

Model Name: American Alligator Habitat Suitability Index

Functional Area: Ecosystem Services / Upper Trophic Level

Model Proponents: Coastal Protection and Restoration Authority

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

Table of Contents

1. Background..... 1

 a. Purpose of Model 1

 b. Model Description and Depiction 1

 c. Contribution to Planning Effort 2

 d. Description of Input Data 2

 e. Description of Output Data..... 3

 f. Statement on the capabilities and limitations of the model..... 3

 g. Description of model development process including documentation on testing conducted (Alpha and Beta tests)..... 3

2. Technical Quality 3

 a. Theory 3

 b. Description of system being represented by the model..... 9

 c. Analytical requirements..... 9

 d. Assumptions 9

 e. Identification of formulas used in the model and proof that the computations are appropriate and done correctly 9

3. System Quality..... 9

 a. Description and rationale for selection of supporting software tool/programming language and hardware platform 9

 b. Proof that the programming was done correctly..... 9

 c. Availability of software and hardware required by model 10

 d. Description of process used to test and validate model..... 10

 e. Discussion of the ability to import data into other software analysis tools (interoperability issue) 10

4. Usability..... 10

 a. Availability of input data necessary to support the model 10

 b. Formatting of output in an understandable manner..... 10

 c. Usefulness of results to support project analysis- 11

 d. Ability to export results into project reports 11

 e. Training availability 11

 f. Users documentation availability and whether it is user friendly and complete..... 11

 g. Technical support availability 11

 h. Software/hardware platform availability to all or most users..... 11

 i. Accessibility of the model 11

 j. Transparency of model and how it allows for easy verification of calculations and outputs 11

APPENDIX D-5 AMERICAN ALLIGATOR HABITAT SUITABILITY INDEX TECHNICAL REPORT

5. Sources of model uncertainty 11

6. Suggested model improvements 11

7. Quality review 12

8. Uncertainty analysis..... 12

9. References 14

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 American alligators 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 American alligator (*Alligator mississippiensis*) occurs throughout the southeastern United States. Small alligators feed primarily on fish and crustaceans (Platt et al. 1990, Wolfe et al. 1987). Large alligators feed primarily on nutria (*Myocastor coypus*) and muskrat (*Ondatra zibethicus*) (Wolfe et al. 1987) but may also feed regularly on deer (*Odocoileus virginianus*) and other terrestrial mammals (e.g., Shoop and Ruckdeschel 1990). Alligator harvest began in earnest in the 1870's and alligators as small as 0.6 m were harvested prior to the 1960's (Joanen and McNease 1987). Alligator populations in Louisiana were low in the late 1950's because of illegal over-harvest fueled by a demand for skins from small individuals; harvest was suspended in 1962 (Joanen and McNease 1987). State and federal law enforcement agents were able to virtually eliminate poaching in parts of southwest Louisiana by the early 1960's with the cooperation of the public and courts (Tarver et al. 1987). Alligator populations quickly recovered so that by 1972 there was an experimental harvest of 1,337 hides in southwest Louisiana (Tarver et al. 1978). Alligator numbers continued to increase and by 1981 the harvest was state wide and 15,534 hides were taken (Joanen et al. 1984). Harvest and nest counts increased rapidly throughout the 1990s but slowed or stabilized since 2000 (Figure 1). In 2008, the harvest of wild American alligators was worth \$9,018,473 in skins and \$3,687,084 in meat (LDWF 2009). Over 250,000 farm-raised American alligators also are sold annually in Louisiana; they provide approximately four times more value for skins but a similar value for meat compared to wild American alligators (LDWF 2009); farm-raised animals are not considered in this model.

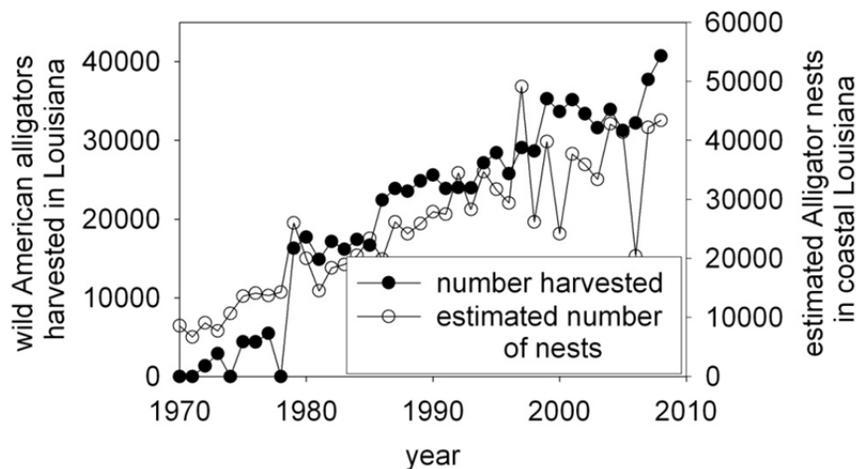


Figure 1. Harvest of wild American alligators and estimated nests of wild American alligators in coastal Louisiana. Data are from the Louisiana's Alligator Management Program 2008-2009 Annual Report prepared by the Louisiana Department of Wildlife and Fisheries.

APPENDIX D-5 AMERICAN ALLIGATOR HABITAT SUITABILITY INDEX TECHNICAL REPORT

Simulation models have been used since the 1970s to guide harvest and habitat management for American alligators (Nichols et al. 1976, Newsom et al. 1987) because American alligator life spans are too long to allow field experiments. This American alligator model, prepared for Louisiana's 2012 Coastal Master Plan, is a Habitat Suitability Index (HSI). Habitat Suitability Indices predict habitat suitability rather than actual numbers of animals 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 models is that predicted changes in habitat area may or may not translate into actual changes in numbers of American alligators because factors other than habitat quality, such as harvest mortality, affect the numbers of American alligators. The 2004 Louisiana Coastal Area Study (LCA Study; USACE 2004) and 2007 Coastal Master Plan (CPRA 2007) used an American alligator model (2007 model; Foret et al. 2004) based on the HSI model prepared by Newsom et al. (1987). This American alligator model prepared for the 2012 Coastal Master Plan was based on the model used in these previous reports (Foret et al. 2004) but was revised regarding habitat distribution, salinity, and wetland edge effects.

The 2007-version of the model (Foret et al. 2004) was the subject of an in-depth review and comparison with the American alligator model used by the South Florida Management District in planning Everglades' restoration (Draugelis-Dale 2007). That review concluded that the Louisiana model would benefit from using seasonal rather than yearly water levels as the Florida model did, and that the Florida model would benefit from incorporating a variable accounting for percent open water as the Louisiana model did (Drauglis-Dale 2007). As suggested by Draugelis-Dale (2007), the American alligator model used for the 2012 Coastal Master Plan takes advantage of monthly water level estimates, which were unavailable for the 2007 model. Draugelis-Dale (2007) also suggested that the Louisiana model should use a different habitat classification, such as one based on dominant vegetation or on the Cowardin et al. (1987) system, but that suggestion is illogical because the Cowardin et al. (1987) system would lead to only two habitat classes whereas there were 10 habitat classes used in the LCA Study and 2007 master plan, which were based on dominant vegetation. Foret et al. (2004) also suggested that future American alligator models incorporate edge effects, which concentrate many wildlife prey species near edges of open water and emergent vegetation (Kaminski and Prince 1981, Minello et al. 1994, Peterson and Turner 1994, Prolux and Gilbert 1983, Rozas and Zimmerman 2000). Edge effects were unavailable as input for the 2007 model (Foret 2004) but were incorporated into the 2012 Coastal Master Plan model.

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 American alligator 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, water salinity, percent land, marsh edge, and habitat type. Monthly water salinity data (parts per thousand) are provided by the Eco-Hydrology model; Water depth (m) is calculated from outputs from both the Eco-Hydrology and Wetland Morphology models, percent land and 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 Alligator 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 of 0 to 1, with 0 representing unsuitable habitat and 1 representing optimum habitat. 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 American alligators than smaller changes. The model is also limited by the lack of input data for some variables known to be important to American alligators such as the percentage of water areas that are greater than 1.2 m deep, which is a variable in the 1987 HSI for this species (Newsom et al. 1987) but is not available for use as an input variable.

The model may also be limited by the quality of the input data for the variables used. For instance, any errors in the model used to predict water salinity will be transmitted through this model and create artifacts in the predictions of habitat quality for American alligator. Many such artifacts should not influence ranking the effects of various coastal protection and restoration projects according to their effects on habitat quality for American alligator because such artifacts should be present in all model runs.

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

This model was based upon the American alligator model used in the 2007 Coastal Master Plan (Foret et al. 2004). That model was updated with new information regarding habitat distribution (LDWF 2009), flooding (Nyman et al. 2009), salinity (personal communication, Ruth Elsey, Rockefeller Wildlife Refuge, Louisiana Department of Wildlife and Fisheries [LDWF]), and wetland edge effects.

2. Technical Quality

a. Theory

Habitat capacity for American alligator is based on data reported by McNease and Joanen (1978), the HSI model by Newsom et al. (1987), water level data from coastal Louisiana (Nyman

APPENDIX D-5 AMERICAN ALLIGATOR HABITAT SUITABILITY INDEX TECHNICAL REPORT

et al. 2009), and water salinity data from LDWF (unpublished data, Ruth Elsey, Rockefeller Wildlife Refuge, LDWF).

For the 2007 model (Foret 2004), the relative ability of fresh marsh, intermediate marsh, brackish marsh, and saline marsh to support American alligators was based on data from McNease and Joanen (1978); whereas, this version is based on data from LDWF (2008) and reflects the ratio of average number of tags allotted by habitat type during the 2007 season. The LDWF (2008) data provided a basis for comparing density of American alligators in baldcypress swamp; in the previous version of this model that comparison was based on best professional judgment for that habitat type. Those 2007 tag allotments showed more tags were allotted per hectare of fresh marsh in some regions but more were allotted per hectare of intermediate marsh in other regions. Averaged overall however, the ratio of tags was greater in fresh marsh (1 tag per 35 ha) than in equal areas of intermediate marsh 1:0.74 (fresh:intermediate). The ratio of tags in baldcypress swamp and brackish marsh were considerably lower and averaged 1:0.51 (fresh:baldcypress) and 1:0.39 (fresh:brackish), respectively. Zero value was assigned to other habitat types, i.e., open water, open water with submersed aquatic vegetation (SAV), saline marsh, and bare ground, because American alligators cannot complete their life cycle in such habitats even though adults use them extensively. Inclusion of a factor accounting for wetland 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 predicting high habitat quality for extensive areas of open water such as Lake Pontchartrain that are devoid of American alligators. Wetland edge effects were incorporated because fish, crustacean, and water bird density all are greater in water adjacent to emergent vegetation than in open water (La Peyre et al. 2007, O'Connell and Nyman 2010) and these items are important prey of American alligators (Newsom et al. 1987). For the 2007-version of the model (Foret 2004), American alligators were assumed to be unable to tolerate water salinity greater than 12 ppt. This model was updated and assumed American alligators can tolerate only 10 ppt for extended time based on unpublished data provided by Ruth Elsey (Rockefeller Refuge, LDWF).

American alligator: land:water; SI_1 - (Figure 2)

American alligators require emergent land to nest. A relationship between percent land; i.e. percent of area with emergent vegetation, and American alligator habitat suitability was previously presented in the HSI model by Newsom et al. (1987). That relationship therefore used in this model and is represented by:

$$\begin{aligned} SI_1 &= (\text{percent land})/60 && \text{for } (\text{percent land}) < 60 \\ SI_1 &= 1 && \text{for } 60 \leq (\text{percent land}) \leq 80 \\ SI_1 &= 5 - ((\text{percent land}) * 0.05) && \text{for } 80 < (\text{percent land}) \leq 100 \end{aligned}$$

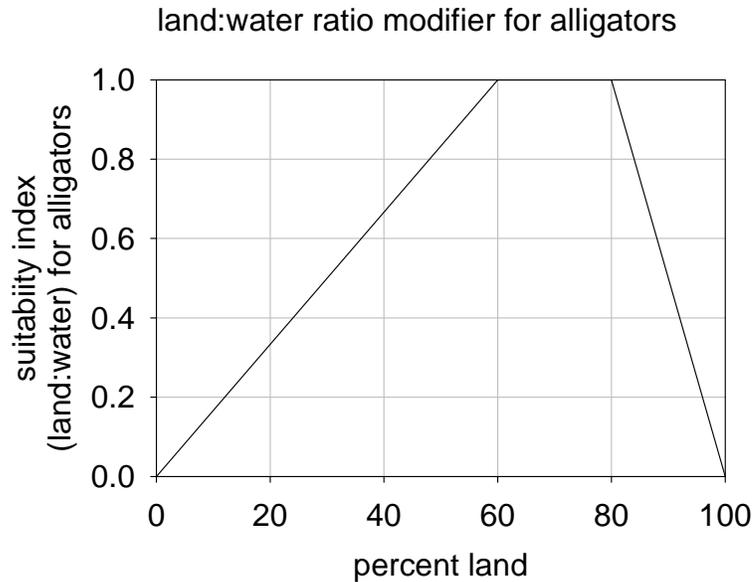


Figure 2. Relationship between percent land and habitat suitability for the American alligator.

American alligator: water depth; SI_2 - (Figure 3)

When flooding is low, disease and predation may increase as animals concentrate near deep water; feeding activity may be reduced and American alligators and/or their prey may drown when flooding is high (Kinler et al. 1990). Despite a widespread recognition that extreme flooding or lack of flooding reduces habitat quality for American alligators, there are no data that can be used to develop a relationship between water depth and habitat quality for American alligators 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 American alligators 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 American alligators is assumed to be ideal when water depth annually averages 15 cm below the elevation of the soil surface in emergent marsh. This is based on the observation that water depths annually average at 15 cm below marsh elevation on the central Louisiana coast (Nyman et al. 2009), where wildlife habitat quality is assumed to be high. As suggested by Draugelis-Dale (2007), the 2012-version of the American alligator model takes advantage of monthly water level estimates, which were unavailable for the 2007-version of the model.

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

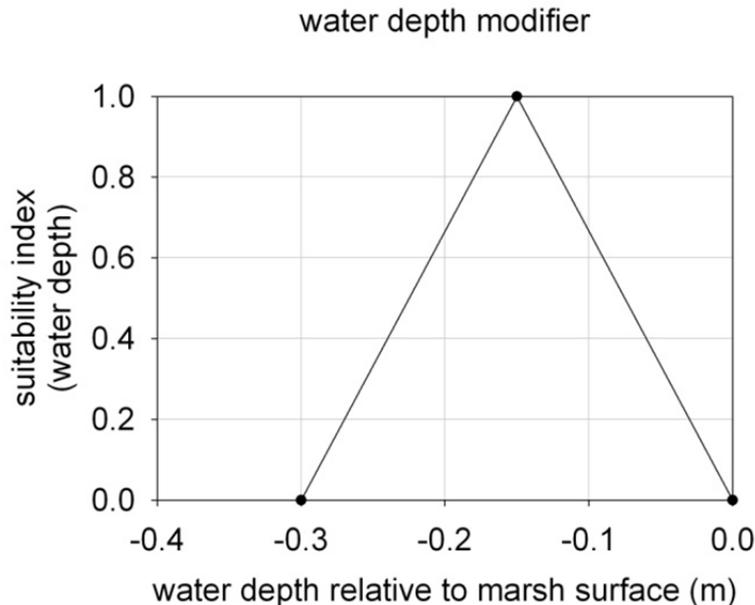


Figure 3. Relationship between water depth and habitat suitability for the American alligator.

American alligator: habitat type; SI_3 - (Figure 4)

The version of this model used in the 2007 master plan was based on habitat-specific density harvest data from table 2 in McNease and Joanen (1978): 1.9, 3.6, and 2.0 gators/km² in fresh, intermediate, and brackish marsh respectively but recent allotment of alligator tags for harvest consistently provide more tags for fresh marsh habitat than any other (see <http://www.wlf.louisiana.gov/wildlife/alligator-program-annual-reports>). Tag allotment varies somewhat among years; however, the allotment for 2007 (LDWF 2008) was used in this model because the tags per acre were greatest that year. These recent data also provided an additional habitat type of baldcypress swamp for American alligator that was not previously available. Subsequent data show similar ratios in alligator tag density among the marsh types (LDWF 2009). Zero value was assigned to open water, open water with submersed aquatic vegetation (SAV), saline marsh, and bare ground habitat types because American alligators cannot complete their life cycle in such habitats even though adults use them extensively. The relationship between habitat type and alligator habitat suitability can be represented by:

$$SI_3 = (0.51 * \text{portion baldcypress swamp}) + (1.00 * \text{portion fresh marsh}) + (0.74 * \text{portion intermediate marsh}) + (0.39 * \text{portion brackish marsh})$$

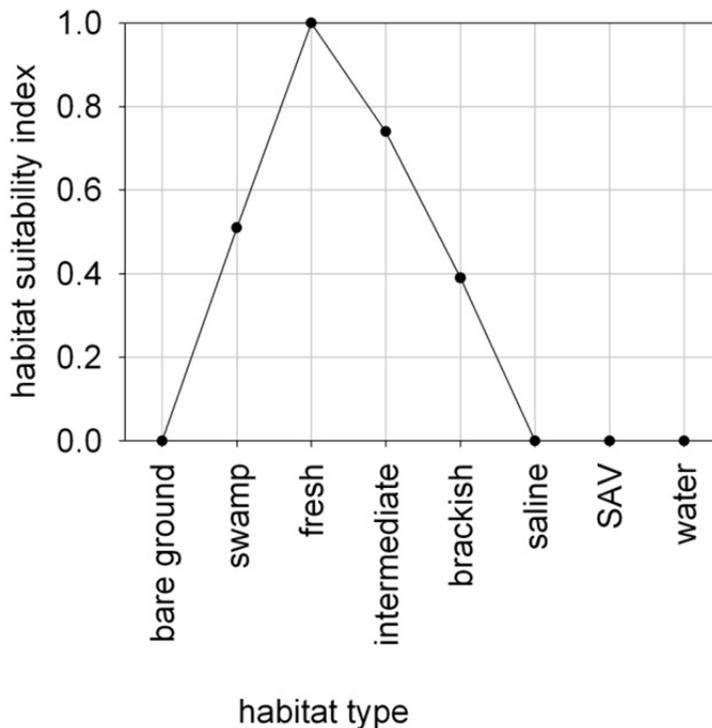


Figure 4. Relationship between habitat type and habitat suitability for the American alligator.

American alligator: edge; SI_4 - (Figure 5)

Habitat quality for American alligators 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, fish, and waterbirds are more densely populated in edge habitat than in open water (La Peyre et al. 2007, O’Connell and Nyman 2010). The Edge input is simulated by the Wetland Morphology modeling group working on the 2012 Coastal Master Plan; the distribution of its output was used to scale this relationship such that values less than the 50th percentile produce an index of approximately 0.5 and such that values greater than the 90th percentile produce an index of 1.0. The median of all nonzero values of EDGE input was 4.62 and the 90th percentile was 11.12; for simplicity, these values were divided by 10 to generate this modifier.

$$SI_4 = \left\{ \begin{array}{ll} \text{Edge}/10 & \text{for } 0 \leq \text{Edge} \leq 10.0 \\ 1.0 & \text{for } \text{Edge} > 10.0 \end{array} \right\}$$

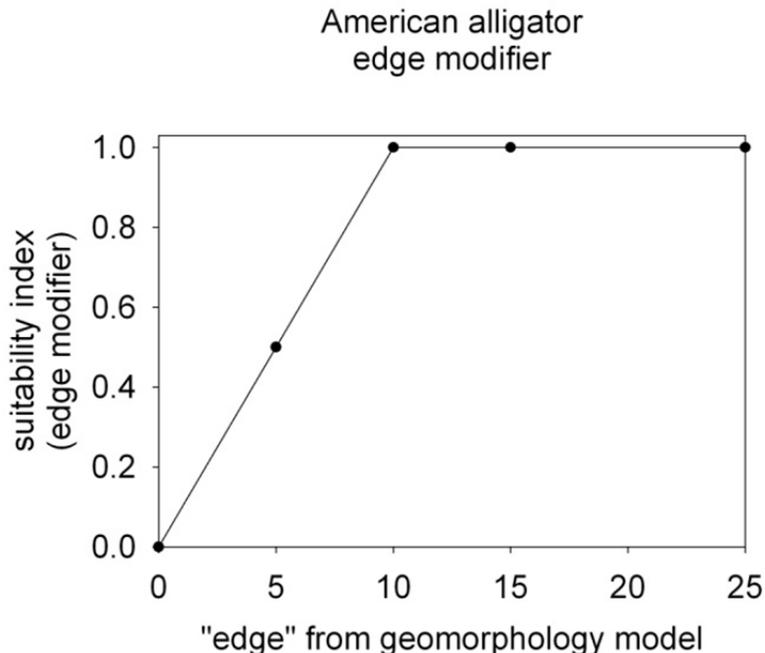


Figure 5. Relationship between edge and habitat suitability for the American alligator.

American alligator: salinity; SI_5 - (Figure 6)

Habitat quality for American alligators is assumed to be ideal in fresh water and to decline to 0 when salinity reaches 10 ppt based on unpublished data provided by the LDWF (Ruth Elsey, Rockefeller Refuge, LDWF).

$$SI_5 = \begin{cases} (-0.1 * salinity) + 1.0 & \text{for } 0 \leq salinity < 10 \\ 0 & \text{for } salinity \geq 10 \end{cases}$$

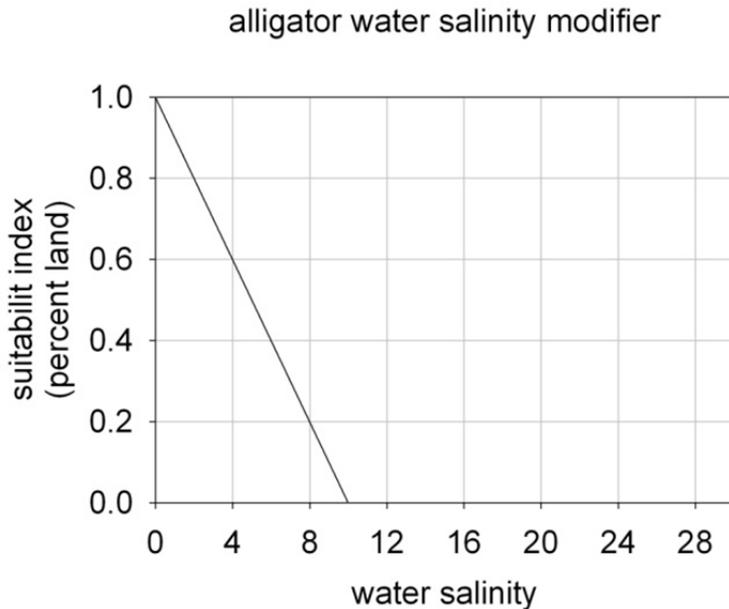


Figure 6. Relationship between water salinity and habitat suitability for the American alligator.

APPENDIX D-5 AMERICAN ALLIGATOR HABITAT SUITABILITY INDEX TECHNICAL REPORT

HSI for alligator is computed as the geometric mean of the 5 factors:

$$HSI = (SI_1 \times SI_2 \times SI_3 \times SI_4 \times SI_5)^{1/5}$$

where 1 is highly suitable habitat and 0 is unsuitable habitat per grid area per year.

b. Description of system being represented by the model

This model simulates the effects of habitat type, water depth, water salinity, and marsh edge effect on habitat suitability for the American alligator within a 500 x 500 m cell per year.

c. Analytical requirements

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

d. Assumptions

Because there are no data that can be used to develop a relationship between water depth and habitat quality for American alligators either across all those 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.

American alligator life spans are too long to allow field experiments; therefore, the habitat type variable (SI_3) reflects the ratio of average number of tags allotted by habitat type during the 2007 season. Previous versions of the American alligator HSI relied on professional judgment to assign suitability values to habitat types.

Habitat quality for American alligators is assumed to increase with the amount of edge habitat. Habitat quality for American alligators is assumed to be ideal in fresh water and to decline to 0 when salinity reaches 10 ppt.

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 were either developed by teams which ensured

multiple individuals conducted real-time code reviews or when codes were developed individually spot checks were performed 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 American alligators. For example, habitat quality for American alligators 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, water salinity, and 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 American alligator 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 American alligator habitat suitability. Therefore, projects such as marsh creation, river diversions, or hydrologic restoration that change water salinity, water depth, and 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 American alligator. For instance, it is possible that important factors controlling habitat quality for the American alligator 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 by increasing the resolution of the input data provided by the other master plan models. In addition, the suitability indices could be further refined if more data on habitat utilization by American alligators were available as well as a relationship based on water depth and habitat quality. The model could be improved by including additional variables such as harvest mortality and percentage of water areas greater than 1.2m in depth.

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 American alligators. Habitat quality for American alligators was projected to be low in areas modeled as saline marsh, and it was verified in model validation.

8. Uncertainty analysis

Of the five variables included in this alligator model, three of these variables will be included in the model uncertainty analysis (water depth, edge, and salinity) See Appendix D-27 Model Uncertainty Analysis. These variables and decision rules were selected because of their high impact on the habitat quality and the perceived uncertainties associated with specifying their decision rules. The following table (Table 1) is a representation of how the three decision rules will be varied within the uncertainty analysis.

Despite a widespread recognition that extreme flooding or lack of flooding reduces habitat quality for American alligators, there are no data that can be used to develop a relationship between water depth and habitat quality for American alligators 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 American alligators 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. These relationships can be related graphically with a narrower tolerance indicated by “option a” and a broader tolerance indicated by “option b” (Figure 7): Narrower and broader tolerance to water depth were assessed during the analyses assessing uncertainty (See Appendix D-27 for more detailed information). This model also assumed that average daily low water and average daily high water reported by Nyman et al. (2009) represent the limits; i.e., lowest and highest average daily water depths; that can be tolerated by American alligators. It is possible that actual limits differ but we were unaware of any data that could be used to quantify those limits.

Variations in the suitability of edge habitat of American alligators will also be assessed during the model uncertainty analyses, Figure 8.

APPENDIX D-5 AMERICAN ALLIGATOR HABITAT SUITABILITY INDEX TECHNICAL REPORT

Table 1: Variations on Alligator Decision Rules for the Uncertainty Analysis.

	A ₀	A ₁	A ₂
V ₂ (Water Depth)	SI = 0 V2 < -0.3 & V2 > 0 SI = V2/0.15 + 2 -0.3 < V2 < -0.15 SI = V2/(-0.15) -0.15 < V2 < 0	SI = 0 V2 < -0.3 SI = V2/0.1 + 3.0 -0.3 < V2 < -0.2 0.2 SI = V2/(-0.1) -0.1 < V2 < 0 SI = 1 -0.2 < V2 < -0.1 0.1 SI = 0 V2 > 0	SI = 0 V2 < -0.3 SI = V2/0.08 + 3.75 -0.3 < V2 < -0.22 SI = V2/(-0.08) -0.08 < V2 < 0 SI = 1 -0.22 < V2 < -0.1 0.08 SI = 0 V2 > 0
V ₄ (Edge)	SI = 0 V4 < 0 SI = 0.1V4 0 < V4 < 10 SI = 1 V4 > 10	SI = 0 V4 < 0 SI = 0.05V4 0 < V4 < 5 SI = 0.15V4 - 0.5 5 < V4 < 10 SI = 1 V4 > 10	SI = 0 V4 < 0 SI = 0.15V4 0 < V4 < 5 SI = 0.05V4 + 0.5 5 < V4 < 10 SI = 1 V4 > 10
V ₅ (Salinity)	SI = 1 - 0.1V5 0 < V5 < 10 SI = 0 V5 > 10	SI = 1 - 0.091V5 0 < V5 < 11 SI = 0 V5 > 11	SI = 1 - 0.0833V5 0 < V5 < 12 SI = 0 V5 > 12

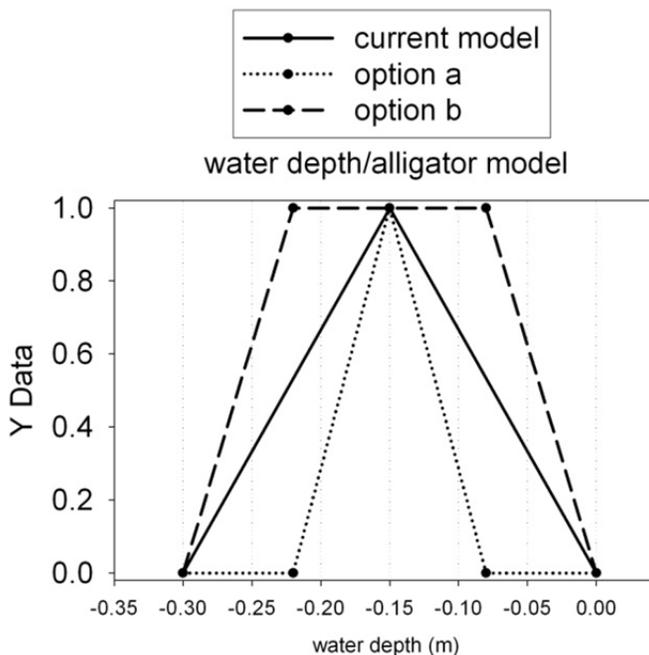


Figure 7. Variations in the assumed tolerance of American alligators to monthly average water depth assessed during uncertainty analyses.

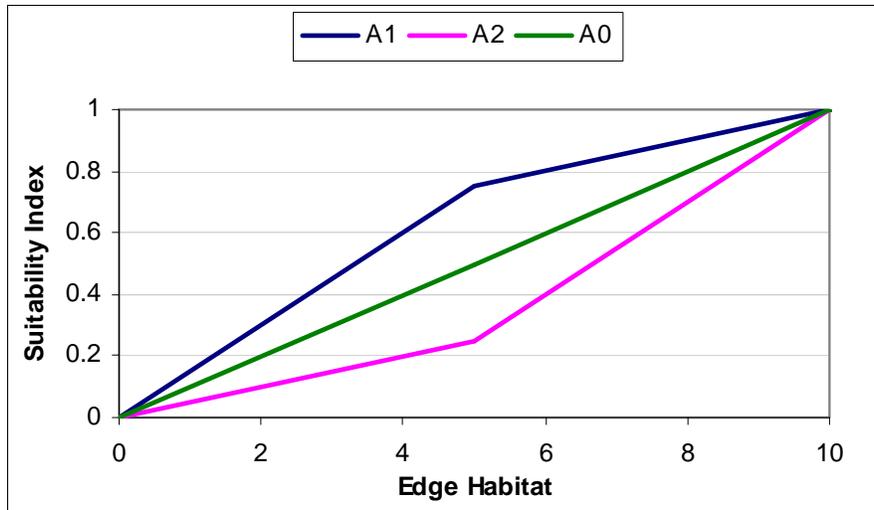


Figure 8. Variations in the suitability of edge habitat of American alligators to be assessed during uncertainty analyses.

9. References

- Anderson SH, Gutzwiller KJ (2005) Wildlife habitat evaluation. In: Braun CE (ed.) Techniques for wildlife investigations and management, 6th edn. The Wildlife Society, Bethesda, MD, pp 489–502.
- CPRA. 2007. Integrated Ecosystem Restoration and Hurricane Protection: Louisiana’s Comprehensive Master Plan for a Sustainable Coast. Coastal Protection and Restoration Authority, Baton Rouge, Louisiana.
- Conzelmann, C., and Romañach, S.S., 2010, Visualizing NetCDF Files by Using the EverVIEW Data Viewer: U.S. Geological Survey Fact Sheet 2010–3046.
- Draugelis-Dale, Rassa. 2007. Assessment of effectiveness and limitations of habitat suitability models for wetland restoration. U.S. Geological Survey Open File Report 2007-1254, 136p.
- Foret, J.D., J.A. Nyman, L.P. Rozas, K.A Rose, J.H. Cowan, and D. Baltz. 2004. Habitat Use Module. Louisiana Coastal Area - Ecosystem Restoration Study, Volume 4, Appendix C, Chapter 10. U.S. Army Corps of Engineers, New Orleans District.
- Joanen, T., and L. McNease. 1987. The management of Alligators in Louisiana, USA. pages 33-42 in G.J.W. Webb, S.C. Manolis, and P.J. Witehead (eds.) Wildlife management: crocodiles and alligators. Surrey Teatty and Sons Pty Limited, Chipping Norton, Australia.
- Joanen, T., L. McNease, G. Perry, D. Richard, and D. Taylor. 1984. Louisiana's alligator management program. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38:210-211.
- Kaminski, R.M., H.H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. Journal of Wildlife Management 45:1-15.
- Kinler, Q.J., R.H. Chabreck, N.W. Kinler, and R.G. Linscombe. 1990. Effect of tidal flooding on mortality of juvenile muskrats. Estuaries 13:337-340.
- La Peyre, M.K., B. Gossman, and J.A. Nyman. 2007. Assessing functional equivalency of nekton habitat in enhanced habitats: Comparison of terraced and unterraced marsh ponds. Estuaries and Coasts 33 (3), 526-536.
- LDWF. 2008. Louisiana’s Alligator Management Program 2008-2009 Annual Report Presented to the House Committee on Natural Resources and Environment and the State Committee on

APPENDIX D-5 AMERICAN ALLIGATOR HABITAT SUITABILITY INDEX TECHNICAL REPORT

- Natural Resources. Prepared by the Louisiana Department of Wildlife and Fisheries, Office of Wildlife, Coastal and Nongame Resources Division. December 2008.
- LDWF. 2009. Louisiana's Alligator Management Program 2008-2009 Annual Report Presented to the House Committee on Natural Resources and Environment and the State Committee on Natural Resources. Prepared by the Louisiana Department of Wildlife and Fisheries, Office of Wildlife, Coastal and Nongame Resources Division. December 2009.
- Minello T.J., R.J. Zimmerman, and R. Medina. 1994. The importance of edge for natant macrofauna in a created salt marsh. *Wetlands* 14:184-198.
- Newsom, J.D., T. Joanen, and R. Howard. 1987. Habitat suitability index model: American alligators. Biological Report 82(10.136). National Wetlands Research Center, Fish and Wildlife Service, U.S. Dept. of the Interior, Washington, D.C.
- Nyman, J.A., M.K. La Peyre, A. Caldwell, S. Piazza, C. Thom, C. Winslow. 2009. Defining restoration targets for water depth and salinity in wind-dominated *Spartina patens* (Ait.) Muhl. coastal marshes. *Journal of Hydrology* 376:327-336.
- O'Connell, and J.A. Nyman. 2010. Marsh terraces in coastal Louisiana increase marsh edge and densities of waterbirds. *Wetlands*. 30:125-135.
- Platt, S.G., R.W. Hastings, and C.G. Brantley. 1995. Nesting ecology of the American Alligator in southeastern Louisiana. *Proceedings of the Southeastern Association of Fish and Wildlife Agencies* 49:629-639.
- Prolux, G., and F.F. Gilbert. 1983. The ecology of the muskrat, *Ondatra zibethicus* at Luther Marsh, Ontario. *Canadian Field Naturalist* 97:377-390.
- Rozas, L. P. and R. J. Zimmerman. 2000. Small-scale patterns of nekton use among marsh and adjacent shallow nonvegetated areas of the Galveston Bay Estuary, Texas (USA). *Marine Ecology Progress Series* 193:217-239.
- Shoop, C.R., and C.A. Ruckdeschel. 1990. Alligators as predators on terrestrial mammals. *American Midland Naturalist* 124:407-412.
- Tarver, J., G. Linscombe, and N. Kinler. 1987. Fur animals, alligator, and the fur industry in Louisiana. *Miscellaneous publications of the Fur and Refuge Division, Louisiana Department of Wildlife and Fisheries, Baton Rouge, Louisiana.* 74pp.
- Wolfe, J.L., and D.K. Bradshaw, and R.H. Chabreck. 1987. Alligator feeding habits: new data and a review. *Northeast Gulf Science* 9:1-8.