Model Name: White Shrimp Habitat Suitability Index

Functional Area: Ecosystem Services / Upper Trophic Level

Model Proponents: Coastal Protection and Restoration Authority

Model Developer(s): Donald Baltz, Louisiana State University

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.

Table of Contents

1. *Background*

a. *Purpose of Model*

The approach taken to develop this model involved examining previously existing habitat suitability index (HSI) models for white shrimp as developed for the Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) program and utilized for the Louisiana Coastal Area (LCA) planning effort (Twilley et al. 2003) as well as older, longer standing models (Turner and Brody, 1982). The purpose of this white shrimp HSI model is to compare the effects of various coastal protection and restoration projects on habitat quality for white shrimp in coastal Louisiana. The model was created to provide information for consideration by the State of Louisiana in its preparation of the 2012 Coastal Master Plan. This model will assist the Coastal Protection and Restoration Authority (CPRA) and other water management agencies (e.g., U.S. Army Corps of Engineers) in evaluating the benefits and impacts of various protection and restoration projects. In addition, this model can be used to indicate habitat suitability in a scenario with no increased future action.

b. Model Description and Depiction

A Habitat Suitability Index (HSI) is defined as a numerical index that represents the capacity of a given habitat to support a selected fish or wildlife species. This index is an estimate or measure of habitat conditions in the study area divided by the optimum habitat conditions for the same evaluation species (Turner and Brody 1983). The HSI has a range of zero to one, with zero representing unsuitable habitat and one representing optimum habitat. This model does not consider or estimate population size, dynamics or recruitment; it only estimates suitable habitat. This white shrimp HSI model is based on the juvenile life stage and uses food/cover (marsh type) and water quality (salinity and water temperature) conditions to estimate habitat suitability.

An HSI for the white shrimp, *Litopenaeus setiferus*, was developed in 1983 for the US Fish & Wildlife Service (Turner and Brody 1983). The index was then modified for the CLEAR effort in 2003 (Foret et al. 2003). For the 2012 Coastal Master Plan modeling effort, the model has been further modified based on analysis of Louisiana Department of Wildlife and Fisheries (LDWF) data for juveniles from the shrimp monitoring programs (LDWF 2002) based on 16 foot otter trawls and beach seines.

HSI curves (Baltz 1993) for monitoring data were developed by using all samples to characterize habitat availability, and a subset of the same data set (from capture sites for species and size classes of interest) was used to characterize habitat use. Juvenile size classes for life history stages were determined from literature and cut-off sizes were estimated as the size of maturity and a smaller size for early life history stages (Table 1). In consultation with LDWF biologists, the initial curves from CLEAR models were compared to newly developed curves from trawl and seine data sets to develop generalized salinity and temperature curves.

Table 1. Life history stages were assigned to size classes (SC1-3) based on size at maturity and other information in the literature. Sample sizes in the analyses are indicated for trawl and seine data bases (e.g., $N_{t/s}$ = 620/3816).

Species	ELH (SC1)	Juvenile (SC2)	Adult or SC3*	References
White shrimp	LE 28 $N_{t/s}$ = 44151/4868	GE 28 mm TL (28-135) $N_{t/s}$ = 4.6M/75247	135-155 mm TL $N_{t/s}$ = 136496/265	Shrimp Management Plan 1981 citing Perez Farfante 1969

Sample sizes were deemed inadequate for some early life history stages (SC1) and adults (SC3), so the emphasis was placed on modeling juveniles (SC2) (Table 1). After reviewing shrimp monitoring data sets and other sources, the model developer did not find significant justification to greatly modify the previously existing HSI curves.

Patterns of habitat suitability for juvenile white shrimp in seine and trawl data bases were similar to the HSI curves reported in 2003. Salinity patterns near the optimum range were only slightly lower in the current analysis but there may be a slight downward bias due to enhanced catchability at low temperatures (Figure 1). Temperature patterns for juveniles in the seine data set closely approximated the old HSI curve (Figure 2).

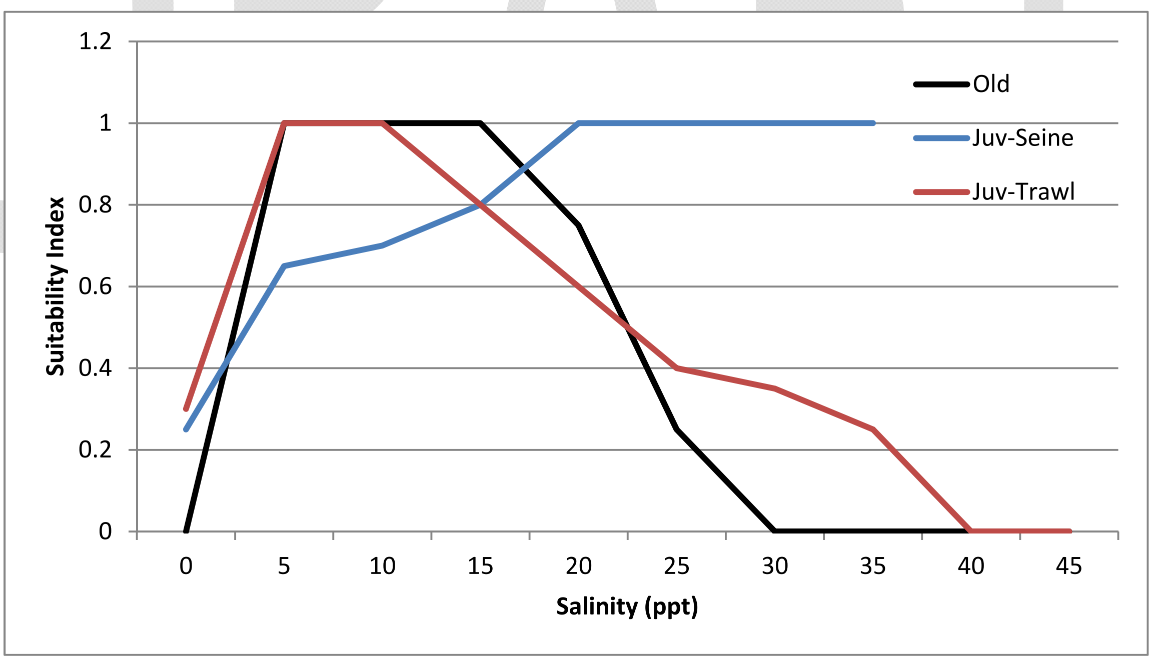


Figure 1. White shrimp salinity suitability curves.

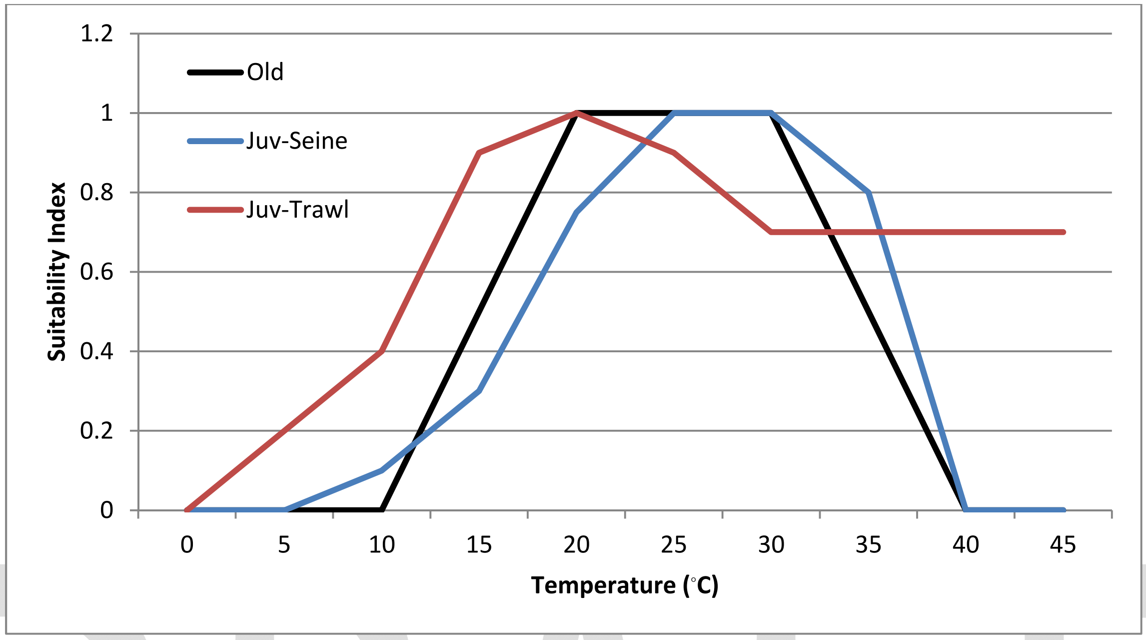


Figure 2. White shrimp temperature suitability curves.

c. Contribution to Planning Effort

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

d. Description of Input Data

Running this model requires several input data sets. From the Eco-Hydrology model, monthly salinity (parts per thousand) and monthly water temperature (degrees Celsius) are required. From the Vegetation model, the percent of marsh vegetation in a 500 m^2 cell size is required. All of these input data sets are converted from their native format into netCDF format.

The inputs and outputs to the White Shrimp 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 of zero to one, with zero representing unsuitable habitat and one 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 US 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

This model is adequate for assessing large-scale habitat suitability in response to changes in salinity, temperature, and the coastal vegetation. As constructed, the HSI value describes the ability of each spatial unit (500 m x 500 m grid cell) to support a population of white shrimp. This model does not consider or estimate population size, dynamics or recruitment. Proper interpretation of this model is one of comparative analysis rather than as a definitive measure of absolute values. Comparisons across geographic locations in similar time periods or for similar geographic locations across different time periods are appropriate.

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

The Turner and Brody (1982) White Shrimp HSI model included variables for food/cover and water quality in relation to post-larval and juvenile life stages. Water quality was divided into salinity and water temperature. Salinity consisted of the mean monthly summer salinity. Water temperature consisted of the mean monthly summer water temperature. Food/cover was divided into the percentage of study area with submerged and emergent vegetation and substrate composition. The geometric mean of temperature and salinity was compared to the geometric mean of vegetation and substrate (with vegetation doubly weighted) and the lower of the two was kept as the HSI.

When the model was revised for the CLEAR program, all of the suitability functions were combined into one geometric mean with vegetation doubly weighted. Substrate was removed from the equation due to lack of available data. The suitability function for vegetation was modified based on relationships between nekton populations and marsh-water patterns shown by Minello and Rozas (2002).

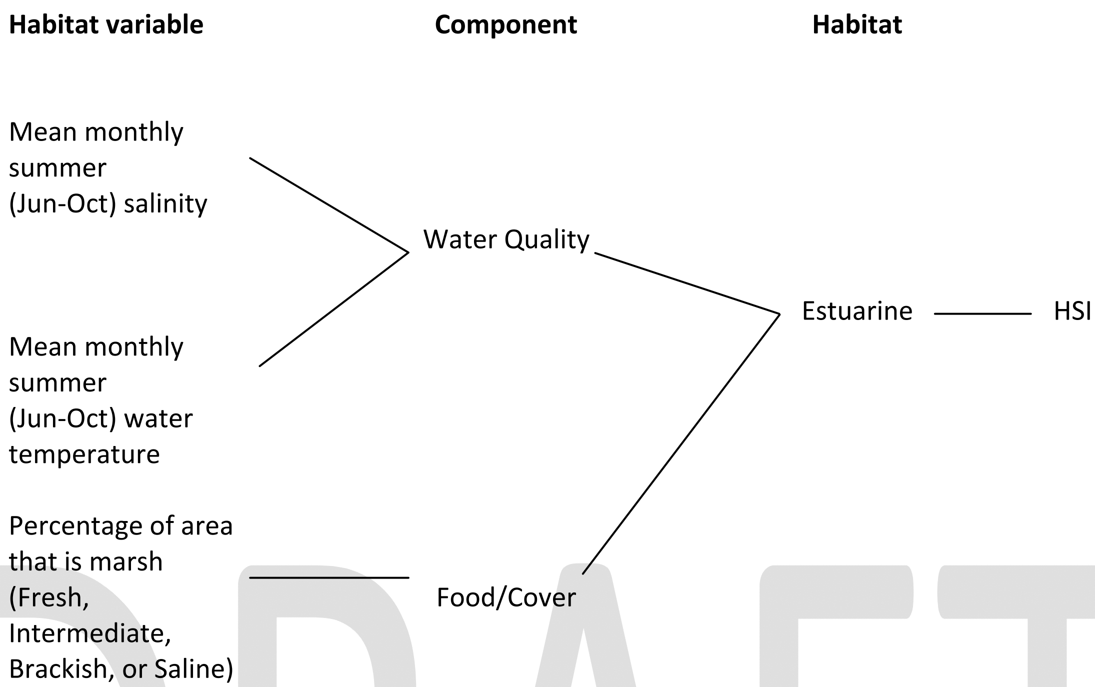
After review of LDWF databases on shrimp monitoring and consultation with LDWF staff, the suitability functions for temperature and salinity were updated for this effort. The model now includes the mean monthly summer salinity, the mean monthly summer water temperature, and percentage of the area that is covered by marsh vegetation (sum of fresh, intermediate, brackish and saline marsh habitat type).

2. Technical Quality

a. Theory

The white shrimp HSI model predicts the suitability of habitat for the juvenile life stage. This stage is sensitive to environmental variation and is assumed to be important in contributing to population size (Turner and Brody 1983). An index between zero (unsuitable habitat) and one (optimal habitat) is generated by this model.

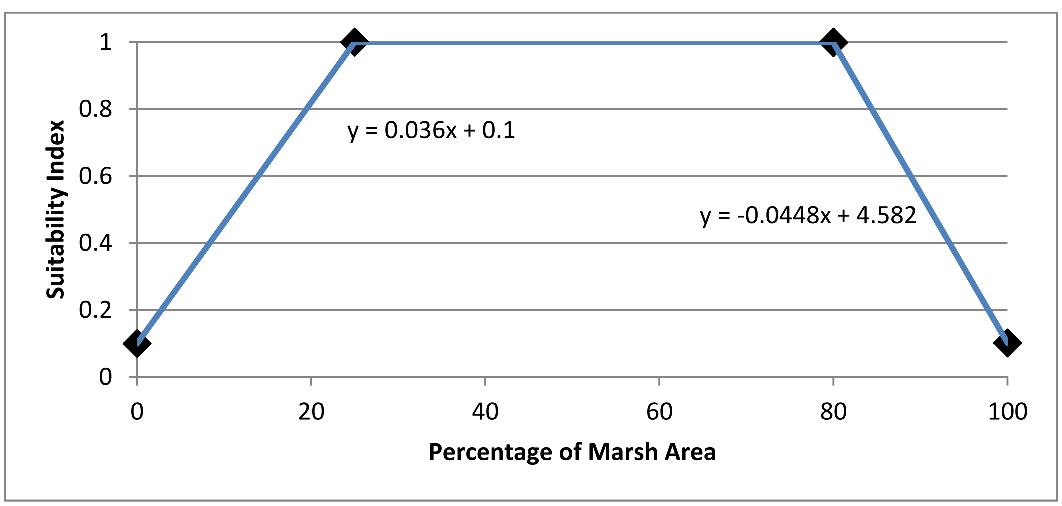
The model is generated by using two primary habitat components: water quality & food/cover.



The variables included in this model are: V1 - Percentage of area km^2 that is land, V2 - Mean salinity for summer (June - October), and V3 - Mean water temperature for summer (June - October). The model outputs on a yearly time step for a period of 50 years.

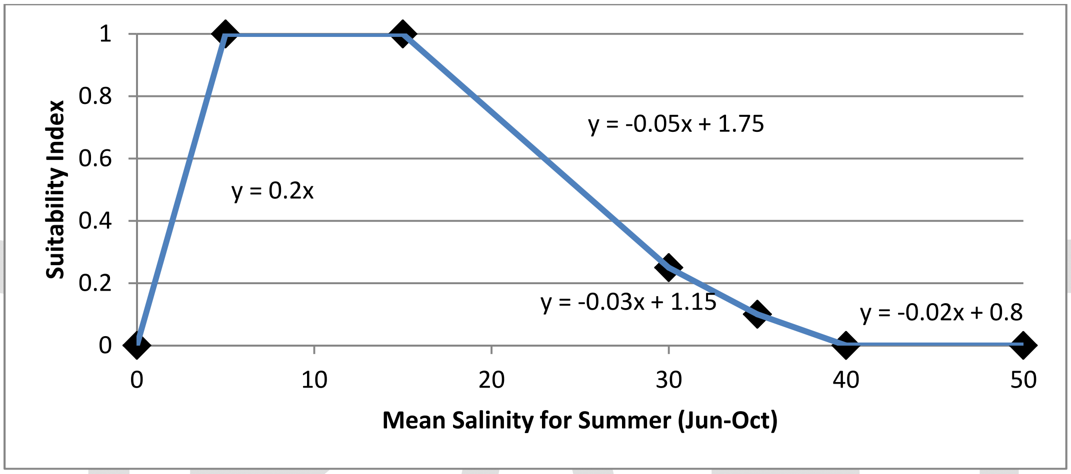
Variable 1: Percentage of Area (km2) Covered by Marsh Vegetation

$$SI_1 = \begin{cases} 0.036 * V1 + 0.1 & \text{for } 0 \le V1 \le 25 \\ 1.0 & \text{for } 25 < V1 \le 80 \\ 4.582 - 0.0448 * V1 & \text{for } 80 < V1 \le 100 \end{cases}$$



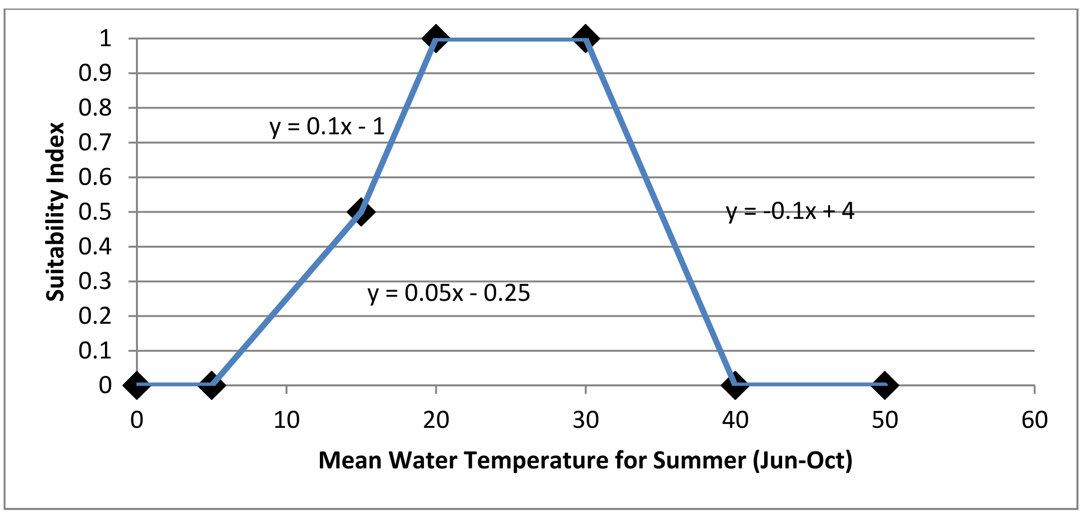
Variable 2: Mean Salinity for Summer (June-October)

SI_2 =	0.2 * V2	for V2 ≤ 5
	1.0	for 5 < V2 ≤ 15
	-0.05 * V2 + 1.75	for 15 < V2 ≤ 30
	-0.03 * V2 + 1.15	for 30 < V2 ≤ 35
	-0.02 * V2 + 0.8	for 35 < V2 ≤ 40
	0.0	for V2 > 40



Variable 3: Mean Water Temperature for Summer (June-October)

SI_3 =	0.0	for V3 ≤ 5
	0.05 * V3 - 0.25	for 5 < V3 ≤ 15
	0.1 * V3 - 1.0	for 15 < V3 ≤ 20
	1.0	for 20 < V3 ≤ 30
	-0.1 * V3 + 4.0	for 30 < V3 ≤ 40
	0.0	for V3 > 40



Habitat Suitability Index
The formula for combining the variables is: $HSI = (SI_1^2 \times SI_2 \times SI_3)^{1/4}$

b. Description of system being represented by the model
This model predicts presence of suitable habitat for white shrimp within each 500 m x 500 m grid cell per year. It does not predict population abundance, density, or dynamics. This model is dependent on water temperature, salinity, and percent of vegetation.

c. Analytical requirements
In order to adequately investigate white shrimp habitat suitability, several key factors were identified: percentage of vegetation, mean salinity for summer (June - October), and mean water temperature for summer (June - October).

d. Assumptions
Various assumptions were made in the development of this model. The HSI value is assumed to share a linear relationship with species carrying capacity. This assumption has not been field tested, thus this model is a hypothesis. This model represents habitat suitable for juvenile life stages of white shrimp and neither spawning nor larval habitat is represented. The model is applicable to the Northern Gulf of Mexico. The vegetated area, in or near a bay estuary is directly proportional to the habitat's long-term carrying capacity. Finally, contiguous hydrologic connections within marsh are assumed.

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 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 developed for this model can run on common desktop computers 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. The model outputs are produced in netCDF format, which can be viewed using EverVIEW.

d. Description of process used to test and validate model

Model outputs were reviewed by CPRA staff and master plan advisors. 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 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 method 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.

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 EverVIEW software 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 model requires readily available or predictable data on temperature, salinity, and coastal vegetation. These parameters are either monitored or may be modeled. Some of the required input data was provided as output from the Eco-Hydrology and Vegetation models. Some data could be obtained through the Coastwide Reference Monitoring System (CRMS), which is the monitoring system utilized to support projects constructed under the Coastal Wetlands Planning Protection and Restoration Act (CWWPRA). Those data can be accessed via the internet at http://www.lacoast.gov/crms2/Home.aspx. 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 zero to one that represents the white shrimp habitat suitability of a 500m^2 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 white shrimp habitat suitability. Therefore, projects such as diversions that result in changes to water salinity, temperature, 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 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 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

This model relies on measured data as well as modeled inputs. As with all data, errors occur during measurement, and as with all modeled data, model outputs are estimates with varying levels of confidence. Other errors from the omission of important variables, such as turbidity and substrate type, may cause model uncertainty.

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 fishery data were available. In addition, the model could be improved by including additional variables such as turbidity, bottom substrate type, food source, refuge from predators, and additional life history stages such as early life history stages and adults.

7. Quality review

Specific quality review procedures for the white shrimp HSI included comparison of modeled predictions with expected outcomes given the known inputs. The model developer as well as internal CPRA staff used known and observed spatial patterns and temporal patterns in input data to predict habitat suitability for white shrimp.

8. *Uncertainty analysis*

No uncertainty analysis was performed for this model.

9. *References*

Baltz, D. M. 1990. Autecology. In: Schreck CB, Moyle PB (ed) Methods for fish biology. Am Fish Soc, Bethesda. pp 585-607.

Conzelmann, C., and Romañach, S.S., 2010, Visualizing NetCDF Files by Using the EverVIEW Data Viewer: U.S. Geological Survey Fact Sheet 2010–3046.

Foret, J.D., J.N. Nyman, L.P. Rozas, K.H. Rose, J.H. Cowan, and D. Baltz. 2003. Habitat Use Model, Chapter 10. In, R.R. Twilley. Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) model of Louisiana Coastal Area (LCA) comprehensive ecosystem restoration plan. Volume I: Tasks 1-8. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, Louisiana. Contract No. 2511-02-24. 319 pp.

LDWF (Louisiana Department of Wildlife and Fisheries). 2002. Marine fisheries division field procedure manual. Version 02-1. LDWF.)

Minello, T.J. and L.P. Rozas. 2002. Nekton in Gulf Coast wetlands: fine-scale distributions, landscape patterns, and restoration implications. Ecological Applications 12:441-455.

Turner R.E. and M.S. Brody. 1983. Habitat suitability index models: northern Gulf of Mexico brown shrimp and white shrimp. U.S. Department of the Interior Fish and Wildlife Service, FWS/OBS-82/10.54. 24 p.

Twilley, R. R. 2003. Conceptual Ecological Models for Planning and Evaluation of LCA Restoration Program, Chapter 1. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Model of Louisiana Coastal Area (LCA) Comprehensive Ecosystem Restoration Plan. Volume I: Tasks 1-8. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2511-02-24. 319 pp.