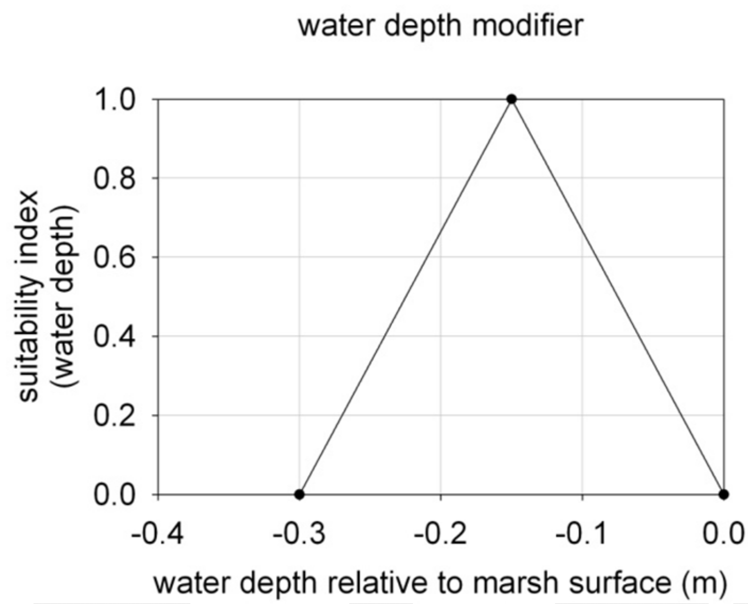
SI_1 =	(percent land)/50	for (percent land) < 50
SI_1 =	1	for 50≤ (percent land) ≤ 80
SI_1 =	1.4 – ((percent land)*0.005))	for 80 < (percent land) ≤ 100



Muskrat: water depth, SI_2

Habitat quality for muskrats is assumed to be ideal when water depths annually average 15 cm below the elevation of the soil surface in emergent marsh (based on the observation that water depths annually average 15 cm below marsh elevation at Marsh Island, Louisiana (Nyman et al. 2009)), where wildlife habitat quality is assumed to be high; .

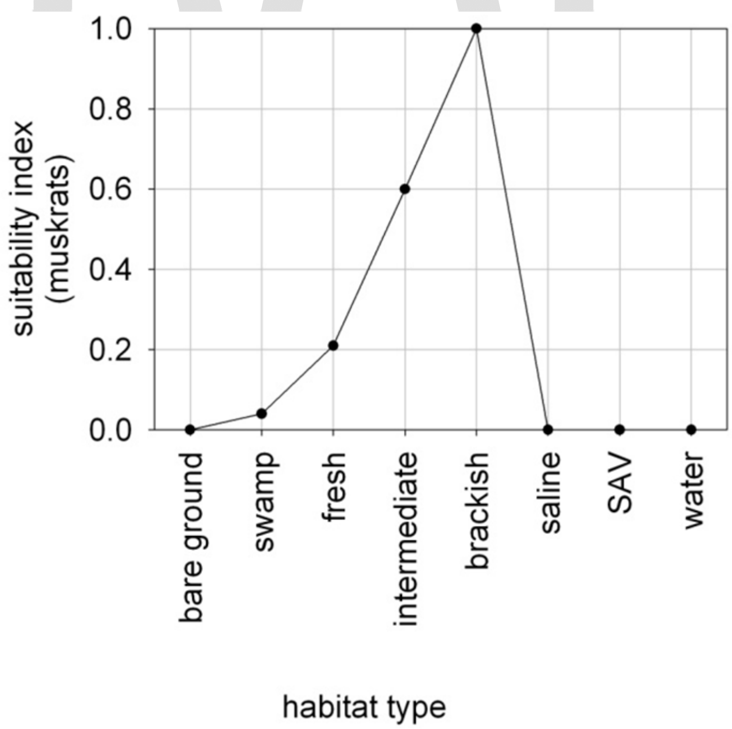
$$SI_2 = \begin{cases} 0 & \text{for depth during previous 12 months} \le -0.3\,m \\ 2.0 + (depth \bullet 6.7) & \text{for} -0.3\,m < \text{depth during previous 12 months} < -0.15\,m \\ 1 & \text{depth during previous 12 months} = -0.15\,m \\ depth \bullet -6.7 & \text{for} -0.15\,m < \text{depth during previous 12 months} \le 0.0\,m \\ 0 & \text{for depth during previous 12 months} > 0.0\,m \end{cases}$$



Muskrat: habitat type; SI_3

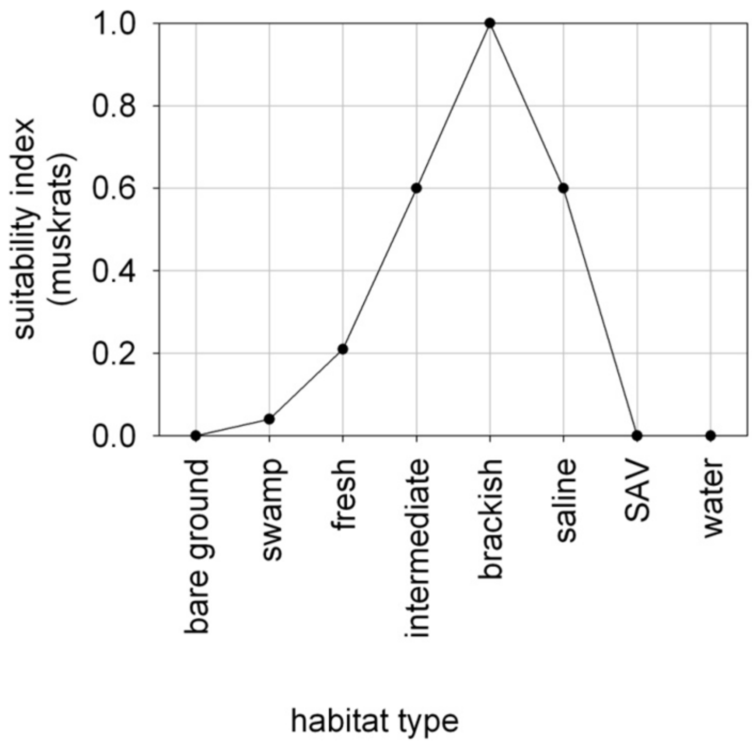
Habitat capacity for muskrat in different habitat types was based on data reported by Linscombe and Kinler (1985) who determined the muskrat harvest distribution using statewide trapping records from 1977 through 1983. They reported muskrat pelt harvest averaged 2.0/km^2, 9.4/km^2, 4.7/km^2, and 44.1/km^2 in swamp, fresh marsh, intermediate marsh, and brackish marsh respectively. Those data indicate that optimum muskrat habitat occurs in brackish marsh; thus, this variable is based on the Linscombe and Kinler (1985) data:

SI_3 = (0.04 * portion swamp) + (0.21 * portion fresh marsh) + (0.60 * portion intermediate marsh) + (1.0 * portion brackish marsh)



Muskrats also inhabit saline marshes but data from Linscombe and Kinler (1985) lack a means of comparing the habitat value of saline marsh to other marsh types. The value of saline marsh relative to brackish can be estimated from the ratio of muskrat house density in brackish and saline marsh, which was calculated from house count data in Palmisano (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). This information was not included in the muskrat model used by the master plan. The relationship would be:

SI_x = (0.04 * portion swamp) + (0.21 * portion fresh marsh) + (0.60 * portion intermediate marsh) + (1.0 * portion brackish marsh) + (0.60 *portion saline marsh)



Incorrectly assuming that saline marsh fails to provide habitat for muskrats will make the predicted habitat quality for muskrats insensitive to changes in saline marsh.

HSI for muskrat is computed as the geometric mean of the three factors:
$HSI = (SI_1 \times SI_2 \times SI_3)^{1/3}$

b. Description of system being represented by the model

This model simulates the effects of emergent wetland and open water, habitat type, and water depth on habitat suitability for muskrats within each 500 x 500 m cell per year.

c. Analytical requirements

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

d. Assumptions

Habitat quality for muskrats is assumed to be ideal when water depths annually average 15 cm below the elevation of the soil surface in emergent marsh. The variable for preferred habitat type is based on statewide trapping records.

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 upon 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" species model to be 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 review the code in real time or when they are individually coded they 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

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 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 in input were used to predict output patterns in habitat quality for muskrats. For example, habitat quality for muskrats was projected to be low in areas modeled as fresh marsh.

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, and water depth relative to marsh surface. 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 zero to one that represents the crawfish habitat suitability of a 500 x 500 m model grid cell. The output files are in netCDF format and can be viewed using EverVIEW or ESRI ArcGIS. The output is best comprehended by assigning a color to each grid commensurate with its HSI value.

c. Usefulness of results to support project analysis

In general, this model responds to projects which result in changes in muskrat habitat suitability. Therefore, projects such as marsh creation, diversions, or hydrologic restoration that change percent land, habitat type, and water depth relative to marsh surface 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 would 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 would be provided through CPRA.

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

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

i. Accessibility of the model

Access to model and associated installation and execution files would 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*

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 muskrats. For instance, it is possible that important factors controlling habitat quality for muskrats 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*

As noted in Section 2 above, the habitat type variable was incorrectly implemented in the model, indicating an SI of 0 for saline habitat types rather than an SI of 0.6. Incorrectly assuming that saline marsh fails to provide habitat for muskrats will make the predicted habitat quality for muskrats insensitive to changes in saline marsh. Inclusion of the corrected relationship for saline marsh would improve model output.

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. We followed this latter approach and used known spatial and temporal patterns in input to predict patterns in habitat quality for muskrats. For example, we verified that habitat quality for muskrats was projected to be low in areas modeled as saline marsh.

8. *Uncertainty analysis*

No uncertainty analysis was conducted for this model.

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