Model Approval Plan Model Documentation Attachments

BLUEGILL WINTER HABITAT SUITABILITY INDEX MODEL

Attachment 4-1.
Palesh, G. and D. Anderson. 1990. Modification of the habitat suitability index model for the bluegill (Lepomis macrochirus) for winter conditions for the Upper Mississippi River backwater habitats (9 pp.)

Attachment 4-2.
Modification of Bluegill Habitat Model – Model Approval Documentation (15 pp.)

Attachment 4-3.
Bluegill Winter HSI Model life requisite components modification documentation (1 pp.)

Attachment 4-4.

Attachment 4-5

Attachment 4-6
Bluegill HSI Model Review – Final Panel Comment and Proponent Response Discussion Meeting (16 pp.)
Modification of the Habitat Suitability Index Model for the Bluegill (Lepomis macrochirus) for Winter Conditions for Upper Mississippi River Backwater Habitats

by

Gary Palesh and Dennis Anderson

January 1990

St. Paul District
Corps of Engineers
Modification of the Habitat Suitability Index Model for the Bluegill (*Lepomis macrochirius*) for Winter Conditions for Upper Mississippi River Backwater Habitats

by

Gary Palesh and Dennis Anderson

The current U.S. Fish and Wildlife Service Habitat Suitability Index (HSI) Model (Stuber et al., 1982) does not contain any variables that allow for the consideration of winter habitat conditions. In northern climates, where ice cover can last for five months, winter habitat conditions take on great importance in an evaluation of the quality of aquatic habitat for the bluegill as well as other fish species.

The St. Paul District, Corps of Engineers (Corps) is involved in the management of the Upper Mississippi River (UMR) through operation and maintenance of the 9-Foot Navigation Channel project, and through the Upper Mississippi River Environmental Management Program. Under the Environmental Management Program, the Corps, along with the U.S. Fish and Wildlife Service and the States bordering the river, is evaluating various measures to enhance habitat quality for fish and wildlife. As the bluegill is one of the most common and sought after sport fish on the UMR, many projects are designed to improve habitat conditions for this species.

We have found that the absence of winter habitat variables in the existing bluegill habitat suitability index model limits its usefulness as a planning and evaluation tool. We therefore undertook to modify the model to include variables that address winter habitat conditions.

PROCEDURES

Important considerations in the decision on how to accomplish the task of modifying the model were time and money. Time was the most important consideration in that the Environmental Management Program is an active, ongoing effort, and we wanted to develop a usable product within as short a time as practicable. Because funding within the program is limited, we had to develop a usable product at a minimum of cost.

There has been only limited investigation into the winter habitat requirements of the bluegill on the UMR for factors other than dissolved oxygen. This is changing with increased recognition that other factors may be impacting the suitability of winter habitat for bluegills in many backwater areas of the UMR. Because of the general lack of research in this area, we believe that the best knowledge concerning the winter habitat requirements of the bluegill on the UMR lies with the State and Federal fishery biologists who manage the resource. We used a modified version of the Delphi process to tap this knowledge base.

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We internally identified dissolved oxygen, water depth, current velocity, and water temperature as probably the most important variables affecting the value of winter habitat for the bluegill on the UMR. We then developed draft suitability index curves for each of these variables. We also modified the life requisite component formulas for cover, water quality, and other from the existing Fish and Wildlife Service (FWS) habitat suitability index model to incorporate these winter habitat variables.

We sent the above material to eight State and Federal fisheries biologists currently involved in management of fishery resources of the UMR. This group included representatives of the U.S. Fish and Wildlife Service, Iowa Department of Natural Resources, Minnesota Department of Natural Resources, and Wisconsin Department of Natural Resources. Responses were received from six of the eight individuals.

We modified the suitability index curves based on comments received from the reviewing biologists. The next iteration of the review process involved sending this same group a draft of this report. Comments received on the draft report and draft suitability index curves were incorporated into this report.

APPLICABILITY

This model is a modification of the riverine portion of the existing U.S. Fish and Wildlife Service bluegill habitat suitability index model (Stuber et al., 1982). The area of applicability includes the backwater lakes, ponds, sloughs, etc., of pools 1 through 10 of the Upper Mississippi River.

WINTER HABITAT VARIABLES

Basic Components

Using the five basic components identified in the existing FWS habitat suitability index model - food, cover, water quality, reproduction, and other - as a starting point, we looked at what were the most significant factors contributing to the value of winter bluegill habitat on the UMR within these general components.

Food - It is recognized empirically, and in the literature, that bluegills have a low food requirement in the winter in northern climates (Becker, 1983; Carlander, 1977; Moffett and Hunt, 1973) due to a slowed metabolism brought about by low water temperatures (Carlander, 1977; Lagler et al., 1962). In addition, in a eutrophic environment such as the UMR, it is unlikely that food for generalist feeders such as the bluegill (Becker, 1983; Carlander, 1977; Snow et al., 1970) is ever a significant limiting factor. Therefore, we believe that food is not an important component in evaluating the quality of winter bluegill habitat on the UMR and as such, a food component should not be be included in a winter habitat suitability model.

Cover - We identified water depth and aquatic vegetation as the two most important variables affecting winter cover for bluegills on the UMR. Aquatic vegetation provides physical protection from predators, while water depths
provide cover in terms of space and darkness. We decided not to consider aquatic vegetation at this time as a variable for winter habitat quality evaluation because it would be a difficult parameter to predict for under ice cover conditions, it would be a parameter very difficult to quantitatively measure under those conditions, and very little is known concerning bluegill vegetation preferences under ice cover conditions.

We decided to use water depth as a winter cover variable because of its importance and because it is a relatively easy variable to predict or measure.

**Water Quality** - Dissolved oxygen and water temperature were identified as the two water quality variables of concern under ice cover conditions. Dissolved oxygen is essential for most aquatic life, and the depletion of dissolved oxygen and associated fishkills in the winter in northern climates has been well documented (Schneberger, 1970).

The effect of winter water temperatures on freshwater fish in terms of lower lethal temperature has not received a lot of attention in the past in fisheries management on the UMR. Over the last few years, fishery biologists on the UMR have become increasingly aware that winter water temperatures may play an important role in fish survival and/or habitat use. This takes on increased importance on the UMR where the main channel stays open in many locations year round and this water may become super cooled (< 0 degrees C). Introduction of this supercooled water into backwater habitats could impact habitat suitability for the bluegill and other fish species (Sheehan et al., 1988).

**Reproduction** - Since reproduction for the bluegill is exclusively a warm season activity (Becker, 1983; Carlander, 1977), there is no reason to consider any variables for reproduction when evaluating winter habitat suitability.

**Other** - Under the other component, we identified current velocity as a winter habitat variable of importance for the bluegill. As with water temperature, winter current velocity has not received a great deal of management consideration in the past on the UMR. Fishery biologists on the UMR have become increasingly aware over the last few years that even minor currents appear to have an impact on bluegill winter habitat use in UMR backwater habitats.

**Suitability Index Curves**

**Water Depth** - The suitability index (SI) curve for the winter water depth variable ($V_d$) is shown on figure 1. Water depth conditions are considered optimum when 50 percent or more of a backwater area is 4 feet deep or greater at normal pool elevation.

**Dissolved Oxygen** - The SI determination for the winter dissolved oxygen variable ($V_o2$) is shown on figure 1. A dissolved oxygen level of 5 mg/l or greater is considered optimum. This variable is a duplicate of variable $V_d$ in the existing FWS model which addresses summer dissolved oxygen levels.
Figure 1
Water Temperature - The SI curve for the winter water temperature variable ($V_c$) is shown on figure 2. A water temperature of 4 degrees C is considered the optimum condition, with any temperature below 4 degrees C considered less than optimum.

Current Velocity - The SI curve for the winter current velocity variable ($V_d$) is shown on figure 2. Zero current is considered the optimum condition, with any current present considered suboptimal.

CALCULATION OF THE HABITAT SUITABILITY INDEX

Because the summer and winter life requisites of the bluegill are so different (i.e., a time of reproduction and growth vs. a time of semi-dormancy and survival), we believe it is appropriate to calculate separate summer and winter HSI. The summer HSI would be calculated using the methods described in the existing FWS habitat suitability index model. The winter HSI would be calculated as follows.

Winter Cover

\[ C_{w-c} = V_a \]

Winter Water Quality

\[ C_{w-wq} = \frac{(2V_b + V_c)}{3} \]

In $V_b$ or $V_c \leq 0.4$, $C_{w-wq}$ equals the lowest of these variables.

Winter Other

\[ C_{w-ot} = V_d \]

Winter HSI Determination

Winter HSI = \( (C_{w-c} \times C_{w-wq}^2 \times C_{w-ot})^{1/4} \)

If $C_{w-wq}$ is $\leq 0.4$, use this value as the winter HSI.

Determination of Overall HSI

Two methods are suggested for determination of an overall HSI value for a particular UMR backwater habitat.

Scenario 1

The backwater habitat being evaluated is a relatively isolated area that must serve as both the summer and winter habitat for the resident bluegill population. The lowest quality habitat (summer or winter) will likely be the limiting factor on the bluegill population.

Overall HSI = the lowest of the summer HSI or winter HSI
WINTER WATER TEMPERATURE

CURRENT VELOCITY

Figure 2
Scenario 2

The backwater habitat being evaluated is well connected to other suitable habitat for bluegill such that it does not have to provide both summer and winter habitat for survival of a particular bluegill population.

\[ \text{Composite HSI} = (\text{summer HSI} \times \text{winter HSI})^{1/2} \]

SUMMARY

This modification of the existing FWS habitat suitability index model for the bluegill was undertaken to incorporate variables that allow for the consideration of winter habitat conditions. Currently, there is limited research-generated information concerning the winter habitat requirements for the bluegill in Upper Mississippi River backwaters. We expect that, as this information becomes available, the model will continue to be modified to take advantage of new information.
REFERENCES


Model Name: A Modification of US Fish and Wildlife Service’s Habitat Suitability Index Model for Bluegill (*Lepomis macrochirus*) for Winter Conditions for Upper Mississippi River Backwater Habitats (see attached).

Functional Area: Upper Mississippi River and similar northern temperate waters.

Model Proponent: USACE – St. Paul District

Model Developer: Dennis Anderson, USACE-St. Paul District
Model Documentation as identified in Protocols for Certification of Planning Models by Almodovar et al. 2007 below.

1. **Background**
   a. **Purpose of Model:** To incorporate variables in the USFWS’s Bluegill HEP model to account for winter conditions in northern climates.

   b. **Model Description and Depiction:** See page 1 of attachment

   c. **Contribution to Planning Effort:** Provides approach for evaluating effects of proposed actions on bluegills, including winter ice conditions.

   d. **Description of Input Data:** Variables for input into the model are: 1) Water Depth, 2) Dissolved Oxygen, 3) Water Temperature, and 4) Current Velocity. See Pages 3-6 of attachment.

   e. **Description of Output Data:** The model outcome is a Habitat Suitability Index (HSI) with a value from 0 to 1).

   f. **Statement on the capabilities and limitations of the model:** The HSI model provides habitat information useful for impact assessment. The model is a hypothesis of species-habitat relationships and does not reflect proven cause and effect relationships.

   g. **Description of model development process including documentation on testing conducted (Alpha and Beta tests):** Page 1 and 2 of attachment. Model is based on information from other models, scientific literature and input from resource professionals knowledgeable of species requirements. Model drafts were reviewed and comments incorporated into final versions of the model.

2. **Technical Quality**
   a. **Theory:** Page 2 of attachment. The current U.U. Fish and Wildlife Service Habitat Suitability Index Model (Stueber et al., 1982) does not contain variables that allow for the consideration of winter habitat conditions. In northern climates, where ice cover can last five months, winter habitat conditions take on a great importance in an evaluation of the quality of aquatic habitat for bluegill and other fish species. Therefore, we modified the model to address the limitations with the existing bluegill model.
o **Description of system being represented by the model:** The Upper Mississippi River. The model was developed to address potential quality of habitat conditions for bluegill throughout the seasons in large riverine systems and associated backwaters.

b. **Analytical requirements:** The simple arithmetic calculations for this model are made using a MS Excel spreadsheet.

c. **Assumptions:** A major assumption is that an increase in habitat value results in an increase in carrying capacity.

d. **Conformance with Corps policies and procedures:** This information was developed for the model certification process, which is a requirement for the Corps as stated in EC 1105-2-407, “Planning Models Improvement Program: Model Certification.” This documentation follows guidance provided in the July 2007 Protocols for Certification of Planning Models, Planning Models Improvement Program.

e. **Identification of formulas used in the model and proof that the computations are appropriate and done correctly:** The formula used to calculate the HSIs are incorporated into the Excel spreadsheet. The model spreadsheet has been set-up to enter data and automatically populate the HIS for the variable. Some limited amount of user guide information has been entered into the model. Use of the spreadsheets will still require user knowledge concerning how HIS values are determined and thorough knowledge of the model documentation. The spreadsheet was developed by two individuals, who cross QA each other's work.

3. **System Quality**

a. **Description and rationale for selection of supporting software tool/programming language and hardware platform:** The simple nature of this model allows the use of readily-available MS Excel software that can run on personal computers. It is also very suitable for entering into

b. **Proof that the programming was done correctly:** The simple arithmetic formulas incorporated into the spreadsheet have been checked and were found to be correct. Two individuals at MVP were tasked to program excel spreadsheets for several models and cross QA each other’s work to ensure programming and formula’s were correct.

Modifications to Bluegill Model
c. **Availability of software and hardware required by model:** The MS Excel software and personal computers required to run the model are readily available.

d. **Description of process used to test and validate model:** Page 2 of attachment – Verification Level. The model was not field validated prior to use but has been used on in planning numerous habitat improvement projects on the Upper Mississippi River. Pre and post project monitoring of several large habitat projects on UMR have documented improvements in winter habitat conditions and subsequent use by bluegills and other similar lentic species.

e. **Discussion of the ability to import data into other software analysis tools (interoperability issue):** The model is based on calculations using Excel spreadsheets. This software has strong capabilities to import/export the data into other software analysis tools.

4. **Usability**

a. **Availability of input data necessary to support the model:** In most cases, the model uses data that is readily available such as aerial images, long term monitoring data, existing bathymetric data or acquisition of data from field studies.

b. **Formatting of output in an understandable manner:** Data output is formatted in terms of Habitat Suitability Index values which is on a scale of 0 to 1 and is used (using the same Excel spreadsheet) to calculate Habitat Units averaged over the lifespan of the project (AAHUs). This is a common way of displaying project outputs and is easily transferrable to a cost effectiveness analysis.

c. **Usefulness of results to support project analysis:** The results of model output are directly relevant to support decisions on project alternatives and benefits. Direct comparisons of project alternatives are possible using the model outputs and associated costs.

d. **Ability to export results into project reports:** Output is in terms that are commonly used in project reports (i.e., HSI values).

Modifications to Bluegill Model
e. **Training availability**: This model uses simple mathematical equations and requires no formal training for application. The user need only be familiar with the use of Excel spreadsheets and the model documentation.

f. **Users’ documentation availability and whether it is user friendly and complete**: Additional details of the model are available from the St. Paul District. The model is user friendly and complete as it uses Excel spreadsheets and involves simple mathematical equations.

g. **Technical support availability**: If needed, technical support is available by contacting the model developer at the St. Paul District.

h. **Software/hardware platform availability to all or most users**: The model uses Microsoft Excel, a commonly available software application found on most personal computers.

i. **Accessibility of the model**: The model is available by requesting a copy of the spreadsheet from the St. Paul District.

j. **Transparency of model and how it allows for easy verification of calculations and outputs**: The excel spreadsheet allows a user to view all calculations in the model and resulting outputs.
Attachment

A Modification of US Fish and Wildlife Service’s Habitat Suitability Index Model for Bluegill (*Lepomis macrochirus*) for Winter Conditions for Upper Mississippi River Backwater Habitats
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**Reproduction** - Since reproduction for the bluegill is exclusively a warm season activity (Becker, 1983; Carlander, 1977), there is no reason to consider any variables for reproduction when evaluating winter habitat suitability.

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**Suitability Index Curves**

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CALCULATION OF THE HABITAT SUITABILITY INDEX

Because the summer and winter life requisites of the bluegill are so different (i.e., a time of reproduction and growth vs. a time of semi-dormancy and survival), we believe it is appropriate to calculate separate summer and winter HSI. The summer HSI would be calculated using the methods described in the existing FWS habitat suitability index model. The winter HSI would be calculated as follows.

Winter Cover

\[
C_{W-C} = V_a
\]

Winter Water Quality

\[
C_{W-WQ} = \frac{(2V_b + V_c)}{3}
\]

In \( V_b \) or \( V_c \leq 0.4 \), \( C_{W-WQ} \) equals the lowest of these variables.

Winter Other

\[
C_{W-OT} = V_d
\]

Winter HSI Determination

\[
\text{Winter HSI} = \left( C_{W-C} \times C_{W-WQ}^2 \times C_{W-OT} \right)^{1/4}
\]

If \( C_{W-WQ} \) is \( \leq 0.4 \), use this value as the winter HSI.

Determination of Overall HSI

Two methods are suggested for determination of an overall HSI value for a particular UMR backwater habitat.

Scenario 1

The backwater habitat being evaluated is a relatively isolated area that must serve as both the summer and winter habitat for the resident bluegill population. The lowest quality habitat (summer or winter) will likely be the limiting factor on the bluegill population.

Overall HSI = the lowest of the summer HSI or winter HSI
Scenario 2

The backwater habitat being evaluated is well connected to other suitable habitat for bluegill such that it does not have to provide both summer and winter habitat for survival of a particular bluegill population.

\[ \text{Composite HSI} = (\text{summer HSI} \times \text{winter HSI})^{1/2} \]

SUMMARY

This modification of the existing FWS habitat suitability index model for the bluegill was undertaken to incorporate variables that allow for the consideration of winter habitat conditions. Currently, there is limited research-generated information concerning the winter habitat requirements for the bluegill in Upper Mississippi River backwaters. We expect that, as this information becomes available, the model will continue to be modified to take advantage of new information.
REFERENCES


Trials have been conducted using the Modification for the Habitat Suitability Index Model for the Bluegill (Lepomis macrochirus) for Winter Conditions for Upper Mississippi River Backwater Habitats (Henceforth referred to as the "Winter HSI model"). During trials, a problem was discovered in the model’s wording that can cause poor cover and velocity conditions to not be accounted for in the Winter HSI calculation.

In certain situations, the Winter HSI score can be inflated by having a marginal ‘Winter Water Quality’ component index value along with poor ‘Winter Cover’ and ‘Winter Other’ index values. This is due to the original model wording which states that if the Water Quality component is below a threshold of 0.4, then the water quality score is used as the final winter HSI score. In this scenario, the Winter Cover and Winter Other components are not incorporated into the determination, even if they are very poor. Therefore, even if the Winter HSI equation would produce a lower value by incorporating all of the variables, the output will still consist of the inflated water quality value (see example below). This also means that if the Water Quality component is improved above 0.4 and the Winter Cover and Winter Other components are still poor, the Winter HSI can actually decrease in the current model, as it begins to account for the poor cover and velocity indices.

<table>
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<tr>
<th>Model Output Example:</th>
<th>Poor Water Quality</th>
<th>Improved Water Quality</th>
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<tbody>
<tr>
<td>C\textsubscript{W-C}</td>
<td>Winter Cover (Depth)</td>
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<tr>
<td>C\textsubscript{W-WQ}</td>
<td>Water Quality</td>
<td>0.40</td>
</tr>
<tr>
<td>C\textsubscript{W-OT}</td>
<td>Other (Current Velocity)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Original Model Winter HSI | 0.40 | 0.35
Modified Model Winter HSI | 0.28 | 0.35

Therefore, it is recommended that the model incorporate the following change of wording in the Winter HSI determination so that poor cover and velocity conditions are considered even if the water quality index value is low:

**Winter HSI Determination**

\[
\text{Winter HSI} = (C_{W-C} \times C_{W-WQ}^2 \times C_{W-OT})^{1/4}
\]

“If C\textsubscript{W-WQ} is \leq 0.4, use this value as the winter HSI.”
HABITAT SUITABILITY INDEX MODELS: BLUEGILL
HABITAT SUITABILITY INDEX MODELS: BLUEGILL

by

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Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior
Washington, D.C. 20240
This report should be cited as:

The habitat use information and Habitat Suitability Index (HSI) models presented in this document are an aid for impact assessment and habitat management activities. Literature concerning a species' habitat requirements and preferences is reviewed and then synthesized into HSI models, which are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Assumptions used to transform habitat use information into these mathematical models are noted, and guidelines for model application are described. Any models found in the literature which may also be used to calculate an HSI are cited, and simplified HSI models, based on what the authors believe to be the most important habitat characteristics for this species, are presented.

Use of the models presented in this publication for impact assessment requires the setting of clear study objectives and may require modification of the models to meet those objectives. Methods for reducing model complexity and recommended measurement techniques for model variables are presented in Appendix A.

The HSI models presented herein are complex hypotheses of species-habitat relationships, not statements of proven cause and effect relationships. Results of model performance tests, when available, are referenced; however, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, the FWS encourages model users to convey comments and suggestions that may help us increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send comments to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
2625 Redwing Road
Ft. Collins, CO 80526
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ACKNOWLEDGEMENTS

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BLUEGILL (Lepomis macrochirus)

HABITAT USE INFORMATION

General

The bluegill (Lepomis macrochirus) is native from the Lake Champlain and southern Ontario region through the Great Lakes to Minnesota, and south to northeastern Mexico, the Gulf States, and the Carolinas (Scott and Crossman 1973). The species has been widely introduced outside its native range (Pflieger 1975). Three subspecies are currently recognized: L. m. macrochirus (northcentral United States), L. m. speciosus (Texas and northern Mexico), and L. m. purpurascens (Atlantic and Gulf States) (Hubbs and Lagler 1958).

Age, Growth, and Food

Bluegills usually mature at age I or II (Schloemer 1939; James 1946; Cross 1951). The maximum known age is 11 years, but most live 1 to 4 years (Schloemer 1939; Carlander 1977). Maximum recorded size is 39 cm and 2.1 kg (Emig 1966).

Bluegills are opportunistic feeders which can alter their diet according to food availability (Keast and Webb 1966). Fry feed primarily on zooplankton and small insects (Werner 1969). Juveniles and adults feed on zooplankton, aquatic and terrestrial insects, and some plant materials (Scidmore and Woods 1960; Emig 1966; Scott and Crossman 1973).

Reproduction

Bluegills are repeat spawners and the spawning season may extend from spring through summer (Anderson, pers. comm.). Spawning occurs from 17 to 31° C, with peak spawning at 24–27° C (Clugston 1966; Emig 1966; Scott and Crossman 1973; Kitchell et al. 1974; Pflieger 1975). Bluegills are guarding, nest building lithophils (Balon 1975). Nests are usually found in quiet, shallow (1-3 m) water (Swingle and Smith 1943). Although spawning will occur over almost any substrate, fine gravel or sand is preferred (Stevenson et al. 1969; Pflieger 1975). Incubation time ranges from 1.5 to 5 days, depending on ambient water temperature (Morgan 1951; Childers 1967; Heckman 1969; Hall et al. 1970; Merriner 1971).

Specific Habitat Requirements

Bluegills are most abundant along shoreline areas in lentic and lentic-type environments such as ponds, lakes, reservoirs, and large low velocity streams (Whitmore et al. 1960). In riverine habitats, bluegills are mostly restricted to areas of low velocity (Hubbs and Lagler 1958). Adult bluegills were captured primarily in backwater areas of the Missouri River (Kallemy and Novotny 1977). Hardin and Boeve (1978) developed probability of use curves showing that adults prefer current velocities < 10 cm/sec but will tolerate up to 45 cm/sec. Abundance has been positively correlated to a high percent (> 60%) pool area and negatively correlated to a high percent riffle/run area.
(Moyle and Nichols 1973). Optimal stream gradient (≤ 0.5 m/km) is based on the preference for low gradient, lentic-type waters (Troutman 1957).

Optimal lacustrine habitat is characterized by fertile lakes, ponds, and reservoirs with extensive (≥ 20% of lacustrine surface area) littoral areas (Emig 1966; Scott and Crossman 1973). However, deeper areas are also required for overwintering and retreat from the summer heat (Scott and Crossman 1973). Jenkins (1976) reported a significant positive correlation between TDS levels of 100-350 ppm and sportfish (including sunfishes) standing crops in a group of predominately southeastern reservoirs.

Cover in both lacustrine and riverine habitats in the form of submerged vegetation or logs and brush is utilized by the species, especially juveniles and small adults (Moyle and Nichols 1973; Scott and Crossman 1973). However, an excessive abundance of vegetation can inhibit utilization of prey by bluegills. Populations of stunted individuals have been associated with an excessive amount of aquatic vegetation which may inhibit the utilization of bluegills as prey (Anderson, pers. comm.). Bluegills also nest in unvegetated areas (Weaver and Ziebell 1976). Lack of cover may also be a problem (Anderson, pers. comm.).

Water quality criteria for bluegills in both riverine and lacustrine habitats are outlined as follows: optimal growth and reproductive potential occurs in waters of low to moderate turbidities (< 50 ppm) (Buck 1956; Hastings and Cross 1962; Shireman 1968). Bluegills can tolerate a pH range of 4.0 to 10.3 (Trama 1954; Ultsch 1978) but pH levels at these extremes have caused at last partial kills (Calabrese 1969). Optimal levels are 6.5-8.5 based on Stroud's (1967) criteria for freshwater fish. Bluegills can tolerate dissolved oxygen levels < 1.0 mg/l for short durations (Baker 1941; Cooper and Washburn 1946; Moss and Scott 1961; Petrosky and Magnuson 1973) but will avoid levels of 1.5-3.0 mg/l (Whitmore et al. 1960). Optimal levels are > 5.0 mg/l (Petit 1973). Bluegills will not tolerate salinities > 5.6 ppt (Kilby 1955), and prefer salinity levels < 3.6 ppt (Tebo and McCoy 1964; Carver 1967).


Embryo. Optimal temperatures for successful embryo development are 22-27° C, and development will occur from 22-34° C (Banner and Van Arman 1973). Optimal current velocities are < 7.5 cm/sec, and embryos are not found at current velocities > 30 cm/sec (Hardin and Bovee 1978). Because bluegill spawn at 1-3 m depth (Swingle and Smith 1943), reservoir drawdown during spawning should not exceed 3 m during spring and summer.

Fry. Optimal temperatures for fry are 25-32° C (Hardin and Bovee 1978). Fry will not survive temperatures below 11° C or above 34° C (Banner and Van Arman 1973). Optimal current velocities are < 5 cm/sec; fry are not found in areas with velocities greater than about 7.5 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978).

Juvenile. The highest specific growth rate of juvenile bluegill occur in waters of 30° C and the growth range is 22-34° C (Lemke 1977). Preferred
current velocities are < 5 cm/sec; juveniles are not found in areas with velocities greater than about 15 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978).

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The model is applicable wherever bluegills occur in North America. The standard of comparison for each individual variable suitability index is the optimum value of the variable that occurs anywhere within this region. Therefore, the model will never provide an HSI of 1.0 when applied to water bodies in the North where temperature related variables do not reach the optimum values found in the South.

Season. The model provides a rating for a riverine or lacustrine habitat based on its ability to support all life stages of bluegills through all seasons of the year.

Cover types. The model is applicable in riverine and lacustrine habitats as described by Cowardin et al. (1979).

Minimum habitat area. Minimum habitat area is defined as the minimum area of contiguous suitable habitat that is required for a population to live and reproduce. No attempt has been made to establish a minimum habitat size for survival and growth of a bluegill population.

Verification level. The acceptance goal of the model is to produce an index between 0 and 1 which has a positive relationship to spawning success of adults and carrying capacity for fry, juveniles, and adults. In order to verify that the model output was acceptable, HSI's were calculated from sample data sets. These sample data sets and their relationship to model verification are discussed in greater detail following the presentation of the model.

Model Description - Riverine

Variables which have been shown to affect growth, survival, abundance, or other measure of well-being of bluegill are placed in the appropriate component (Figs. 1 and 2).

Food component. Percent cover (logs and other objects) \( V_2 \) is included because this type of cover in pools is favorable prey habitat. Percent cover (vegetation) \( V_1 \) is included as a separate variable because vegetation density can influence both feeding ability of bluegills and abundance of food. Percent pools \( V_3 \) is included to quantify the amount of food habitat.

Cover component. Percent cover (logs and other objects) \( V_2 \) and percent cover (vegetation) \( V_3 \) are included because bluegills exhibit cover-seeking behavior. Percent vegetative cover is separate from other cover because too much vegetation can cause a habitat problem, while logs, brush, and other debris provide good cover.
Habitat Variables

% cover (logs and other objects) \( (V_2) \)
% cover (vegetation) \( (V_3) \)
% pools \( (V_1) \)

% cover (logs and other objects) \( (V_2) \)
% cover (vegetation) \( (V_3) \)

Turbidity \( (V_6) \)
pH \( (V_7) \)
Dissolved oxygen \( (V_8) \)
Temperature (adult) \( (V_{10}) \)
Temperature (fry) \( (V_{12}) \)
Temperature (juvenile) \( (V_{13}) \)
Salinity \( (V_9) \)

Water quality \( (C_{wq}) \)
Reproduction \( (C_R) \)
Other \( (C_{OT}) \)

Food \( (C_F) \)
Cover \( (C_C) \)

HSI

Figure 1. Tree diagram illustrating relationship of habitat variables and life requisites in the riverine model for the bluegill. Dashed line indicates optional variable in the model.
Habitat Variables

% cover (logs and other objects) \( (V_2) \)
% cover (vegetation) \( (V_3) \)
Total dissolved solids \( (V_5) \)
pH \( (V_7) \)

% cover (logs and other objects) \( (V_2) \)
% cover (vegetation) \( (V_3) \)
% littoral area \( (V_4) \)

Turbidity \( (V_6) \)
pH \( (V_7) \)
Dissolved oxygen \( (V_8) \)
Temperature (adult) \( (V_{10}) \)
Temperature (fry) \( (V_{12}) \)
Temperature (juvenile) \( (V_{11}) \)
Salinity \( (V_9) \)

Temperature (embryo) \( (V_{11}) \)
Reservoir drawdown \( (V_{19}) \)
Substrate composition \( (V_{20}) \)

Life Requisites

Food \( (C_F) \)
Cover \( (C_C) \)
Water quality \( (C_{WQ}) \)
Reproduction \( (C_R) \)

HSI

Figure 2. Tree diagram illustrating relationships of habitat variables and life requisites in the lacustrine model for the bluegill. Dashed line indicates optional variable in the model.
Water quality component. Turbidity \((V_e)\), pH \((V_f)\), dissolved oxygen \((V_o)\), and temperature \((V_{10}, V_{12},\) and \(V_{11}\)) are crucial parameters that affect development, growth, and survival. Dissolved oxygen and temperature are weighted in the model and are considered to be limiting factors. Salinity \((V_s)\) is an optional variable since it is not considered to be a problem in most areas where bluegills are found.

Reproduction component. Temperature \((V_{11})\) is included because embryo survival and development depends on the temperature being warm enough for incubation and hatching. Current velocity in spawning areas \((V_{15})\) is included because the embryo will not survive in areas of higher velocities. Substrate composition \((V_{20})\) is included since bluegill show a preference for spawning over fine gravel and sand.

"Other" component. The variables in the "other" component are those which aid in describing habitat suitability for bluegills, yet are not specifically related to life requisite components already presented. Current velocity for the different life stages \((V_{14}, V_{16},\) and \(V_{17}\)) is included because all stages cannot tolerate swifter velocities. Stream gradient \((V_{18})\) is included because bluegills are most often found in lower gradient streams.

Model Description - Lacustrine

Food component. Percent cover (logs and other objects) \((V_2)\) is included because this type of habitat promotes good habitat for foraging and food organisms. Percent cover (vegetation) \((V_3)\) is included because, though vegetation can be a measure of lacustrine productivity, too much vegetation can seriously reduce foraging capabilities. Total dissolved solids (TDS) \((V_8)\) is included because TDS is a measure of general lacustrine productivity and dissolved solids are a vital prerequisite for the development of the food chain. Bluegills are opportunistic feeders on whatever is abundant. pH \((V_6)\) is included in the food component because a low pH may indicate low alkalinity and low productivity.

Cover component. Percent cover (logs and other objects) \((V_2)\) and percent cover (vegetation) \((V_3)\) are important since cover-seeking behavior indicates that some cover must exist for good habitat. Too much vegetative cover may indicate poor habitat. Percent littoral area \((V_4)\) is included to quantify the amount of cover habitat.

Water quality component. See description for riverine water quality component.
Reproduction component. Temperature ($V_{11}$) is included because embryo survival and development is related to temperature. Reservoir drawdown ($V_{19}$) is included because bluegills spawn at a certain depth and eggs may be exposed if water levels drop too low (this variable is excluded in a natural lake or pond). Substrate composition ($V_{20}$) is included because bluegill show a preference for spawning over fine gravel and sand.

Suitability Index (SI) Graphs for Model Variables

This section contains suitability index graphs for the 20 variables described above. The "R" pertains to riverine habitat variables, and the "L" refers to lacustrine habitat variables.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>($V_{1}$)</td>
<td>Percent pool area during average summer flow.</td>
</tr>
<tr>
<td>R, L</td>
<td>($V_{2}$)</td>
<td>Percent cover (e.g., logs, brush, and debris) within pools or littoral areas during summer.</td>
</tr>
</tbody>
</table>
R, L ($V_3$) Percent cover (aquatic vegetation, submersed, dense stands, finely divided leaves).

L ($V_4$) Percent littoral area during summer stratification.

L ($V_5$) Average TDS level during growing season.

Note: SI values should be lowered about 0.2 if ionic concentration of sulfate-chlorides exceeds that of carbonate-bicarbonates.
R,L \hspace{1cm} (V_o) \hspace{1cm} \text{Maximum monthly average turbidity during average summer flow or summer stratification.}

R,L \hspace{1cm} (V_s) \hspace{1cm} \text{pH range during growing season.}
A) 6.5-8.5
B) 6.0-6.5 or 8.5-9.0
C) 5.0-6.0 or 9.0-10.0
D) < 5.0 or > 10.0

R,L \hspace{1cm} (V_s) \hspace{1cm} \text{Minimum dissolved oxygen range during summer.}
A) Seldom below 5.0 mg/l
B) Usually between 3.0 and 5.0 mg/l
C) Usually between 1.5 and 3.0 mg/l
D) Often below 1.5 mg/l

Note: Lacustrine D.O. levels refer to littoral areas; riverine, pools.
R,L \hspace{1em} (V_9) \hspace{1em} Maximum monthly average salinity during growing season (optional).

R,L \hspace{1em} (V_{10}) \hspace{1em} Maximum midsummer temperature within pools or littoral areas (adult).

R,L \hspace{1em} (V_{11}) \hspace{1em} Average of mean weekly water temperature within pools or littoral areas during spawning (embryo).
R, L \quad (V_{12}) \quad \text{Maximum early summer temperature within pools or littoral areas (fry).}

R, L \quad (V_{13}) \quad \text{Maximum midsummer temperature within pools or littoral areas (juvenile).}

R \quad (V_{14}) \quad \text{Average current velocity in pools and backwater areas during growing season (adult).}
R \ (V_{15}) \ Average \ current \ velocity \ in \ spawning \ areas \ (embryo).

R \ (V_{16}) \ Average \ current \ velocity \ in \ pools \ and \ backwater \ areas \ during \ early \ summer \ (fry).

R \ (V_{17}) \ Average \ current \ velocity \ in \ pools \ and \ backwater \ areas \ during \ growing \ season \ (juvenile).
R \quad (V_{18}) \quad \text{Stream gradient within representative reach.}

L \quad (V_{19}) \quad \text{Reservoir drawdown during spawning (embryo).}

R,L \quad (V_{28}) \quad \text{Substrate composition within pools or littoral areas during spawning (embryo).}

A) Fines and gravel present
B) Fines and gravel scarce
Riverine Model

This model utilizes the life requisite approach and consists of five components: food, cover, water quality, reproduction, and other.

Food \((C_F)\).

\[
C_F = (V_1 \times V_2 \times V_3)^{1/3}
\]

Cover \((C_C)\).

\[
C_C = \frac{V_2 + V_3}{2}
\]

Water Quality \((C_{WQ})\).

\[
C_{WQ} = \frac{V_6 + V_7 + 2V_8 + V_9 + 2[(V_{10} \times V_{12} \times V_{13})^{1/3}]}{7}
\]

If \(V_8\) or \((V_{10} \times V_{12} \times V_{13})^{1/3} \leq 0.4\), \(C_{WQ}\) equals the lowest of the following: \(V_8\), \((V_{10} \times V_{12} \times V_{13})^{1/3}\), or the above equation.

Note: \(V_8\) may be dropped and the denominator changed to 6 if salinity is not considered to be a problem or potential problem in the study area.

Reproduction \((C_R)\).

\[
C_R = (V_{11} \times V_{15} \times V_{23})^{1/3}
\]

Other \((C_{OT})\).

\[
C_{OT} = \frac{V_{14} + V_{16} + V_{17}}{3} + \frac{V_{18}}{2}
\]
HSI determination. If all component ratings > 0.4,

\[ \text{HSI} = (C_F \times C_C \times C_{WQ}^2 \times C_R \times C_{OT})^{1/6} \]

If \( C_{WQ} \) or \( C_R \) are \( \leq 0.4 \), use lowest component rating as the species HSI.

**Lacustrine Model**

This model utilizes the life requisite approach and consists of four components: food, cover, water quality, and reproduction.

**Food (C\(_F\)).**

\[ C_F = (V_2 \times V_3 \times V_5 \times V_7)^{1/4} \]

**Cover (C\(_C\)).**

\[ C_C = (V_2 \times V_3 \times V_9^2)^{1/4} \]

**Water Quality (C\(_{WQ}\)).**

\[ C_{WQ} = \frac{V_6 + V_7 + 2V_8 + V_9 + 2[(V_{10} \times V_{12} \times V_{13})^{1/3}]}{7} \]

If \( V_8 \) or \( (V_{10} \times V_{12} \times V_{13})^{1/3} \leq 0.4 \), \( C_{WQ} \) equals the lowest of the following: \( V_8 \), \( (V_{10} \times V_{12} \times V_{13})^{1/3} \), or the above equation.

**Note:** \( V_9 \) may be dropped and the denominator changed to 6 if salinity is not considered to be a problem or potential problem in the study area.

**Reproduction (C\(_R\)).**

\[ C_R = (V_{11} \times V_{19} \times V_{20})^{1/3} \]

**Note:** If the lacustrine environment is a natural lake or pond, \( V_{19} \) will not be applicable. Thus,

\[ C_R = (V_{11} \times V_{20})^{1/2} \] in a natural lake or pond.
HSI determination. If all component ratings > 0.4,

\[ HSI = (C_F \times C_C \times C_{WQ}^2 \times C_R)^{1/5} \]

If \( C_{WQ} \) or \( C_R \) ≤ 0.4, use lowest component ratings as the species HSI.

Sources of data and assumptions made in developing the suitability indices are presented in Table 1.

Sample data sets for the above riverine and lacustrine HSI models are listed in Tables 2 and 3. The data sets are not actual field measurements but represent combinations that could occur in a riverine or lacustrine habitat. The HSI's calculated from the data reflect what the carrying capacity trends would be in riverine and lacustrine habitats with the listed characteristics. Thus, the model meets the acceptance goal of producing an index between 0 and 1 which is believed to have a positive relationship to the spawning success of adults and carrying capacity of fry, juvenile, and adult bluegill.

Interpreting Model Outputs

Habitats with an HSI of 0 may contain some bluegills; habitats with a high HSI may contain few. The bluegill HSI determined by use of these models will not necessarily represent the population of bluegill in the study area. This is because the standing crop does not totally depend on the ability of the habitat to meet all life requisite requirements of the species. If the model is a good representation of bluegill riverine or lacustrine habitat, the model should be positively correlated with long term average population levels in areas where population levels are determined primarily by habitat related factors. However, this has not been tested. The proper interpretation of the HSI produced by the model is one of comparison. If two habitats have different HSI's, the one with the higher HSI should have the potential to support more fish than the one with the lower HSI, given the model assumptions have not been violated.

ADDITIONAL HABITAT MODELS

Model 1

Optimal riverine habitat for bluegills is characterized by the following conditions, assuming water quality is adequate: large, low gradient (< 0.5 m/km) streams; warm water temperatures (> 20° C); sluggish current velocities (< 5 cm/sec); clear water (< 50 ppm suspended solids); and an abundance of bottom cover within pool areas.

\[ HSI = \frac{\text{number of above criteria present}}{5} \]
Table 1. Data sources for bluegill suitability indices.

<table>
<thead>
<tr>
<th>Variable and source</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_1$ Moyle and Nichols 1973</td>
<td>The amount of pool area that is correlated to a high abundance of bluegills is optimum.</td>
</tr>
<tr>
<td>$V_2$ Moyle and Nichols 1973 Scott and Crossman 1973 Pflieger 1975</td>
<td>The percent cover (logs and other objects) where bluegill are most abundant is optimum.</td>
</tr>
<tr>
<td>$V_3$ Moyle and Nichols 1973 Scott and Crossman 1973 Weaver and Ziebell 1976 Anderson, pers. comm.</td>
<td>The percent cover (vegetation) that is associated with abundant fish is optimum. Not enough vegetative cover or too much vegetative cover are suboptimum, since the former restricts the food availability and the latter restricts foraging capabilities.</td>
</tr>
<tr>
<td>$V_4$ Emig 1966 Scott and Crossman 1973</td>
<td>Since the bluegill inhabits shallow vegetated areas, a certain percentage of littoral area must exist for habitat to be suitable. Since bluegills require deeper water in winter and to get away from summer heat, too much littoral area would be suboptimum to unsuitable.</td>
</tr>
<tr>
<td>$V_5$ Jenkins 1976</td>
<td>TDS levels associated with high standing crops are optimum. Levels that reduce food availability are suboptimum to unsuitable.</td>
</tr>
<tr>
<td>$V_6$ Buck 1956 Trautman 1957 Hastings and Cross 1962 Shireman 1968 Pflieger 1975</td>
<td>Turbidity levels where growth rates are fastest are optimum. Levels that retard growth and development and that adversely affect reproduction are suboptimum to unsuitable.</td>
</tr>
<tr>
<td>$V_7$ Trama 1954 Stroud 1967 Calabrese 1969 Ultsch 1978</td>
<td>pH levels that promote good production and maximum survival are optimum. Levels that reduce reproductive capabilities and feeding are suboptimum to unsuitable.</td>
</tr>
<tr>
<td>$V_8$ Cooper and Washburn 1946 Whitmore et al. 1960 Doudoroff and Shumway 1970 Petit 1973</td>
<td>D.O. levels where survival is maximum and development is normal are optimum. Levels causing stress reactions are suboptimum. Levels that are tolerated for short durations are unsuitable.</td>
</tr>
<tr>
<td>Variable and source</td>
<td>Assumption</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>$V_9$ Kilby 1955</td>
<td>Salinity levels that promote successful reproduction and good growth are optimum. Levels where the species does not reproduce are unsuitable.</td>
</tr>
<tr>
<td>Tebo and McCoy 1964</td>
<td></td>
</tr>
<tr>
<td>Carver 1967</td>
<td></td>
</tr>
<tr>
<td>$V_{10}$ Anderson 1959</td>
<td>Temperatures that promote maximum growth are optimum. Temperatures where no growth occurs are unsuitable.</td>
</tr>
<tr>
<td>Emig 1966</td>
<td></td>
</tr>
<tr>
<td>$V_{11}$ Clugston 1966</td>
<td>Temperatures where embryo development is successful and normal and survival is maximum are optimum. Temperatures where survival is reduced but development may occur are suboptimum. Temperatures where no development occurs are unsuitable.</td>
</tr>
<tr>
<td>Emig 1966</td>
<td></td>
</tr>
<tr>
<td>Banner and Van Arman 1973</td>
<td></td>
</tr>
<tr>
<td>Scott and Crossman 1973</td>
<td></td>
</tr>
<tr>
<td>Kitchell et al. 1974</td>
<td></td>
</tr>
<tr>
<td>Pflieger 1975</td>
<td></td>
</tr>
<tr>
<td>$V_{12}$ Banner and Van Arman 1973</td>
<td>Temperatures that reach levels where maximum growth occurs are optimum. Temperatures where the species does not survive are unsuitable.</td>
</tr>
<tr>
<td>Hardin and Bovee 1978</td>
<td></td>
</tr>
<tr>
<td>$V_{13}$ Lemke 1977</td>
<td>Temperatures that reach levels where maximum growth occurs are optimum. Temperatures where feeding is reduced but where growth still occurs are suboptimum. Temperatures that cause no growth or death are unsuitable.</td>
</tr>
<tr>
<td>$V_{14}$ Kallemyn and Novotny 1977</td>
<td>Current velocities where bluegills are most often collected are optimum. Velocities where the species is seldom or never found are suboptimum to unsuitable.</td>
</tr>
<tr>
<td>Hardin and Bovee 1978</td>
<td></td>
</tr>
<tr>
<td>$V_{15}$ Same as $V_{14}$</td>
<td>Same as $V_{14}$</td>
</tr>
<tr>
<td>$V_{16}$ Same as $V_{14}$</td>
<td></td>
</tr>
<tr>
<td>$V_{17}$ Same as $V_{14}$</td>
<td></td>
</tr>
<tr>
<td>$V_{18}$ Trautman 1957</td>
<td>Stream gradients where bluegills are collected in abundant numbers are optimum. Gradients where the fish occur in fewer numbers or are absent are suboptimum to unsuitable.</td>
</tr>
<tr>
<td>Variable and source</td>
<td>Assumption</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------</td>
</tr>
<tr>
<td>$V_{10}$ Swingle and Smith 1943</td>
<td>Because bluegill spawn at specific depths, stable water levels are optimum. Any reservoir drawdown would be suboptimum to unsuitable.</td>
</tr>
<tr>
<td>$V_{20}$ Stevenson et al. 1969 Pfieger 1975</td>
<td>Substrates that the species prefers are optimum. Almost any other substrate has high suitability.</td>
</tr>
</tbody>
</table>
Table 2. Sample data sets using riverine HSI model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Data set 1</th>
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<td>Data</td>
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<td>% pools</td>
<td>$V_1$</td>
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<td>% cover (logs, brush)</td>
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<td>% cover (vegetation)</td>
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<td>Dissolved oxygen (mg/l)</td>
<td>$V_8$</td>
<td>Class C</td>
<td>0.4</td>
<td>Class A</td>
<td>1.0</td>
<td>Class B</td>
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<td>Salinity (ppt)</td>
<td>$V_9$</td>
<td>1.2</td>
<td>1.0</td>
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<td>Current velocity - adult (cm/sec)</td>
<td>$V_{14}$</td>
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<td>30</td>
<td>0.4</td>
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<td>Current velocity - embryo (cm/sec)</td>
<td>$V_{15}$</td>
<td>28</td>
<td>0.3</td>
<td>30</td>
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<td>Current velocity - fry (cm/sec)</td>
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<td>Current velocity - juvenile (cm/sec)</td>
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<td>20</td>
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<td>30</td>
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<td>Stream gradient (m/km)</td>
<td>$V_{18}$</td>
<td>2</td>
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<td>2.7</td>
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<td>Substrate comp.</td>
<td>$V_{20}$</td>
<td>Class B</td>
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20
Table 2. (concluded)

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<tr>
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<tr>
<td>$C_F$</td>
<td>0.33</td>
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<td>$C_C$</td>
<td>0.35</td>
<td>0.60</td>
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<td>$C_{WQ}$</td>
<td>0.67</td>
<td>0.93</td>
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<td>$C_R$</td>
<td>0.28</td>
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<td>0.93</td>
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<tr>
<td>$C_{OT}$</td>
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<td>0.28</td>
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Table 3. Sample data sets using lacustrine HSI model.

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<td>Data</td>
<td>SI</td>
<td>Data</td>
<td>SI</td>
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<tr>
<td>% cover (logs, brush)</td>
<td>( V_2 )</td>
<td>100</td>
<td>0.2</td>
<td>10</td>
<td>0.6</td>
<td>50</td>
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<tr>
<td>% cover (vegetation)</td>
<td>( V_3 )</td>
<td>5</td>
<td>0.4</td>
<td>35</td>
<td>0.9</td>
<td>25</td>
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<tr>
<td>% littoral area</td>
<td>( V_4 )</td>
<td>8</td>
<td>0.4</td>
<td>17</td>
<td>0.8</td>
<td>60</td>
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<tr>
<td>TDS (ppm)</td>
<td>( V_5 )</td>
<td>50</td>
<td>0.4</td>
<td>10</td>
<td>0.1</td>
<td>200</td>
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<tr>
<td>Turbidity (ppm)</td>
<td>( V_6 )</td>
<td>15</td>
<td>1.0</td>
<td>10</td>
<td>1.0</td>
<td>90</td>
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<tr>
<td>pH</td>
<td>( V_7 )</td>
<td>Class A</td>
<td>1.0</td>
<td>Class A</td>
<td>1.0</td>
<td>Class A</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/l)</td>
<td>( V_8 )</td>
<td>Class A</td>
<td>1.0</td>
<td>Class A</td>
<td>1.0</td>
<td>Class A</td>
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<tr>
<td>Salinity (ppt)</td>
<td>( V_9 )</td>
<td>0.4</td>
<td>1.0</td>
<td>0.2</td>
<td>1.0</td>
<td>0.5</td>
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<tr>
<td>Temperature - adult (°C)</td>
<td>( V_{10} )</td>
<td>24</td>
<td>0.9</td>
<td>24</td>
<td>0.9</td>
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<tr>
<td>Temperature - embryo (°C)</td>
<td>( V_{11} )</td>
<td>19</td>
<td>0.3</td>
<td>21</td>
<td>0.7</td>
<td>24</td>
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<tr>
<td>Temperature - fry (°C)</td>
<td>( V_{12} )</td>
<td>21</td>
<td>0.7</td>
<td>22</td>
<td>0.8</td>
<td>28</td>
</tr>
<tr>
<td>Temperature - juvenile (°C)</td>
<td>( V_{13} )</td>
<td>20</td>
<td>0.4</td>
<td>22</td>
<td>0.5</td>
<td>28</td>
</tr>
<tr>
<td>Reservoir drawdown ( m )</td>
<td>( V_{14} )</td>
<td>4</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Substrate</td>
<td>( V_{20} )</td>
<td>Class B</td>
<td>0.7</td>
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<td>1.0</td>
<td>Class A</td>
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</table>

Component SI

\[ C_F = 0.42 \]
\[ C_C = 0.34 \]
\[ C_{WQ} = 0.89 \]
\[ C_R = 0.28 \]
\[ HSI = 0.28 \]
Model 2

Optimal lacustrine habitat for bluegill sunfish is characterized by the following conditions, assuming water quality is adequate: fertile lakes, reservoirs, and ponds (TDS levels 100-350 ppm); extensive littoral areas (≥ 20% surface area); maximum water temperature > 20°C; and clear water (< 50 ppm suspended solids).

\[ HSI = \frac{\text{number of above criteria present}}{4} \]

Model 3

Use the regression models for bluegill standing crop in reservoirs presented by Aggus and Morais (1979) to calculate an HSI.

REFERENCES CITED


----------. 1981. Personal communication. Missouri Cooperative Fishery Unit, Columbia, Missouri.


Habitat Suitability Index Models: Bluegill

Robert J. Stuber, Glen Gebhart, and O. Eugene Maughan

Habitat Evaluation Procedures Group Western Energy and Land Use Team U.S. Fish and Wildlife Service Drake Creekside Building One 2625 Redwing Road Fort Collins, Colorado 80526

Western Energy and Land Use Team Office of Biological Services Fish and Wildlife Service U.S. Department of Interior Washington, D.C. 20240

A literature review encompassing habitat and species characteristics of the bluegill (Lepomis macrochirus) is followed by a discussion of the relationship of habitat variables and life requisites of this species. These data are then incorporated into Habitat Suitability Index models for the bluegill.

This is one in a series of publications describing habitat requirements of selected fish and wildlife species. Numerous literature sources have been consulted in an effort to consolidate scientific data on species habitat relationships. These data have subsequently been synthesized into Habitat Suitability Index (HSI) models. The models are based on suitability indices formulated for variables found to affect the life cycle and survival of the species. The models are designed to be modified to evaluate specific habitat alterations using the HSI model building techniques presented in the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures.

Habitat Suitability
Fishes

Bluegill
Lepomis macrochirus
Habitat
Habitat Suitability Index

Unlimited

Unclassified

Unclassified

See Instructions on Reverse
U.S. GOVERNMENT PRINTING OFFICE: 1982—578-130/192 REGION NO. 8
Department of Commerce

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Executive Summary

A planning model quality assurance review of the Modification of US Fish and Wildlife Service’s Habitat Suitability Index Model for Bluegill (*Lepomis macrochirus*) for Winter Conditions for Upper Mississippi River Backwater Habitats (the “Bluegill HSI model”) was conducted for the U.S. Army Corps of Engineers (the “Corps”) Institute for Water Resources (IWR) in cooperation with the Corps Ecosystem Restoration Planning Center of Expertise (ER-PCX) under Contract # W912HQ-10-D-005; Delivery Order 03. The objective of the model review is to evaluate the technical and system quality and usability of the model in accordance with the Corps’ *Planning Models Improvement Program: Model Certification* (EC 1105-2-407, dated May 31, 2005)¹ and *Protocols for Certification of Planning Models* (July 2007). The Corps’ ultimate goal is to determine the degree to which the Bluegill HSI Model can be certified or otherwise approved for use within the geographic area specified in the model documentation (i.e., the Upper Mississippi River (UMR) System and other large rivers in the upper Midwest region).

Abt Associates, Inc., an independent, nationally-recognized organization specializing in research and analyses to support public sector programs, policies and initiatives, was engaged to conduct the model certification review for the Bluegill HSI Model. The purpose of the review is to provide independent, objective peer review with regard to the technical quality, system quality, and usability of the model. Two subject matter experts (i.e., model reviewers) were selected to serve on the model review panel. As appropriate for the technical subject matter of the Bluegill HSI Model, the technical expertise of the selected peer reviewers included two fishery ecologists, one plan formulation expert and one spreadsheet auditor/specialist.

The model reviewers were provided with electronic copies of the Bluegill HSI Model document, the accompanying spreadsheet and supporting documentation - identified in the Corps Scope of Work (SOW) as Exhibits #4-#7 (see Table 1) - along with a set of panel charge questions (see Appendix A) that solicit their comments on specific aspects of the document. The charge questions direct reviewers to consider key technical quality, system quality and usability criteria that are central for model certification, as described in the USACE *Protocols for Certification of Planning Models* (July 2007). Comments were submitted to Abt Associates through a project-specific Comment and Response Tracking (CaRT) system.

A total of 129 individual comments were received from the model reviewers in response to the 42 charge questions. Following compilation and summarization of the comments of the reviewers, a model review teleconference was conducted to review comments on the key model review criteria, discuss charge questions for which there were conflicting responses, and reach agreement on the Final Panel Comments to be provided to the Corps. The panel members’ findings regarding the model’s technical quality, system quality and usability are documented in specific sections of this report, and Final Panel Comments are provided in Appendix C, which also documents responses of the Model Proponent, and summaries of the final project teleconference. A complete list of panel comments is provided in Appendix D.

The Draft Model Review Report (dMRR) for the Bluegill HSI Model introduced the model review process, described the model reviewers and their selection, and summarized the findings and draft Final Panel Comments of the reviewers. The findings and substantive comments of the dMRR were

¹ Plans for HQUSACE to update EC 1105-2-407 and reissue the planning model quality assurance review guidance as EC 1105-2-412 are being implemented by HQUSACE and publication of the new EC is pending.
reviewed by the Corps representatives and Model Proponent and discussed with the model reviewers during a project teleconference held on April 6, 2011. Participants in this teleconference included the model reviewers (Chris Yoder, Dennis McCauley, Jason Weiss and Jin Huang), the model proponent (Dennis Anderson), IWR representatives (Shawn Komlos and Bruce Kish), ER-PCX representative (Jodi Staebell), Headquarters representative (Jeff Trulik) and Abt Associates (David Mitchell, Jim Palardy). Summaries of the discussion on individual final panel comments are provided in Appendix C under each comment. A list of individual comments made during the teleconference is provided as Appendix E.

This final Model Review Report (fMRR) clarifies points of confusion, documents notable discussion and consensus reached on the Final Panel Comments during the teleconference, and provides information that will be taken into consideration by the Corps as part of its decision to certify or otherwise approve for use the Bluegill HSI model.

Overall, model reviewers agreed that the Bluegill HSI Model is sound for use in Corps planning studies. However, they suggested making several modifications to the model that would improve its accuracy and usability.

The review panel provided the following recommendations for improving the model based on their most significant concerns:

1. More explicit definitions must be established for minimum dissolved oxygen and substrate composition to ensure objective model output. Additionally, the usefulness of the isolation variable should be reassessed.

2. Several existing “percent” habitat variables, including percent cover of logs & brush (V₁₂) and vegetation (V₁₃), and percent backwater depth > 4 feet (V₅₈), should be altered to include qualitative habitat characteristics that are overlooked by continuous variables.

3. Technical documentation should be updated to reflect the current spreadsheet-based model, and expanded to include methodologies for collecting data, uncertainty analysis, and preparing HSI output for inclusion in other Corps planning models.

4. The Corps must ensure that the model is field-validated, and that any relevant changes be made to model calculations when necessary. To achieve this, the Corps must ensure that relevant data are being collected for all model variables, and ideally for any variables that might be included in future model improvements.

The reviewers suggest incorporating the recommended resolutions to the issues identified above into the Bluegill HSI Model and its documentation to improve the model for widespread use and to reduce the probability of errors within Corps planning projects.
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Attachment 1: Review of Eight Midwest Ecosystem Output Models – Final Work Plan
List of Acronyms

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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>AAHU</td>
<td>Average Annual Habitat Units</td>
</tr>
<tr>
<td>CE/ICA</td>
<td>Cost-Effective Incremental Cost Analysis</td>
</tr>
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<td>COI</td>
<td>Conflict of Interest</td>
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<td>dMRR</td>
<td>Draft Model Review Report</td>
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<td>Ecosystems Planning Center of Expertise</td>
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<td>Final Model Review Report</td>
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<td>HEP</td>
<td>Habitat Evaluation Procedure</td>
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<td>HQUSACE</td>
<td>Headquarters of the United States Army Corps of Engineers</td>
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<tr>
<td>HSI</td>
<td>Habitat Suitability Index</td>
</tr>
<tr>
<td>IWR</td>
<td>Institute for Water Resources</td>
</tr>
<tr>
<td>OMB</td>
<td>Office of Management and Budget</td>
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<td>PFE</td>
<td>Plan Formulation Expert</td>
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<td>Planning Models Improvement Program</td>
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<tr>
<td>SAS</td>
<td>Spreadsheet Auditor / Specialist</td>
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<td>SOW</td>
<td>Scope of Work</td>
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<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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<td>USFWS</td>
<td>United States Fish and Wildlife Service</td>
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<td>UMR</td>
<td>Upper Mississippi River</td>
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1.0 Introduction

The United States Army Corps of Engineers (the “Corps”) is engaged in the ecological restoration of several big river ecosystems in the Upper Midwest, including the Upper Mississippi River Restoration, Missouri River Recovery and Enhancement Programs, and the Upper Mississippi River Navigation and Ecosystem Sustainability Program. To ensure these investments in the Nation’s water resources and natural environment result in favorable ecosystem restoration outcomes, the Corps requires accurate and scientifically-sound assessment and analytical tools that produce relevant and interpretable data to support planning and decision-making.

To ensure that high quality methods and tools are available to support these programs, the Corps Planning Models Improvement Program (PMIP) was established in 2003 to review, improve and certify models for the Corps’ Civil Works programs. The main objective of the PMIP is to carry out “a process to review, improve and validate analytical tools and models for Corps Civil Works business programs” (EC 1105-2-407, May 2005). In accordance with the Planning Models Improvement Program: Model Certification (EC 1105-2-407, May 2005)\(^2\), certification or approval for use by HQUSACE is required for all planning models developed and/or used by the Corps.

Planning model quality assurance reviews are performed to ensure that Corps planning decisions are based on theoretically sound, computationally accurate analyses/tools that comply with Corps policy in compliance with the requirements of Corps PMIP Model Certification (E.C. 1105-2-407), the Protocols for Certification of Planning Models (the Protocols).

As part of the PMIP process, a model certification review of the Modification of US Fish and Wildlife Service’s Habitat Suitability Index Model for Bluegill (*Lepomis macrochirus*) for Winter Conditions for Upper Mississippi River Backwater Habitats (the “Bluegill HSI Model”) was conducted for the Corps Ecosystem Restoration Planning Center of Expertise (ER-PCX) under Contract W912HQ-10-D-0005; Delivery Order 03 to the Corps Institute for Water Resources (IWR).

Under this Delivery Order, expert panels reviewed the Bluegill HSI Model in accordance with E.C. 1105-2-407 and the Protocols. The Bluegill HSI Model was evaluated on the basis of technical soundness, computational correctness, and overall effectiveness, efficiency and usability, identify deficiencies, and offer recommendations to improve the models. The overall goal is to determine the extent to which the Bluegill HSI Model can/should be certified or otherwise approved for use within the geographic area specified in the model documentation.

1.1 Model Purpose

The Bluegill HSI Model is a modification of the United States Fish and Wildlife Service (USFWS) Habitat Suitability Index Models: Bluegill model (Steuber 1982). This original model incorporates 20 habitat variables to evaluate habitat suitability for bluegill in lacustrine and riverine habitats. To account for overwintering habitat, Palesh and Anderson (1990) added four additional habitat variables: water depth, dissolved oxygen concentration, water temperature and current velocity. The resulting riverine and lacustrine habitat models are designed to evaluate the quality of year-round habitat for bluegill in Pools 1 through 10 of the Upper Mississippi River.

---

\(^2\) Plans for HQUSACE to update EC 1105-2-407 and reissue the planning model quality assurance review guidance as EC 1105-2-412 are being implemented by HQUSACE and publication of the new EC is pending.
1.2 Model Assessment

The main objective of the PMIP is to carry out “a process to review, improve and validate analytical tools and models for Corps Civil Works business programs” (USACE, 2005). The objective of planning model review is to ensure that models used by the Corps are technically and theoretically sound, computationally accurate, and in compliance with Corps planning policy.

The basic steps of the Corps planning model review process which generally guide planning model development and review are outlined below (USACE, 2007). Model development is a multi-step, iterative process, with the number of steps and iterations being dependent upon the complexity of the planning challenges and associated planning model(s). In general, these steps occur in four fundamental stages.

- **Stage 1 (Requirements Stage)** involves identifying the need for a specific analytical capability and the options for tools to meet the need.
- **Stage 2 (Development Stage)** involves the development of software programming code or a spreadsheet and testing by the model developer.
- **Stage 3 (Model Testing Stage)** involves a beta test of the model by selected users whose objective is to validate the model and ensure that it is usable in real-world applications.
- **Stage 4 (Implementation Stage)** involves providing training, user support, maintenance and continuous evaluation of the model.

The planning model quality assurance review procedure depends on the stage of model development. The process is summarized in the following steps:

1. Model reviewers determine whether project needs/objectives are clearly identified and whether the model described is meeting those needs/objectives.
2. Model reviewers evaluate the technical quality of the model.
3. Model reviewers evaluate system quality of the model.
4. Model reviewers evaluate the usability of the model.

In addition to providing an assessment of Steps 1-4 above, this review is intended to improve the continued maintenance and advancement of the Bluegill HSI Model for widespread use. In this review, most of the assessment criteria are being evaluated by independent peer review. While reviewers can comment on the extent to which available information suggests the model is easily accessible, model training is readily available, and adequate technical support is available, the Corps may be best qualified to more completely address its internal training and support practices.

The level of effort for a model review depends on the complexity of the model developed, the risks associated with planning decisions made using the model, and the stage of model development. An intermediate level of review was conducted on the Bluegill HSI Model based on the model’s intermediate level of complexity relative to other planning models. The model review presented in this document included a review of all model documentation.

1.3 Contribution to Planning Effort

The Corps planning regulations require that ecosystem restoration benefits be quantified in non-monetary terms for use during Cost-Effective Incremental Cost Analysis (CE/ICA) and to inform decisions associated with selection and recommendation of alternatives. The Bluegill HSI Model will be used to
support decision-making in ecosystem restoration projects associated with large rivers and associated backwater lake, pond, and slough habitats of Pools 1 through 10 in the Upper Mississippi River. The model is used to estimate the suitability of year-round habitat for bluegill (*Lepomis macrochirus*) in this geographical area.

### 1.4 Report Organization

This final Model Review Report (fMRR) for the Bluegill HSI Model is organized into the following components:

- **Section 1.0 Introduction** – identifies the model to be review and introduces the model assessment and certification process.
- **Section 2.0 Model Description** — describes the applicability of the model for planning projects and summarizes the model inputs and components.
- **Section 3.0 Model Evaluation Assessment Criteria and Approach** - describes the criteria used to assess technical quality, system quality, and usability and the approach to the model review.
- **Section 4.0 Technical Quality Assessment** – an assessment of the scientific aspects and technical merits of the model under review, including the underlying theory, the representation of the system, analytical requirements, model assumptions, evaluation of risk and uncertainty,
- **Section 5.0 System Quality Assessment** – an assessment of the supporting software, programming accuracy and model testing and validation.
- **Section 6.0 Usability** – an assessment based on data availability, ease of results interpretation, and level of model documentation.
- **Section 7.0 Model Assessment Summary** - identification of the significant issues and comments raised by the panel reviewers.
- **Section 8.0 Conclusions** —summarizes the overall conclusions of the model review
- **Section 9.0 References** — provides the references used for this model assessment.
- **Appendix A** - the list of charge questions posed to model reviewers
- **Appendix B** - contains biographic information on the model reviewers.
- **Appendix C** – contains the final Final Panel Comments, which include the basis for the comment, significance, recommendations for resolution, the Model Proponent’s response, and a summary of the discussion held during the teleconference between reviewers and Model Proponent.
- **Appendix D** – a list of all reviewer comments.
- **Appendix E** – a list of the comments made during the teleconference discussing Final Panel Comments held between reviewers and Model Proponent.
2.0 Model Description

The Bluegill Habitat Suitability Index (HSI) Model was designed to aid in impact assessment and habitat management. The model evaluates the ability of riverine or lacustrine water bodies to support a population of bluegill in Pools 1 through 10 of the Upper Mississippi River (Stuber et al. 1982; Palesh and Anderson 1990). It was designed to be applicable for bluegill fish in all stages of life and throughout all seasons of the year. The standard of comparison for all variables within the model represents the optimum value that occurs anywhere within the areas where bluegill can be found.

The Bluegill HSI Model, as provided by the Corps to the model review team, included technical documentation and a spreadsheet file (Table 1).

<table>
<thead>
<tr>
<th>Table 1. Documents Reviewed for the Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Modification of the Bluegill Habitat Suitability Index Model – Certification Document</td>
</tr>
<tr>
<td>4. Diving Duck Migration Habitat Model Spreadsheet_07-28-10.xls</td>
</tr>
</tbody>
</table>

2.1 Model Applicability

The Bluegill HSI Model uses a suitability index approach to estimate the relative ability of a particular geographic location to provide for the maintenance of a population of bluegill. The model estimates habitat value by integrating the ecological requirements for food, cover, water quality, and reproduction to an indexed value between 0 (unsuitable habitat) and 1 (optimal habitat). In turn, each ecological requirement is estimated by combining several habitat variables (e.g., water pH, dissolved oxygen, turbidity, substrate composition etc.) relevant to habitats of bluegill fish in Pools 1 through 10 of the UMR.

2.2 Model Components

The Bluegill HSI Model estimates habitat quality based upon a location’s ability to meet life history requirements for food, cover, water quality, and reproduction. These requirements are, in turn, estimated by combining habitat variables that affect fish growth, survival, abundance, and other measures of well-being. Including winter modifications (Palesh and Anderson 1990), a total of 21 habitat variables may be used to calculate the HSI of an individual lacustrine or riverine environment.

Although similar in many respects, separate models are used to evaluate the quality of riverine and lacustrine habitats:

**Riverine Habitats** – The riverine habitat HSI model includes the following components:
- **Food** – the ability of a habitat to provide food is estimated by combining values of percent pools, percent cover from logs and other objects, as well as percent cover from vegetation.
- **Cover** – cover is estimated by percent cover from vegetation as well as percent cover from logs and other objects.
- **Water Quality** – water quality is estimated by combining habitat variables of pH, dissolved oxygen, turbidity, water temperature (for fry, juvenile, and adult), and salinity.
• **Reproduction** – reproduction is estimated by combining values of temperature (for the embryo), current velocity (for the embryo), and substrate composition.

• **Other** – the riverine model accounts for current velocity (for fry, juvenile, and adult) and stream gradient.

• **Winter Habitat** - habitat variables considered to have important influences on overall HSI include winter measures of water depth, dissolved oxygen concentration, water temperature and current velocity.

**Lacustrine Habitats** – The lacustrine habitat HSI model includes the following components:

• **Food** – the ability of a habitat to provide food is estimated by combining values of pH, total dissolved solids, percent cover from logs and other objects, as well as percent cover from vegetation.

• **Cover** – cover is estimated by combining values of percent littoral areas, percent cover from logs and other objects, as well as percent cover from vegetation.

• **Water Quality** – water quality is estimated by combining habitat variables of pH, dissolved oxygen, turbidity, water temperature (for fry, juvenile, and adult), and salinity.

• **Reproduction** – the ability of a habitat to allow for successful reproduction is estimated by combining values of water temperature (for the embryo), reservoir drawdown, and substrate composition.

• **Winter Habitat** - habitat variables considered to have important influences on overall HSI include winter measures of water depth, dissolved oxygen concentration, water temperature and current velocity.

### 3.0 Model Evaluation Criteria Assessment and Approach

The purpose of the Bluegill HSI Model review is to evaluate the technical quality, system quality and usability of the planning model. The results of the model review will be used by the Corps to determine whether to certify or approve for use the model for regional or more widespread application and inclusion in the toolbox of Corps planning models. The process and evaluation criteria for the review are outlined by USACE (2007) and described in Section 1.2 (Model Assessment) of this report.

### 3.1 Model Review Approach

Details of the review process and charge guidance are provided in the *Review of Eight Midwest Ecosystem Output Model - Final Workplan* (dated 11/16/10) (provided as Attachment 1). The review process consisted of seven tasks, including:

• Task 1 – Participate in Project Kick-off Meeting

• Task 2 – Development of the Work Plan

• Task 3 – Identification of Candidate and Selected Reviewers

• Task 4 – Conduct Assessment of the Model (including panel kickoff meeting)

• Task 5 – Prepare Draft Model Review Report

• Task 6 – Meeting to Discuss Panel Findings

• Task 7 – Prepare Final Model Review Report

Abt Associates participated in a project kick-off teleconference meeting with representatives from the Corps IWR, including the Contracting Officer Representative (COR), Technical and Alternative Technical Points of Contact (POC); representatives from the ER-PCX; and the identified Model Proponents on October 15, 2010 (Task 1). The purpose of the kickoff meeting was to discuss Abt...
Associates’ draft Scope of Work (SOW) and technical approach for reviewing the eight ecosystem models, as well as clarify and better understand the Corps’ specific goals and objectives for the model review.

At the meeting, Abt Associates provided a draft review schedule, discussed the potential charge questions for the panels, and determined if additional information was required to comply with the requirements of the Protocols. This information was incorporated into the development of draft and final work plans (Task 2). The Abt Associates’ Review of Eight Midwest Ecosystem Output Models– Final Work Plan was issued on November 16, 2010. The panel charge questions are provided in Appendix A.

Since highly qualified, independent and objective peer review is a critical element in the review process, considerable effort was extended in the identification and selection of highly qualified panel members (Task 3). Due to the large number of required technical experts (15) required for roles in the eight model reviews, Abt Associates initially identified more than 60 candidate model reviewers. Potential candidates for the review panels were identified and screened for academic qualifications and technical experience, availability during the expected review period and for actual or perceived conflicts of interest (COIs). All candidate reviewers met or exceeded the general requirements and academic field-specific technical requirements for each expert as provided in the proposal SOW.

Abt Associates chose qualified candidates based on background, experience, and a lack of actual or perceived COI (Task 3) and confirmed their interest and availability. The Bluegill HSI Model review panel included:

- Two fish ecologists familiar with methods for evaluating habitat suitability. These experts were also required to have general ecological knowledge of the Upper Midwest river systems.
- A plan formulation expert (PFE) with understanding of Corps ecosystem restoration planning policies and demonstrated experience/expertise with application of models during the planning and evaluation of ecosystem restoration projects or regulated activities.
- A spreadsheet auditor/specialist (SAS) with demonstrated experience with the development, testing of spreadsheets, identifying analytical errors, characterizing susceptibility to delivering flawed results, and developing/prioritizing recommendations for enhancing performance.

Information on the experts selected for the model review panel is summarized in Table 2 and a short biography for each model reviewer is provided in Appendix B.

<table>
<thead>
<tr>
<th>Name</th>
<th>Panel Role</th>
<th>Organizational Affiliation</th>
<th>Degree and Years of Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jin Huang</td>
<td>Spreadsheet Auditor/Specialist</td>
<td>Abt Associates</td>
<td>Ph.D.; 8 years</td>
</tr>
<tr>
<td>Jason Weiss</td>
<td>Plan Formulation Expert</td>
<td>URS Corporation</td>
<td>M.S.; 11 years</td>
</tr>
<tr>
<td>Chris Yoder</td>
<td>Fish Ecologist</td>
<td>Midwest Biodiversity Institute</td>
<td>M.A.; 35 years</td>
</tr>
<tr>
<td>Dennis McCauley</td>
<td>Fish Ecologist</td>
<td>Great Lakes Environmental Center</td>
<td>M.E.P.D.; 26 years</td>
</tr>
</tbody>
</table>

As the initial review task, Abt Associates conducted a panel kick-off teleconference with the panel model reviewers, representatives from the USACE IRW and ER-PCX, and the Model Proponent to brief them on the purpose and approach for the review process, provide the model reviewers an opportunity to be briefed specifically on the models, and to direct questions and/or get further clarification from the Model Proponent.
The model reviewers were provided with an electronic version of the review document, along with guidance and set of 42 charge questions. The intent of the charge questions was to focus the review on the assessment criteria that are critical for the certification or approval of planning models (see Section 3.2).

The model reviewers were asked to review the Bluegill HSI Model and associated documentation using the guidance and charge questions provided at the panel kickoff meeting (Task 4). Communication between the model reviewers and the Model Proponents during the peer review process was directed through the Abt Associates Task Manager and the IRW POC.

The model reviewers submitted their comments on the Abt Associates CaRT system (Task 4). A total of 129 individual comments were received from the model reviewers in response to the 42 charge questions. Following submittal of all reviews of the Bluegill HSI Model documentation, individual comments were compiled into a merged comment form. A list of all comments is provided as Appendix D.

Following compilation and summarization of the comments of the reviewers, a model review teleconference was conducted with the panel to review comments on the key model review criteria, discuss charge questions for which there were conflicting responses, and reach agreement on the Final Panel Comments to be provided to the Corps. The panel members’ findings regarding the model’s technical quality, system quality and usability are documented in specific sections of this report, and Final Panel Comments are provided in Appendix C.

The draft Model Review Report (dMRR) for the Bluegill HSI Model introduced the model review process, described the model reviewers and their selection, and summarized the findings and draft Final Panel Comments of the reviewers (Task 5). These comments identified and discussed key issues identified with the model and its documentation during the review process, and presented recommendations for resolution. The findings and substantive comments of the dMRR were reviewed by the Corps representatives and the Model Proponent provided responses.

A teleconference was held on April 6, 2011 to discuss the Final Panel Comments (Task 6). Participants in this call included model reviewers (Chris Yoder, Dennis McCauley, Jason Weiss and Jin Huang), the model proponent (Dennis Anderson), IWR representatives (Shawn Komlos and Bruce Kish), ER-PCX representative (Jodi Staebell), Headquarters representative (Jeff Trulik) and Abt Associates (David Mitchell, Jim Palardy). Summaries of the discussion on individual final panel comments are provided in Appendix C under each comment. A list of individual comments made during the teleconference is provided as Appendix E.

This final Model Review Report (fMRR) clarifies points of confusion, documents notable discussion and consensus reached at the teleconference, and provides information that will be taken into consideration by the Corps as part of its decision to certify or otherwise approve for use the Bluegill HSI Model (Task 7). The results and conclusions of the model review are discussed in Sections 4.0 through 6.0 of this report, and Final Panel Comments are provided in Appendix C.

3.2 Assessment Criteria

In accordance with USACE (2005), the Bluegill HSI Model was subjected to an independent peer review. The review was conducted based on guidance in the USACE Protocols for Certification of Planning Models (July 2007). As required by the PMIP, the Bluegill HSI Model was reviewed and assessed for technical quality and usability. The Bluegill HSI Model, a spreadsheet-based model, was also evaluated for system quality. A brief overview of the assessment criteria are given in the rest of this section. The results of these assessments are described in Sections 4 through 6.
Technical Quality

Analytical tools, including models, used for planning purposes need to be technically sound and based on widely accepted contemporary scientific theory. The critical ecological features affecting species or guild-specific habitat quality must be realistically represented by the components of the model. The architecture of the model calculations must reflect how the system is expected to respond to changes in measured variables based on the application of scientific theory. Formulas and calculation routines that form the mechanics of the models must be accurate and correctly applied, with sound relationships among variables. The models should be able to reflect natural changes as well as the influence of anthropogenic influences. All model assumptions must be valid and should be well-documented. The analytical requirements of the models must be identified, and the model must address these requirements. In addition, a review of spreadsheet is conducted to check that the programming was done correctly, that formulas and computations are mathematically correct, and accurately propagated throughout the spreadsheet, and results are assigned to the appropriate output. The models should also produce robust, reproducible results that can be used for implementation in the Corps plan formulation process.

System Quality

System quality refers to an assessment of the computational software used to run the model and provide accurate and interpretable results. System quality can include investigation of the rationale for selection of supporting software tool/programming language and hardware platform to see whether the supporting software tool is appropriate for the model and readily available. Finally, an assessment is made of whether data can be readily imported from/into other software analysis tools, if applicable.

Usability

Usability refers to how easily model users can access and run the models, interpret the model output, and use the model output to support planning decisions. An assessment of model usability includes evaluating the availability of data required to run the models and the ability of the user to learn how to use the model properly and effectively. Model outputs must also be easy to interpret, useful for supporting the purpose of the models, easy to export to project reports, and sufficiently transparent to allow for easy verification of calculations and outputs.

4.0 Technical Quality Assessment

4.1 Review of Model Objectives

The overall purpose and technical objectives of the Bluegill HSI Model should be clearly stated in the documentation. Based on their overall review, the panel members were asked to comment on how well the operating model met those stated purpose or objectives.

All reviewers of the Bluegill HSI Model indicated that the model’s design objectives and intended uses are clearly communicated and appropriate. Additionally, all reviewers believe that the modifications to the USFWS bluegill model meet the stated objectives of incorporating winter conditions into measuring an HSI suitable for bluegill. However, it was noted noted that:

- Although the Bluegill HSI model does achieve its objectives, it is likely that the model can be substantially improved in its estimation of habitat quality (see Section 4.3)
- Observable responses appear to be correlated with HSI-driven habitat enhancement for bluegill. However, the extent to which these improvements in habitat quality extend to other fish species in the ecosystem is not clear.
4.2 Review of Theory and External Model Components

Model certification and approval for use requires that the Bluegill HSI Model be “based on well-established contemporary theory” (USACE, 2007). Contemporary theory is generally considered to be based on current and previous research, literature reviews, and/or professional judgment. The reviewers are asked to judge the scope and sufficiency of this theoretical background.

Overall, reviewers note that the concept of species responses to habitat quality is well established in contemporary theory, and that the original USFWS model (Stuber et al 1982) appears to be well documented. However, reviewers note that more recent work focusing on the responses of species assemblages (e.g., Rankin 1989, Rankin 1995, Ohio EPA 2006) should be incorporated to supplement the species-based approach taken by the Bluegill HSI model (Section 4.3). Notably, reviewers believe that the incorporation of community-based approaches should be considered complementary to, and not competing with, species-based approaches.

Reviewers were less convinced by the theoretical underpinnings related to the winter modifications (Palesh and Anderson 1990) to the original USFWS model. Both fish ecologists noted that the logic used to justify “percent backwater greater than 4 feet in depth” as a habitat variable was weak, and based upon two unsupported statements. First, that “water depth provides winter cover by providing space and darkness,” and second, that “We decided to use water depth as a winter cover variable because of its importance and because it is a relatively easy variable to predict or measure” (Palesh and Anderson 1990, p. 2 – 3). Consequently, the reviewers were unclear about the extent to which best professional judgment was used (vs. actual data) to construct the variable’s suitability index plot. Consequently, reviewers were not sure that winter water depth – the only habitat variable included for the cover component of the winter HSI calculation - is adequately supported by the literature.

4.3 Review of Representation of the System

All ecological models are abstractions of real-world systems and, as such, they are inherently simpler than the ecosystems they represent. While basic ecological conditions are represented in the models, additional factors may impact the analysis, and are often not consistently or thoroughly incorporated into the evaluation process. The reviewers also considered the geographic appropriateness and/or limitations of the model for use in the UMR System and other large Midwestern rivers.

All reviewers found that the model would be useful for bluegill habitat in Pools 1 through 10 of the UMR, the geographic location specified in model documentation. Reviewers noted that the model is likely to be relevant in other midwestern floodplain rivers, including the St. Croix, Wisconsin, and Chippewa River systems, where off-main channel backwater habitats are prevalent.

Although they believed the Bluegill HSI Model represented the suite of critical ecosystem attributes and provided for reasonable variation of these attributes, reviewers believed the model could be improved by modifying or expanding existing habitat variables. Additionally, one reviewer provided suggestions for future work on the development and field verification of single- and multi-species indices.
Reviewer suggested modifications to existing habitat variables include:

- Connectivity – although there is a poorly defined ‘isolation’ term in the Bluegill HSI model (see Section 4.5), there is no explicit consideration of connectivity to the main channel of the UMR. Although bluegill may be able to maintain populations in areas poorly connected to the main channel, the work by Bartels et al (2008) has shown that connectivity can be a very important variable in determining the likelihood of population persistence. Additionally, connectivity is likely a significant factor affecting water quality (particularly dissolved oxygen and water velocity). Thus, reviewers believe that connectivity should be explicitly included as a variable within the Bluegill HSI model.

- Adding qualitative criteria to ‘percent’ variables – many of the variables in the Bluegill HSI model are presented as one-dimensional “percent” variables (e.g., percent cover, percent of area > 4 feet deep, percent pool area, etc.). Treating these variables as continuous may not capture important qualitative characteristics of these attributes. For example, one reviewer noted that there are many types of woody cover that are qualitatively different, and that many factors interact with depth to produce high quality habitat. The reviewer believes that these differences may have important consequences for restoration and should be accounted for. To address this issue, the approach of Wakeley (1988) was suggested: adding discrete levels of cover quality, which can alter HSI output for individual habitat variables.

Suggestions for future development and verification of the Bluegill HSI model, and relevant to other HSI models used by the Corps, include:

- Using an assemblage approach to HSI models may provide a more inclusive endpoint that would enhance bluegill populations while also including species likely to have more limiting habitat requirements. Even if additional HSI models are not developed, a strong baseline of assemblage transect data will provide more explicit linkages between single species models, such as the Bluegill HSI model, and assemblage data. The Long-Term Resource Monitoring Program (LTRMP) is likely to have sufficient data to test this approach.

- The use of quantile regression to identify limiting habitat factors for an assemblage of fish species (Fayram and Mitro 2008). Such an approach may enhance the concept of using bluegill as a surrogate or indicator species.

- Developing a Biological Condition Gradient (BCG) for the UMR (Davies and Jackson 2006). The BCG approach creates a biological gradient of assemblage conditions (response variable) anchored in natural conditions and extended through varying levels of disturbance. For such an approach to be used, a sufficiently detailed stressor gradient (predictor variable), including chemical parameters, must be constructed relative to natural conditions. Much of the work necessary to apply such an approach in the UMR may already be complete (Julien et al 2008) or is well underway (Donnelly 2009). The development of such a BCG index may help put the Bluegill HSI model, and other similar HSI models, into better historical and ecological context.

Although reviewers noted that these suggestions may not be incorporated into the Bluegill HSI model in the near-term, they believe that these concepts should be included in the development of new HSI models, and in long-term model improvements for the Bluegill HSI model.

### 4.4 Review of Critical Model Assumptions

All ecological models are based on a set of critical assumptions, and the general utility and/or geographic applicability of the model reflects the strengths and limitations of these assumptions. For some models these critical assumptions are explicitly identified, while in others they are deduced indirectly through the
input of data and review and interpretation of results. Panel reviewers are asked to comment on both the strengths/limitations of the model’s assumptions as well as how well such assumptions are communicated.

Reviewers noted that general assumptions and limitations of the model are generally well stated, while others are implicit. Additionally, they noted that the HSI model seems robust because many variables share partial redundancy with others. However, several assumptions were identified whose violation would influence the validity and usefulness of the model:

- As discussed in Section 4.1, the model is a hypothesis of species-habitat relationships that needs to be more thoroughly tested. The original USFWS document (Stuber et al 1982) implies that new data and information would be collected in a wide number of areas. This does not appear to have occurred. In reality, monitoring and assessment are often viewed as expendable: this view is reinforced by the observation that no explicit verification seems to have occurred for the winter modifications, despite being proposed more than 20 years ago (Palesh and Anderson 1990). Overall, the Corps needs to ensure that a more assertive series of follow-up validations occur for the Bluegill HSI model.

- One major assumption is that all inputs to the model are correct. However, one reviewer noted that several variables, particularly the percent of pool greater than 4 feet depth, may be difficult to accurately estimate. Additionally, the reviewer noted that the spatial distribution and accuracy of water quality measurements may not always be representative of the ecosystem: near-surface dissolved oxygen concentrations may substantially misrepresent water quality, particularly if oxygen and temperature stratification are not accounted for in field measurements. The potential for erroneous HSI model output due to the assumption of input certainty could be addressed through the implementation of uncertainty analysis (see Section 4.7).

- The Winter Cover variable is limited to the single variable of depth, a variable that appears to have less support from the published literature than other habitat variables (Section 4.2). Although reviewers did not believe that this prevents the use of the Bluegill HSI model for planning purposes, they noted that other variables, including ice depth, may be important components of winter cover, and should be explored when time and funding permit.

Overall, the reviewers noted that few model assumptions are likely to have substantial impacts on overall HSI output. However, they recommended validating the model, and implementing uncertainty analysis to minimize the potential for these assumptions to limit the accuracy and usefulness of the Bluegill HSI model.

### 4.5 Review of Analytical Requirement

Including the winter habitat modifications, the Bluegill HSI Model requires the input of as many as 21 environmental variables to produce a single HSI value. These inputs may be derived from field observations, review of maps or remote sensing applications, or other sources of project site characteristics. These data are transformed to habitat quality components based on the relationship between the environment variable and an aspect of habitat quality.

In general, reviewers found the analytical requirements of the Bluegill HSI Model to be relatively simple, easy to understand, clearly stated in model documentation, and (once data has been acquired) easy to assign suitable SI values. However, reviewers noted four exceptions to this general pattern:

- Minimum Dissolved Oxygen (V8): although quantitative values of DO are defined within variable descriptions, these values are tempered by the undefined terms “Seldom”, “Usually” and “Often”. If this habitat variable is intended to be a measure of minimum dissolved oxygen, such terms...
should not be required, and quantitative cut-offs should be directly implemented. Notably, the habitat variable for minimum winter DO ($V_b$) is directly defined in a quantitative manner. Data from state monitoring programs may provide an opportunity to establish quantitative cut-offs.

- **Substrate Composition ($V_{20}$):** the user is forced to decide between options of “Fines and Gravel Present” and “Fines and Gravel Scarce”. Ideally, a quantitative threshold would be set to distinguish between these two options and minimize model subjectivity.

- **Isolation:** the user must determine whether the habitat being evaluated is “relatively isolated” without a description of what is meant by the term. An easily understood and ideally quantitative measure of isolation should be defined for this variable, or the variable should be removed.

- **Winter water temperature ($V_c$):** this variable appears to be artificially limited to temperatures below 4°C. Documentation of the winter modification to the Bluegill HSI Model (Palesh and Anderson 1990) indicates an optimum at 4°C, but does not designate an upper limit. As such, the model should be altered to accept inputs for winter temperature greater than 4°C.

The first three variables pose noted above pose ambiguous questions and as such, different analysts may have different opinions as to the proper assignment of suitability indices for these variables. The effects of this ambiguity on overall HSI may be large: both Isolation and Dissolved Oxygen are limiting variables that (depending on other model inputs) may serve as the upper limit on overall HSI. As such, these variables should be defined quantitatively to minimize the amount of subjectivity present in overall HSI output.

4.6 Review of Model Calculations/Formulas

The computational accuracy of all formulas and data aggregations within the Bluegill HSI Model spreadsheet were reviewed to ensure that calculations are correctly and accurately performed and conveyed to the appropriate output destination. Such a review entails inspection of both data inputs the conversion of intermediate results into useful model output.

The reviewers found no computational errors in model formulas, and noted that calculations within the model are transparent and easily understandable. Although no errors in calculation were discovered, comments to two cells that detail model calculations are incorrect:

- **Cell D28:** the comment for the Lacustrine formula is incorrect. The formula for the Lacustrine model should read: $Cf=(V2xV3xV5xV7)^{(1/4)}$. As noted above, the actual calculation (occurring in cell F28) is correct.

- **Cell D41:** the comment to the formula should read: $Cw-wq=(2Vb+Vc)/3$. As noted above, the actual calculation (occurring in Cell F41) is correct.

Although correcting the formulae in these comment boxes will not improve model output, making these changes will improve model transparency.

4.7 Review Ability to Evaluate Risk and Uncertainty

Output from the Bluegill HSI Model is deterministic: a single set of environmental variables results in the output of a single HSI value. Thus, the model does not explicitly incorporate uncertainty or risk analysis, nor does the documentation provide any guidance or methods to account for it. To overcome this determinism, it is possible to use a range of input variables to provide a measure of uncertainty. Using a range of input variables is particularly important for habitat variables that are difficult to measure with a high degree of accuracy (e.g., winter depth, dissolved oxygen, temperature; see Section 4.4), for variables that have a strong
influence on life requisites (i.e., winter current velocity), and for variables that have the potential to limit overall HSI (i.e., dissolved oxygen and isolation).

Due to the current implementation of the spreadsheet model, multiple worksheets and/or separate spreadsheet files would have to be used to generate estimates of model uncertainty. Multiple uncertainty conditions could be incorporated into the same spreadsheet by varying habitat variables in separate columns. Separate worksheets could then be created for project alternatives and years. The results could then be summarized in a final worksheet to provide a year by year comparison of mean HSI and the variance surrounding these estimates for all project alternatives. Ideally, such an uncertainty analysis would be automated and built into the spreadsheet, potentially using visual basic tools (included in Microsoft Excel) or spreadsheet add-on tools such as @Risk (www.palisade.com/risk).

4.8 Review of Ability to Calculate Benefits for Total Project Life

The Bluegill HSI Model provides habitat assessment inputs (i.e., can be converted into Average Annual Habitat Units (AAHU) by application of areal units) necessary to estimate potential ecosystem restoration benefits as part of the CE/ICA to determine best project alternatives (or “Best Buy”) for implementation. Reviewers were asked to comment on the ability of the model to support the alternative analysis process.

Reviewers believe that the model is useful in providing managers with comparative information that would be of value in selecting the best plan of action for a given set of conditions. Repetitive runs of the model can produce comparable before-and-after project impacts that can provide realistic estimates of functional losses or gains via a particular alternative. However, the model is currently able to evaluate only one condition at a time in a deterministic fashion and as such does not explicitly meet current Corps policy of incorporating risk and uncertainty into analyses. To conduct such an uncertainty analyses, analysts must complete several model runs (See Section 4.7).

Additionally, Corps Plan Formulation procedures require the use of average annual values to account for changes over the planning period. As such, the analyst must complete model runs for different intervals over the planning period. Although the Corps regularly uses HSI values, the analyst working with output from the Bluegill HSI Model would be required to post-process HSI output into another form (e.g. habitat units) external to the model. This information is currently not provided within user documentation.

5.0 System Quality

5.1 Review of Supporting Software

The Bluegill HSI Model operates within a Microsoft Excel ® spreadsheet. Microsoft Excel® is a standard spreadsheet software tool which is available nationwide and is widely used professional for standard calculations, particularly when many reiterations are required (i.e., project alternatives over project lifespan). No review of this software was deemed necessary.

5.2 Review of Programming Accuracy

Programming accuracy usually pertains to the accuracy of model code used to perform the required operations. As noted in Section 5.1, the models are in spreadsheets so that no specialized programming language or code was necessary. A review of the accuracy of the mathematical formulas indicated no errors (see Section 4.6).

5.3 Capacity of the model to inform users of erroneous or inappropriate inputs

The spreadsheet provides warning messages when suitability index data inputs are outside allowed ranges. For example, only inputs of “A” or “B” are permitted for the substrate composition variable; all
other inputs are rejected with a warning message. For “percentage” inputs, only inputs ranging between 0 and 1 (i.e., entries of 0.2 or 20%) are permitted; all other inputs are rejected. For categorical variables, a roll-over box indicates the range of possible choices. In some cases, however, these roll-over boxes do not provide sufficient information for the analyst to make a clear determination of the appropriate input (see Section 4.5). For continuous data, the user is not provided with guidance on the proper range of variables permitted. In all cases, the analyst must ensure that data entry is accurate.

5.4 Review of Model Testing and Validation

Model testing and validation is an important part of the Corps planning model quality assurance review process. Following the kickoff meeting, the Corps provided data sets that generally support model output (Knight et al 1995, Knight et al 1998, Gents et al 1995, Bartels et al 2008). Thus, the use of follow-up assessments for post-mitigation changes in relative abundances of bluegill is evident. However, one reviewer noted that it was not apparent that individual habitat variables within the model are being verified with empirically derived data. Instead, the reviewer noted that the improvement shown in catchable number of bluegill in these documents provides only an overall validation of input variables. Overall, both ecologists reviewing the model stressed that further validation is necessary, and that an assertive series of follow-up validations occur through time for the Bluegill HSI model.

One reviewer noted the scale of habitat degradation is directly related to the expectation of success of a model’s predictions. As such, scale should be explicitly included in any field validations of model output. For example, restoration in locations with widespread habitat degradation (or, alternatively, poor connectivity) is unlikely to respond as strongly as an area surrounded by higher quality habitat. Consequently, restoration in the degraded area may be considered a failure when it is instead an important step in the long-term recovery process of a highly degraded system. Consequently, the Corps must take both information about the degradation of surrounding habitat, as well as the scale of restoration into account (along with before and after-restoration field data), when measuring between failure and success in the restoration process.

6.0 Usability

6.1 Review of Data Availability

Up to 21 habitat variables are required to obtain HSI output from the Bluegill HSI Model. Generally, reviewers agreed with model proponents who suggested that data is readily available. Notably, however, one reviewer found it difficult to find data for all necessary variables from field studies, and was forced to make one or more assumptions about habitat parameters within the Bluegill HSI model. Overall, however, reviewers agree that sufficient data should be available to run the model for many locations in the UMR through the LTRMP.

It was noted, however, that LTRMP methodologies for the suite of inputs required within the Bluegill HSI model are spread across many documents. As such, reviewers recommended that a complete set of methodologies be compiled for all habitat variables found in the Bluegill HSI model. Such a document would ensure that suitable data are collected when existing studies cannot provide all habitat data necessary to complete model runs. This collection of methodologies would also serve as a detailed and explicit description of data requirements for the model.

6.2 Review of Model’s Ease of Use

The Bluegill HSI Model is calculated within a simple Microsoft Excel 2007® spreadsheet. Model outputs adjust to changes in input variables immediately, and comment boxes provide a space to document how
individual SI values were chosen. With habitat variable, life requisite and overall HSI inputs visible, all calculations are transparent making model calculations easy to follow.

Reviewers did have several ideas on how to improve usability:

- The description for winter current velocity (cell D39) should specify that the input velocity is to be measured in areas with a depth exceeding 4 feet (Palesh and Anderson 1990)
- Some of the cells in the “comments” column are protected. This limits the ability to enter notes on the results and inputs. This can be addressed by removing protection for this column.
- One reviewer suggested adding the word “Summer” to descriptions in cells D28 – D33. This will ensure similarity in the appearance of summer and winter HSI calculations. Additionally, this reviewer suggested adding a row at D7 that explicitly labels the HSI calculations occurring between rows 8 and 33 as being “Summer” HSI calculations.

Making these minor changes to the spreadsheet will increase the usability of an already easy to use and highly accessible spreadsheet-based model.

### 6.3 Review of Results

Output from the Bluegill HSI Model consists of a single HSI value whose calculation is transparent, simple, and easy to understand. However, the simplicity of the model’s output limits its direct use in other Corps planning models. Instead an analyst must first make several conversions outside the reviewed spreadsheet.

Overall, the model is not formatted to evaluate changing conditions. Instead, it presents gross values for a single point in time that habitat variables are measured, or unique to a particular scenario. As such, reviewers believe the model to be very useful for estimating near-term conditions.

The model provides less certainty when characterizing future conditions. As has been observed in water and habitat quality studies conducted in past decades, some impacts will lessen in response to targeted management actions, while “new” and previously unassociated impacts such as species invasions and climate change are likely to become more prevalent. Additionally, the direction of change in habitat, flow, and nutrient regimes cannot be accurately predicted far into the future because they are dependent upon agriculture, land use, and environmental policies. However, despite these limitations, all reviewers believe that the Bluegill HSI model is a tool suitable to the task of long-range project planning. However, reviewers noted that the capacity of the model to adequately characterize future conditions would be enhanced by continuous or periodic reviews and update of model input variables, and their derivation with contemporary monitoring data.

### 6.4 Review of Model Documentation

The quality and appropriateness of the model documentation was reviewed.

Overall, reviewers found the model documentation to be readable and easy to understand. However, it was noted that there is no single document that addresses the entire Bluegill HSI Model, as presented in the spreadsheet model. Consequently, it was suggested that a single, complete document be assembled and distributed with the spreadsheet model. Additionally, as noted in Section 6.1, reviewers suggest that LTRMP methodology be used to obtain input data be included in such a document.

Reviewers noted that there is currently no user documentation for the spreadsheet model. However, given the simplicity of the model, reviewers did not find that the development of detailed documentation was necessary. However, it was suggested that a worksheet containing a short series of instructions be added to the Excel workbook.
One reviewer noted that there is currently no documentation that provides guidance on the use of HSI outputs, and no guidance in the model documentation with regard to the calculation of risk and uncertainty. This reviewer suggested developing standard documentation, and possibly a spreadsheet, that could be distributed with all HSI models that explains how to calculate uncertainty (Section 4.7), and how to convert HSI estimates into calculated benefits for total project life (Section 4.8).

7.0 Model Assessment Summary

Overall, reviewers found that the Bluegill HSI Model provides an effective and easy to use tool for evaluating the ability of riverine or lacustrine water bodies to support a population of bluegill in Pools 1 through 10 of the UMR. The associated spreadsheet is very simple and the required inputs are generally straight-forward. Consequently, they do not find any serious faults with the model that preclude its use in project planning in the UMR.

Although many of the submitted comments were designated “High” in significance (Appendix D), a closer inspection indicates that few of these comments identified a fundamental problem with the model’s design such that its ability to render meaningful results was compromised. However, a number of reviewer comments identify potential deficiencies and provided recommendations that may substantially improve model output and accuracy:

1. The definitions for two variables: minimum dissolved oxygen ($V_8$) and substrate composition ($V_{20}$), should be clarified to ensure model output is based on more objective data.
2. The value of the isolation variable (not numbered) should be reassessed and the variable possibly removed from the model.
3. Continuous “percent” variables in the Bluegill HSI model are unlikely to capture important qualitative characteristics habitat. A discrete, qualitative component should be added to these variables to capture important measures of habitat quality.
4. The life requisite of winter cover ($C_{W-C}$) is limited to a single variable of backwater depth greater than 4 feet ($V_a$). The level of data supporting this variable appears to be limited. Effort should be made to validate this variable, and incorporate other relevant variables such as ice cover, snow depth, or vegetation.
5. The winter modification for the Bluegill Habitat HSI model artificially limits model application to areas with winter water temperatures ($V_C$) below 4°C. This limitation does not appear to be based upon either data or theory and should be removed.
6. Model documentation matching the current spreadsheet-based version should be assembled and include information from the original USFWS model (Stuber et al 1982), the winter modification (Palesh and Anderson 1990), all applicable LTRMP methodologies used to obtain input data, and a methodology for conducting uncertainty analyses.
7. There is currently no documentation that provides guidance on the use of HSI outputs. Additional documentation and instructions should be distributed with the HSI model to ensure calculated benefits for total project life are correct.
8. The Corps needs to ensure that an assertive series of follow-up validations occur for the Bluegill HSI model. At a minimum, this requires ensuring that data is being collected for all variables in the current model, as well as for variables that might be included in future iterations of the model (e.g., ice cover, snow, light penetration).
These underlying issues are described in detail in Section 4 – 6 and in the draft Final Panel Comments in Appendix C

8.0 Conclusions

Overall, model reviewers agreed that the Bluegill HSI Model is sound for use in Corps planning studies. However, they suggested making several modifications to the model that would improve its accuracy and usability. The most critical Final Panel Comments include:

1. More explicit definitions must be established for minimum dissolved oxygen and substrate composition to ensure objective model output. Additionally, the usefulness of the isolation variable should be reassessed.

2. Several existing “percent” habitat variables, including percent cover of logs & brush ($V_2$) and vegetation ($V_3$), and percent backwater depth > 4 feet ($V_a$), should be altered to include qualitative habitat characteristics that are overlooked by continuous variables.

3. Technical documentation should be updated to reflect the current spreadsheet-based model, and expanded to include methodologies for collecting data, uncertainty analysis, and preparing HSI output for inclusion in other Corps planning models.

4. The Corps must ensure that the model is field-validated, and that any relevant changes be made to model calculations when necessary. To achieve this, the Corps must ensure that relevant data are being collected for all model variables, and ideally for any variables that might be included in future model improvements.

The reviewers strongly recommend incorporating these suggested changes. By doing so, they believe that the model will be substantially improved, its overall value to project planning increased, and the probability of errors within Corps planning projects reduced.

9.0 References


Ohio Environmental Protection Agency. 2006. Methods for assessing habitat in flowing waters: using the qualitative habitat evaluation index (QHEI). Division of Surface Water, Ecological Assessment Section, Columbus, OH. 23 pp.

Palesh, G. and D. Anderson. 1990. Modification of the Habitat Suitability Index Model for the Bluegill (Lepomis macrochirus) for winter conditions for upper Mississippi River backwater habitats. Environmental Resources Branch, Planning Division, St. Paul District, Corp of Engineers.


Rankin, E.T. 1989. The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application. Ohio EPA, Division of Water Quality Planning and Assessment, Ecological Analysis Section, Columbus, Ohio.


Appendix A: List of Charge Questions for the Bluegill HSI Model Review Panel

General Questions
1. Are the model’s design objectives and intended uses clearly communicated?
2. To what extent does the model meet the expressed design objectives?
3. To what extent is the model suitable for the expressed intended uses?

Technical Quality
4. Comment on the quality of the model’s technical documentation.
5. Comment on the technical quality of the model relative to its expressed design objectives.
6. Comment on the temporal and spatial granularity with which the model is designed to be applied.
7. Comment on the geographic range/applicability of the model.
8. Comment on the degree to which the assumptions and limitations of the model are clearly communicated?
   a. Comment on the degree to which apparent limitations impact the ability of the model to be used for characterization of system/habitat resources?
   b. Comment on the degree to which apparent limitations impact the ability of the model to be used for planning and forecasting of project-related impacts?
   c. Please provide recommendations for resolving or overcoming identified limitations?
9. Is the model based on well-established contemporary theory?
10. Does the model adequately emulate or otherwise address the suite of critical ecosystem attributes necessary to characterize system/habitat resources?
11. Does the model effectively allow for reasonable variation of variables critical to the intended uses (i.e., application of the model during planning of water resource and restoration activities)?
12. Comment on the precision and accuracy of the model outputs and identify which variables/factors have the greatest impact on model precision and accuracy.
13. Comment on sensitivities of the model and identify the variables/factors to which the model is most sensitive.
14. Are the input requirements of the model evident to the user (i.e., types as well as accuracy and precision)?
15. Is it evident to the user how the inputs are used by the model?
16. Are assumptions critical to valid application clearly identified and characterized such that violation of a critical assumption would become apparent?
17. Comment on the degree to which model assumptions might invalidate the model’s use for specific applications.
18. Comment on the degree to which the model facilitates/accommodates uncertainty and risk analyses.
19. Comment on the degree to which the model can be used as a tool to forecast conditions anticipated to occur during the design lifecycle of a water resource and restoration activities project (i.e., from 1 to 50 years).
20. Comment on the degree to which the model delivers information adequate for the purpose of supporting determinations of compensatory mitigation.
21. Are the formulas used in the model(s) correct?
   a. Are model computations adequately documented?
   b. Are model computations correct throughout the document?
   c. Are model computations (mathematical logic) appropriate?
22. Comment on the degree to which the model is inconsistent with USACE policies and accepted procedures.
23. Comment on the degree to which the model is configured to accept modified assumptions and inputs regarding future global events such as, but not limited to, global climate change?
System Quality
24. Comment on the degree to which the model has been tested for errors.
25. Comment on the capacity of the model to inform users of erroneous or inappropriate inputs.
26. Comment on the degree to which post-audits of model applications are documented (i.e.,
documentation of a validation process whereby statistical comparisons of conditions resulting from a
planned action/project are made to model outputs produced during the planning of the action/project)?
   If so:
      a. do results of the validation process indicate the model’s tendency to reasonably characterize
         existing conditions;
      b. do results of the validation process indicate the model’s tendency to reasonably forecast
         future conditions; and
      c. what model outputs were found to most greatly deviate from actual conditions (please
         comment on the likely cause of the deviation if possible)?

Usability
27. Comment on the model’s ease of use.
28. Comment on the model’s practicality and application/input requirements.
29. Comment on the availability of the data required by the model.
30. Comment on the understandability of model output(s).
31. Comment on the transparency of model output(s).
32. Comment on how useful the model is for characterization of near-term conditions.
33. Comment on how useful the model is for characterization of future conditions.
34. Comment on the usability of the model for selecting the best course/plan of action.
35. Is user documentation user friendly and complete?
36. Are the models transparent and do they allow for easy verification of calculations and outputs?

Additional Questions
37. Does model distinguish between habitat types that are relevant to Corps planning (e.g., wetland vs.
    upland)?
38. Is the model output appropriate for inclusion into other Corps planning models (e.g., IWR-Planning
    Suite)?
39. Does the model output account for changes in benefits over the planning period?
40. Is the model output value expected to change over time or is it presented as an average annual value?
41. Does the model provide guidance on the appropriateness of the inputs or is the analyst required to
    determine?
42. Are values calculated as changes from the “without project” scenario or as gross values?
Appendix B: Biographic Information for Reviewers

**Jin Huang – Spreadsheet Auditor / Specialist**  
Ph.D., Environmental Economics, North Carolina State University  
M.S., Statistics, North Carolina State University  
B.S., Economics and Management, Beijing Forestry University

Dr. Jin Huang is an economist with 8 years of experience in cross-disciplinary applied research in the areas of economics, environmental resources management and statistics with extensive statistical and econometric modeling skills. Her range of skills ranges from multiple regression analysis with cross-sectional, time series and panel data; to logistic regression, 2SLS, MLE; stochastic process and spatial analysis (using SAS, R, MatLab and Stata). Dr. Huang has specialties in impact analysis and optimal decision-making when facing uncertainties (e.g., climate change, price risk and fire risk). Dr. Huang currently works on a number of projects including assessment of health and economic impacts of air pollution, risk assessment associated with several pollutants, climate change impact on health risk, environmental justice (distributional analyses), and environmental carcinogen cessation lag project.

**Dennis McCauley – Fish Ecologist**  
M.E.-P.D., Fishery Biology, University of Wisconsin-LaCrosse, 1983  
B.S., Biology, University of Wisconsin-Superior, 1979

Mr. McCauley is a fish biologist with more than 25 years experience monitoring habitat and water quality trends in lakes rivers and streams and assessing the impact of these trends on fish populations in various habitats. A principal research scientist with the Great Lakes Environmental Center, Mr. McCauley’s experience ranges from interlaboratory validation of specific test protocols to complex field evaluations involving stream flow modeling, fish entrainment, fish escapement, fish diversion, shoreline erosion, habitat evaluations and water quality assessment. He has numerous peer-reviewed publications in fisheries management, and currently serves as a technical advisor in the implementation of the National Aquatic Resource Surveys (NARS) with EPA’s Assessment and Watershed Protection Division (AWPD).

**Jason Weiss – Plan Formulation Expert**  
M.S., Resource Economics and Policy, University of Maine  
B.I.E., Industrial Engineering, University of Minnesota, Duluth

Mr. Weiss is a planner, economist, and project manager who specializes in the analysis of US Army Corps of Engineers’ civil works planning projects. He has worked extensively with many USACE Districts and IWR for over 10 years. Mr. Weiss is experienced with model certification reviews – having been involved with both the model submission and review sides of the process. As project manager for the model certification review for IWR-Planning Suite, he was responsible for testing, plan formulation, ensuring policy compliance, and review package preparation of the model, which became the first IWR model to receive certification. Mr. Weiss has conducted plan formulation activities for ecosystem restoration, flood risk management, recreation, and transportation projects for the Corps, and has extensive experience assembling and managing multidiscipline teams for water resource related projects located throughout the United States.
Chris Yoder – Fish Ecologist
M.A., DePauw University, Greencastle, Indiana, 1976
B.S., The Ohio State University, Columbus, Ohio, 1973

Mr. Yoder is a fish ecologist with more than 30 years experience in the development of biological assessment and environmental indicators. Certified as a Tier II Fisheries Scientist by the American Fisheries Society, Mr. Yoder currently serves as the research director of the Midwest Biodiversity Institute’s Center for Applied Bioassessment and Biocriteria. Prior to 2001, he was manager of the Ecological Assessment Section at Ohio EPA. Mr. Yoder’s primary areas of expertise include fish ecology and distribution, water quality, and the design and execution of biological assessments. The author of more than 60 peer reviewed papers and technical reports, Mr. Yoder has served on the U.S. EPA working group on biocriteria and tiered aquatic life uses (2000-2006) and the National Research Council committee on the role of science in the TMDL process (2001).
**Appendix C: Draft Final Project Comments**

### Final Panel Comment 1:

Categorical definitions for three variables: minimum dissolved oxygen ($V_8$), substrate composition ($V_{20}$), and isolation (not numbered), must be made explicit to ensure model output is based upon objective data.

**Basis for Comment**

Suitability Index values for these three habitat variables are not defined explicitly. As such, different analysts may have different opinions as to the proper assignment of suitability indices for these variables. The effects of this subjectivity on overall HSI may be large: both isolation and dissolved oxygen are limiting variables that (depending on the state of other model inputs) may serve as the upper limit on overall HSI.

**Significance – High**

The Bluegill HSI Model is able to provide information useful to project planning in the UMR. Field validation of hypothesized relationships between habitat variables and carrying capacity should be tested to ensure model outputs are accurate.

**Recommendation for Resolution**

Explicitly define category thresholds for these three habitat variables to minimize the amount of subjectivity present in overall HSI output.

**Response of Model Proponent**

Concur. For DO, words like seldom, usually, often and for substrate, present or scarce, are highly subjective for assigning values. It would be possible to define these terms for the DO variable based on percentiles. However, it would still be highly subjective on assigning more precise values, unless you had an extensive baseline database to use. We frequently do not. But even if you had a good baseline database, you are still going to make professional judgments on the future without action and with various action alternatives. I do agree that maybe these terms should be better defined. The two scenarios for whether an area is isolated or contiguous with other bluegill habitat most definitely could be improved. There is some on-going work looking at the spatial distribution and extent of over-wintering habitat in a pool. For a desired standing stock, how far will bluegills move to get to overwintering habitat; what is the optimal spatial distribution; how much overwintering habitat is enough for a desired standing stock? Developing a spatial variable to address these questions would greatly assist in selecting locations for habitat creation and in quantifying benefits. I am not aware of any time that the bluegill model was used with the scenario of having contiguous bluegill overwintering habitat, so it usually isn’t a factor in most evaluations. Hopefully we can modify the model to account for this spatial attribute (see response to comment 7).
Summary of Discussion

Based upon the discussion, it was agreed that the contiguous / isolation term could be removed from the model. Additionally, it was decided that more indicative language could be developed for DO assignment in the short-term, but that assigning values based on percentiles would not be a good use of time or resources. Overall, it was agreed that extensive documentation of the rationale used to select variable conditions would help alleviate the panel’s concerns, and ensure accurate comparisons can be made in post-project monitoring projects. Finally, it was suggested that additional data sources be identified for the substrate composition variable, because LTRM data may not be sufficient.

One suggestion was to have a ‘round-robin’ testing of the model to identify variables that may require additional attention. Various Corps and/or state practitioners could separately parameterize the model and then compare selected inputs. Differences among practitioners’ input values would identify vague and/or incomplete variable description that requires clarification and/or modification.
Final Panel Comment 2:

Continuous “percent” variables in the Bluegill HSI model are unlikely to capture important qualitative characteristics habitat. A discrete, qualitative component should be added to these variables to capture important measures of habitat quality.

Basis for Comment

Many variables in the Bluegill HSI model are presented as one-dimensional “percent” variables (e.g., percent cover, percent of area > 4 feet deep, percent pool area, etc.). Treating these variables as continuous may not capture important qualitative characteristics of these attributes. For example, two sites may have equal proportions of woody cover, but form and location may be substantially different.

Significance – High

Because “percent cover” variables do not account for the quality of many variables, it was not clear to the reviewers that the full suite of ecosystem attributes is adequately addressed in the model.

Recommendation for Resolution

Add qualitative criteria to the following existing variables: percent cover of logs & brush ($V_2$) and vegetation ($V_3$), and percent backwater depth > 4 feet ($V_3$). An approach similar to that used by the Qualitative Habitat Evaluation Index (QHEI; Rankin 1989, 1995; Ohio EPA 2006), the approach of Wakeley (1988), or another suitable approach, should be used to implement qualitative aspects of these continuous variables.

Response of Model Proponent

The variables do attempt to do some qualitative assignment of importance. Expanding these variables, including development of habitat indices to encompass more attributes for cover, would be good. The cited QHEI was developed for smaller rivers and adaption to large floodplain rivers would require significant modification.

Summary of Discussion

It was agreed that there is no short-term solution for this comment, but that long-term monitoring should be conducted that includes a qualitative component – and thereby aid in the development of new input variables. Such variables may be incorporated into WRDA monitoring for long-term variable development.
**Final Panel Comment 3:**

The life requisite of winter cover ($C_{W,C}$) is limited to a single variable of backwater depth greater than 4 feet ($V_a$). The level of data supporting this variable appear to be limited. Effort should be made to validate this variable, and possibly incorporate other relevant variables such as ice cover or vegetation.

**Basis for Comment**

The logic used to justify the use of “percent backwater greater than 4 feet in depth” as a habitat variable appears to be based upon two statements, that “water depth provides winter cover by providing space and darkness,” and that the variable was included “because of its importance and because it is a relatively easy variable to predict or measure” (Palesh and Anderson 1990, p. 2 – 3). Reviewers are unsure about the availability of data used to justify this habitat variable.

**Significance – High**

One of four habitat variables in the winter modification to the Bluegill HSI model may not have sufficient data to be sure of its impact.

**Recommendation for Resolution**

Obtain field data to validate and modify the relationship between percent backwater depth > 4 feet and bluegill habitat quality. Alternatively, incorporate additional variables such as ice cover (assuming sufficient literature references can be found) to modify the existing life requisite component of winter cover.

**Response of Model Proponent**

The water depth variable is one of the weakest in the winter modifications and I agree it could use some modification. Ice and snow cover can affect water quality conditions, which changes throughout the winter season. Generally we assume late season conditions (February) when predicting minimum DO for the model. 2-3 feet deep areas can be important habitat early in the winter season, with 4 feet providing habitat mid-winter habitat and depths greater than 4 feet for late winter and/or for winters with heavy snow/ice cover. Based on WDNR’s late fall fish surveys, there also appears to be a species preference for water depth with largemouth bass congregating in areas with 6 feet or greater. The model could benefit by assigning an index value similar to QHEI based on spatial distribution of depths rather than a percent, as well adding other cover variables like vegetation. I believe we can work with the resource agencies to modify the winter cover variable (see response to comment 7).

**Summary of Discussion**

There was broad agreement that no short-term solution to this panel comment is possible. Instead, additional winter variables should be developed (perhaps in collaboration with state agencies who may have the necessary data). Such variables may include snow and ice cover, vegetation, light penetration and spatial distribution of depths.
**Final Panel Comment 4:**

The winter modification for the Bluegill Habitat HSI model artificially limits model application to areas with winter water temperatures (\(V_C\)) below 4°C. This limitation does not appear to be based upon either data or theory and should be removed.

**Basis for Comment**

The Bluegill Habitat HSI model spreadsheet does not allow water temperatures exceeding 4°C to be entered for the variable of Winter Water Temperature (\(V_C\)). This exclusion does not seem to be rooted in theory or data, because model documentation indicates that a water temperature of 4°C is optimal. As such, it is unlikely that water temperatures of \(> 4°C\) are prohibitive to the establishment of a population of Bluegill.

**Significance – High**

By limiting model application to areas with winter water temperatures below 4°C, the geographical scope of the model is minimized, and potentially important overwintering habitat for Bluegill may be excluded or defined as being of minimal value.

**Recommendation for Resolution**

This model limitation appears to be an oversight; since Bluegill thrive in warm winter waters in the Southern United States. Unless data show that winter temperatures \(> 4°C\) are prohibitive for populations of Bluegill, all data \(> 4°C\) should be assigned a habitat-variable HSI of 1.0.

**Response of Model Proponent**

Good catch. The model was intended to assign any value of \(> 0\) an HSI value of 1.0. The spreadsheet will be modified. Modifications to the spread sheet to address comment 21 in Appendix D will also be made.

**Summary of Discussion**

No significant discussion. Agreement that fix will be made.
<table>
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<th>Final Panel Comment 5:</th>
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<tr>
<td>Model documentation matching the current spreadsheet-based should be assembled and include information from the original USFWS model (Stuber et al 1982), the winter modification (Palesh and Anderson 1990), all applicable LTRMP methodologies used to obtain input data, and a methodology for conducting uncertainty analyses.</td>
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<th>Basis for Comment</th>
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<td>There is no single document that addresses the entire Bluegill HSI Model as presented in the spreadsheet. Instead, separate documents exist for a ‘summer’ model and a ‘winter’ modification. Additionally, relevant methodologies for collecting field data should be made readily available to model users, to ensure high quality data is input into the model. Finally, because the model has several habitat variables that may control overall HSI (e.g., dissolved oxygen and isolation), a methodology for incorporating uncertainty analysis should be included with the spreadsheet.</td>
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<th>Significance – Medium</th>
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<tr>
<td>Assembling a single technical document will increase the ease of use for the model. Including LTRMP methodologies will ensure that, when necessary, standardized field methodologies are used in the field to ensure the collection of high quality data. Finally, ensuring that uncertainty analyses are conducted will help place output from the Bluegill HSI model into context, and help identify individual habitat variables critical to overall project success.</td>
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<th>Recommendation for Resolution</th>
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<td>Assemble complete model documentation, including LTRMP methodologies and a methodology for conducting uncertainty analysis.</td>
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<th>Response of Model Proponent</th>
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<td>Concur that this would improve the utility of the model and we propose to work on this over the next year (see response to comment 7).</td>
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<th>Summary of Discussion</th>
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<td>Discussion indicated widespread agreement that documentation for the Bluegill HSI model requires updating. Additions should include a discussion of critical assumptions and the estimation and use of AAHUs.</td>
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Final Panel Comment 6:
There is currently no documentation that provides guidance on the use of Bluegill HSI output. Relevant documentation and a spreadsheet template should be distributed within the Bluegill HSI model to ensure calculated benefits for total project life are correct.

Basis for Comment
In its current form, the spreadsheet model calculates a single, deterministic HSI value given a single set of conditions. Therefore, the spreadsheet does not explicitly incorporate risk and uncertainty into its estimates, nor does it directly estimate average annual values over a planning period.

To have model output conform to Corps policies and procedures, the Bluegill HSI Model must be run multiple times over the entire planning period to account for changing conditions and uncertainty. The results of these model runs must then be annualized using a separate spreadsheet, converted into a separate unit (such as habitat units) which can then be used in Corps planning models.

Significance – Medium
Model output does not explicitly meet Corps policies and procedures for project planning. Thus, although the Bluegill HSI Model is capable of meeting Corps policies, it is possible that the lack of guidance with may create problems during the project planning process.

Recommendation for Resolution
Reviewers recommend that documentation be developed that outlines the steps necessary to perform uncertainty analysis and to ensure annualized outputs are generated in a manner that conforms with Corps policies and procedures. Such a document, and an associated spreadsheet template, should be disseminated with the Bluegill HSI Model. Reviewers believe that these documents would substantially improve the probability that model output conforms to Corps policy.

Response of Model Proponent
It is assumed/recommended that model users will be familiar with process for using the model outputs for planning use/analysis. Guidance on how target years are established (which are project specific depending on construction schedule, estimated future changes in habitat conditions, etc), estimation of average annual habitat unit, incremental analysis, etc. are documented in the user manuals for IWR-Plan at [http://www.pmcl.com/iwrplan/](http://www.pmcl.com/iwrplan/) and the FWS's 1980 Habitat Evaluation Procedures Handbook at [http://www.fws.gov/policy/ESMindex.html](http://www.fws.gov/policy/ESMindex.html). IWR has a certified model that can be used to annualize benefits and costs. It can be downloaded at the site above along with a user manual.

Summary of Discussion
There was broad agreement that additional documentation is necessary to ensure output is used correctly. Discussion began by communicating an idea developed during the Diving Duck HSI model teleconference, that a short paragraph of instructions that provided hyperlinks to suitable documentation (e.g., blue book, instructions for incremental cost effectiveness analysis, etc.) would be developed, and that such a checklist / short instruction document would be made available to all model users. Reviewers agreed that such a crib sheet would be helpful to minimize the possibility of model misuse. However, it was agreed that additional instructions should be included within the spreadsheet file and discuss model limitations, assumptions, variable definitions and explicit model objectives.
**Final Panel Comment 7:**

There are untested assumptions in the model with respect to the relationships between HSI and the carrying capacity of bluegill. Model validation should occur to ensure the usefulness of model output.

**Basis for Comment**

Technical documentation states that the model is a set of hypotheses of species-habitat relationships. Reviewers were not provided with sufficient data to validate the model. Consequently, the accuracy of the model in predicting carrying capacity needs to be tested, particularly for winter modifications.

**Significance – Medium**

The Bluegill HSI Model is able to provide information useful to project planning in the UMR. Field validation of hypothesized relationships between habitat variables and carrying capacity should be tested to ensure model outputs are accurate.

**Recommendation for Resolution**

Reviewers recommend that model relationships be validated through regular monitoring of project sites that have undergone remediation. Additionally, data from the LTRMP may exist to explicitly test these relationships.

**Response of Model Proponent**

Concur with recommendation. Regular monitoring of Habitat Rehabilitation and Enhancement Projects under the Environmental Management Program is undertaken. This includes water quality (DO, temperature, current velocity) to see if project objectives are met. LTRM uses a random sampling approach, but we generally use transect designs to ensure we are capturing the area proposed for habitat creation. The WDNR is also conducting pre-project and post-project monitoring of fish data. Fish are being sampled using random stratified and fixed site electrofishing runs, following LTRM protocols, in early November each year when temperatures are at or below 10 degrees C. Fish begin moving to their overwintering sites when temperatures fall below 10 degrees C. WQ is also being monitored at these sites. This is being completed for many potential overwintering areas. This will allow us to look at the quality of the fisheries in relationship to water quality, water depth distribution, vegetation, and other factors. This should allow some level of validation of the model and predicted variable values and fish response. It will also allow us to see if there are any fish species related trends. IDNR is also conducting an extensive fish use study of couple of Environmental Management Program HREPs that will also add to the database and assist in modifying the Bluegill HSI Model. There is great interest in the part EMP partners to make use of LTRM data in HREP planning and this would seem like a good opportunity to try to make more use of this data to refine the Bluegill HSI model. If funding allows, we could work with the interagency Fish and Wildlife Work Group over the next year to complete this evaluation and refine the model.

**Summary of Discussion**

There was broad agreement that model validation should occur, that state agency data would be invaluable to any validation effort, and that funding is an issue.

In the short term, discussion focused on ensuring that enough and appropriate data is being collected to allow for future model validation and improvement. This requires ensuring that data is being collected for all variables in the current model, but also for data that might be included in future iterations of the model (e.g., ice cover, snow, light penetration).
Appendix D: Compilation of Reviewers Comments

General Comments

Comment from Jason Weiss  Comment Significance: Unassigned

The lack of user documentation limits the ability of the model to be easily transferred. Although the model proponent knows how the inputs should be developed (e.g., use of average annual values), it may not be known by other analyst working on similar types of projects. Variation on the inputs would limit the ability of the results to be compared across projects or evaluated consistently during the review process. A basic user document would be beneficial in addressing the transferability issue.

1. Are the model’s design objectives and intended uses clearly communicated?

Comment from Jason Weiss  Comment Significance: Unassigned

The objective and intended uses were provided during the presentation given during the kick-off meeting and the certification documentation accompanying the model. The title indicates the specialized intent of this model.

Comment from Dennis McCauley  Comment Significance: High

Yes, the model is intended to adjust bluegill HSI estimates to account for winter habitat conditions, whereas the earlier model (Stuber et al 1982) does not contain variables that allow for winter habitat conditions. The winter habitat modification model includes the variables % backwater greater than 4 feet, minimum winter dissolved oxygen, and current velocity variables, which in turn calculate winter HSI values for winter cover (Cw-c), winter water quality (Cw-wq) and winter other (Cw-ot).

Comment from Chris Yoder  Comment Significance: Low

Yes, fairly straightforward.

2. To what extent does the model meet the expressed design objectives?

Comment from Jason Weiss  Comment Significance: Unassigned

The designed objectives were provided in the certification documentation – the model meets the design of objective of estimating HIS for winter habitat.

Comment from Dennis McCauley  Comment Significance: High

The model is designed to provide an adjustment for winter ice cover conditions and it does that very well.

Comment from Chris Yoder  Comment Significance: High

In concept the model seems to satisfy the intended project objectives, but the question remains can it be improved upon? The answer is clearly yes and specific suggestions are made in response to questions 4, 6, and 10 (also in the two attachments provided).

3. To what extent is the model suitable for the expressed intended uses?

Comment from Jason Weiss  Comment Significance: Unassigned

The model is meant to mimic the finding and procedures presented in the 1982 and 1990 papers. To that effect the model meets the intended use.

Comment from Dennis McCauley  Comment Significance: High

Very suitable, easy to use and is clearly a good fisheries management and/or project alternatives tool.
The results presented thus far seem to indicate that observable responses have occurred that seem correlated with HSI driven habitat enhancements. However, how this extends to other species as is the intent of the HSI is less clear.

4. Comment on the quality of the model’s technical documentation.

Comment from Jin Huang  Comment Significance: Medium
I find the technical documentation clear and easy to understand. But currently the winter HSI documentation and summer HSI documentation are separate. It would be good to combine them and make one technical documentation.

Comment from Jason Weiss  Comment Significance: Low
Documentation describes the mechanics and assumptions for model inputs. The documentation does not describe the proper use of model outputs.

Comment from Dennis McCauley  Comment Significance: High
Although I mostly agree with the professional logic used in the winter cover variable, I do not see that it is entirely supported by the literature, specifically the % pool greater than 4 feet variable. The authors state that: “water depth provides winter cover by providing space and darkness” and go on to say “the authors used water depth as an important overwinter variable because of its importance and because it is relatively easy to measure or predict”, whereas the supporting literature mostly linked off-channel habitats greater than 4 feet in depth to water quality variables such as dissolved oxygen and excess sedimentation. The SI plot shown for % Pool appears to be based on fewer data than the other variables and is scored no lower than 0.4. Depending on the availability of SI plots, other winter habitat variables could be included such as ice depth, snow cover and others to help support the Winter Cover HSI calculation.

Comment from Chris Yoder  Comment Significance: High
The amount of detail on the steps needed to translate field data to HSIs is somewhat lacking. For bluegills, depths of > 1 m were identified as an important component of winter habitat. It is unclear to exactly how much BPJ vs. actual data was used to construct the model for each of the variables. It was also unclear as to the relative scale of assessment of backwater areas without digging through the LTRMP methodologies (which are quite voluminous). Is the data collected pool or backwater-wide? As individual sample (e.g., 200m) transects? If so, then these could be treated as individual samples to gain information on variation within a reach or backwater.

The same uncertainty applies to testing the results of the model for a specific restoration project. Assuming that physical data is collected during sampling efforts to field verify the key response variables which would be the relative abundance of fishable bluegills. It is being asserted by the older HIS literature and the recent model overview that the bluegill functions as a surrogate for other backwater species as well. However, because of it’s rather generalist habits and life history attributes it may not represent more sensitive or less common species that are likewise dependent on the backwater habitats of the UMR.

Model Uncertainty
Some estimate of uncertainty or confidence intervals around HSI estimates would be useful. Lee et al. (2006) conducted uncertainty analyses on some HSIs for a pondweed in Europe and included variation in expert opinion. The ability to collect and test data within a pool or pools or backwaters would be useful if it were collected in transects, along with biological and habitat measures at this same scale to gain an estimation of variability in response. This biological and habitat data does not need to be collected at the finer scale that data for other comparable tools such as PHABSIM is collected, but rather as summary data along each transect that would capture variability in depth and other important model variables. This scale could also be used to estimate cover quality measures (see below) that may provide additional
insight into specific habitat needs for these species. The key is the paired collection of the important physical variables at each site and then among sufficiently different sites to better derive and calibrate the response curves.

*How Transect Data Could be Used*

Transect based data can potentially be used to develop and test HSI outputs. Habitat indices similar to the Qualitative Habitat Evaluation Index (QHEI; Rankin 1989, 1995; Ohio EPA 2006) could easily be collected using this approach. Although QHEI was not originally developed to enhance HSI models, it can be used to explain variation in fish assemblage data along a gradient of habitat complexity. It has been used to explore individual species responses to habitat variables in streams and rivers. Figure 1 provides an example of this use for four redhorse (genus *Moxostoma*) species and white sucker (*Catostomus commersonii*) using presence/absence data and the overall QHEI habitat index that ranges from 0-100. Data for wadeable streams in this case were divided into approximately equal size bins of data along the QHEI axis. Data in the upper and lower 10th percentile of their drainage distributions were dropped and zero values were generated if sites lacked a species, but were collected elsewhere in the same 11-digit HUC watershed. The resulting probability of capture can be interpreted as an “HSI type” of curve.

White suckers are considered to be habitat generalists and show the smallest slope with increasing QHEI and decline at the highest QHEI values; they are basically collected frequently along the entire gradient. Black redhorse (*Moxostoma duquesnei*) are considered the most intolerant of the *Moxostoma* and have a strong positive slope and low probability of occurrence at low QHEI scores (i.e., poor habitat). The other three redhorse species vary in response to QHEI with intolerance ordered as shorthead redhorse (*Moxostoma macrolepidotum*) > golden redhorse (*Moxostoma erythrurum*) > silver redhorse (*Moxostoma anisurum*). Distribution of bin midpoints is also informative with more locations at lower QHEI scores for white sucker and fewest midpoints at low scoring QHEI sites for black redhorse. This analysis could be performed for individual habitat

Figure 2. Example of how transect-based chemical stressor data could be used to provide a more quantitative approach to testing HSI models. Data from wadeable streams in Ohio with data collected primarily by Ohio EPA, the Midwest Biodiversity Institute (MBI) and the Ohio University.
attributes such as maximum depth and for overall and individual cover scores as well as for chemical variables (e.g., D.O.). Figure 2 is an example for two sucker species relative to TKN (organic nitrogen).

5. Comment on the technical quality of the model relative to its expressed design objectives.

Comment from Dennis McCauley  Comment Significance: Medium

The model adequately addresses the overwinter variables given and correctly incorporates them into the adjusted winter HSI, however, the winter cover variable is restricted to depth only.

Comment from Chris Yoder  Comment Significance: Medium

Seems to be 'good', but specific enhancements are suggested and as detailed in the attachment 1 should be considered and explored further.

6. Comment on the temporal and spatial granularity with which the model is designed to be applied.

Comment from Dennis McCauley  Comment Significance: Low

The level of detail provided by the winter habitat modification is much less than that described by Stuber (1982) on which the model is based. This is totally understandable since much of the same information is used.

Comment from Chris Yoder  Comment Significance: Medium

The issues of scale and cumulative impacts are both important and difficult to deal with, but can have a significant impact on the success of an HSI for any species. Here I refer to two levels of scale, a more local one than is generally sampled or referred to (e.g., a specific backwater of the UMR) and a larger scale (navigation pool or other extended reach of the UMR) that can influence the cumulative impacts to habitat (physical or chemical) from upstream watershed areas.

For wadeable streams in Ohio and Indiana we have observed strong limitations related to the percent of habitat disturbance in streams at the Huc14 or Huc11 scale. This seems analogous to both the degree of degraded habitat within the pools of large rivers (local scale) or also from watersheds that drain to the mainstem. This is also related to the degree of connectivity between backwater areas (e.g., are they isolated or connected?). The importance of scale of habitat degradation is directly related to the expectation of success of a model. Restoration in areas that have widespread habitat degradation (or poor connectivity) may not respond as strongly as an area adjacent to higher quality habitats. The restoration in the degraded area could be considered a failure when it is instead an important step in the recovery process. Taking scale into account would bring the ability to distinguish between failure and success in the restoration process.

Connectivity – there is no explicit consideration of connectivity to the main channel of the UMR. Perhaps bluegill can maintain populations in areas that are poorly connected to main channel habitat areas, but perhaps this should be an explicit variable. The work by Bartels et al. 2008 suggests such connectivity (distance) can be an important variable.

7. Comment on the geographic range/applicability of the model.

Comment from Dennis McCauley  Comment Significance: Medium

Clearly relevant to the UCMR lock and dam system and likely relevant to larger tributaries to the watershed (e.g., St. Croix, Wisconsin and Chippewa River systems).

Comment from Chris Yoder  Comment Significance: Low

Almost by definition it is best suited for Midwestern floodplain rivers, specifically the UMR where off-main channel backwater habitats are prevalent.
8. Comment on the degree to which the assumptions and limitations of the model are clearly communicated? Comment on the degree to which apparent limitations impact the ability of the model to be used for characterization of system/habitat resources? Comment on the degree to which apparent limitations impact the ability of the model to be used for planning and forecasting of project-related impacts? Please provide recommendations for resolving or overcoming identified limitations?

Comment from Jason Weiss  Comment Significance: Low

The model does not appear to include any opportunity to document the alternative (no action or project plans) and condition (baseline, base year or future condition) being analyzed.

This limitation could be addressed by incorporating a multiple conditions into the same spreadsheet. One approach would be to setup different tabs/sheets in the spread sheet representing each alternative. Within the alternative different input columns could represent the different years or conditions. The results could then be summarized in a different tab to provide a year by year comparison of the HSIs for the various alternatives.

Comment from Dennis McCauley  Comment Significance: Medium

The winter HSI is limited by the winter cover variable which is limited to depth. However, this should not prevent the adequate characterization of the habitat resources, or at minimum the potential of the model.

If limiting the winter cover variable to depth is a significant limitation (and it may not be), I do not see it as restrictive to using the model as either a planning or forecasting tool or for the evaluation of project alternatives.

Perhaps add another variable to the winter cover variable, such as ice depth or revisit the SI for winter cover (albeit, there may not be SI plots available for those indicators). Alternatively, the connectivity of the back water to the main channel could be made more significant since it is likely a significant factor affecting water quality (specifically dissolved oxygen) and water velocity.

Comment from Chris Yoder  Comment Significance: Medium

General assumptions and limitations are fairly well stated and others are implicit. The extension of the bluegill HSI to other Centrarchidae has some relevance, but extension to other management objectives that include less related fish species and the fish assemblage as a whole are not as well considered. It has, however, had proven results for its specific and presumably intended application. Limitations include the aforementioned narrow, species-specific scope and comments provided for question 10 offer specific suggestions about how to improve it.

9. Is the model based on well-established contemporary theory?

Comment from Dennis McCauley  Comment Significance: High

Yes, the winter habitat modification is based on the Stuber (1982) HSI model which is well vetted. Habitat valuation using HSI is also a common and accepted practice.

Comment from Chris Yoder  Comment Significance: Medium

The concept of species responses to habitat is a well established contemporary theory; however we believe that recent work that also focuses on assemblage responses would not only supplement, but strengthen a species-based approach. Each approach should be considered complementary and not “competing”.
10. Does the model adequately emulate or otherwise address the suite of critical ecosystem attributes necessary to characterize system/habitat resources?

Comment from Dennis McCauley  Comment Significance: Medium

Yes, especially since side channel dredging appears to be one of the preferred management tools and is supported in the literature; this particular model will easily address changes as a result of side channel dredging.

Comment from Chris Yoder  Comment Significance: Medium

One question is whether the full suite of ecosystem attributes is adequately addressed in the model. Many of the variables are couched as “percent” variables (e.g., percent cover, percent of areas > 1 m deep, etc.). This does not seem to capture some of the more qualitative characteristics of these attributes. An example is cover. The model measures “percent cover” (e.g., woody cover). All woody cover may not all be equally consequential. For example two sites could have equal proportions of woody cover, but form and location could be qualitatively different. In smaller streams for example we find that larger, more stable woody cover, adjacent to areas of higher velocity, tend to provide better habitat (e.g., support a greater diversity of sensitive species) than smaller, less stable woody cover or woody cover in shallower areas that may be subject to greater siltation. These differences can be qualitatively accounted for. Although the HSI approach generally employs continuous variables (e.g., percent cover), Wakeley (1988) proposed a way to simplify HSI models to use discrete data. The QHEI for example has 4 discrete levels of cover quality for each cover type. Such an approach could be used to identify cover quality and to translate it to HSI variables in a manner similar to Wakeley (1988). This or some similar approach could then capture some of the “qualitative” differences in cover quality that may not be adequately captured with a continuous variable alone (percent cover). While this may well be less important in larger river systems, it is not clear whether this has been adequately tested. If there is an important difference in responses to quality of cover then this would have important consequences for the design of a type or form of restoration.

Depth has been identified as a key attribute of overwintering areas and it is undeniably important. However, does the one-dimensional aspect of this variable adequately capture a potentially different response to how uniform depth is over a given area of backwater habitat compared to more variable depth regimes that one might find in say a braided channel or a backwater area that receives periodic sediment pulses after flooding or channel meandering? In a manner similar to that suggested for cover quality, the “quality” of depth could be captured by combining depth categories with proximity to key cover types, bottom slope, or high quality shallows. Then rather than a simple depth criterion, depth could be qualified by these other aspects of quality as well.

System Quality

It is unclear how “auditing” or assessment of model applicability is to occur (either by type of auditing or frequency). Precisely, what type of sampling (in terms of both response variables, i.e., bluegill size and abundance and habitat variables) typically occurs? As discussed above questions remain about whether the current level of detail in the habitat data is sufficient to capture variation in key limiting physical factors and at multiple spatial scales. While the measurement of the chemical data is comparatively straightforward the density of samples needed to estimate the limiting effects of physical habitat is not specified.

Single Species and Assemblage Data

HSI models typically focus on individual species with the understanding that they can serve as a surrogate for other related species that presumably have similar habitat requirements. Would an assemblage approach perhaps be a more inclusive endpoint that would likely enhance fishable bluegill populations while also including species that likely could have more limiting habitat requirements? Transect data that
includes more detailed habitat and other stressor variables along with the already collected fish assemblage data could be used for both species-specific and assemblage level HSI models. This does not preclude using the data from other sampling gear (e.g., fyke nets, etc.) for species that are not as susceptible to electrofishing. A strong baseline of transect-based data could provide more explicit linkages between single species models and assemblage data. In addition, it seems that the LTRMP produces the types of large data sets to test this approach.

Biological Condition Gradient (BCG) Concept

The underlying goal seems to be the enhancement and improvement of fish populations in specific UMR habitats. To that end the recognition of the importance of backwater areas is essential. One approach that might be helpful is the Biological Condition Gradient (BCG) approach (Davies and Jackson 2006). This concept creates a biological gradient of assemblage conditions (Y-axis) anchored in natural conditions and extended through varying levels of disturbance to severely impaired conditions. Implicit in this effort is the development of sufficiently detailed “stressor” gradients that comprise the X-axis and determining their influence on biological response positioned on the Y-axis. Habitat conditions are typically an important X-axis gradient, as are chemical parameters such as D.O., TSS, and pH which are considered in an HSI. The underlying principles of the HSI are sufficiently analogous to the development of a BCG relative to differing stressor gradients. An important component of this process is an anchor in “natural” conditions. Although this natural condition may no longer exist or be attainable, historical analyses can be used to reconstruct the biological and stressor (e.g., habitat conditions) attributes that co-existed. Such a reconstruction can help create an expected trajectory of change for not only considering restoration options or “optimal” conditions, but also as a “yardstick” for quantifying the degree of actual change.

A suggestion for this in relation to the bluegill model is that a reconstruction of the biological conditions that existed under natural riverine-backwater conditions can help put in better context the bluegill model, or models for other species, or an assemblage model. The role of bluegill in such a BCG model could then be extracted from an assemblage model to determine the limits of bluegill as a suitable surrogate for other riverine and backwater species. Many rare, threatened and endangered species are often associated with high quality backwater conditions and assemblages, which may not be as evident in species-specific models.

The BCG can be constructed from existing data, with historical data being tempered by input from experts familiar with the ecosystem and fish assemblages in question (e.g., upper Mississippi River). The physical and chemical attributes of a backwater area BCG can be “constructed” from existing data and historical data and knowledge that yields a gradient of the chemical and physical attributes of backwater habitats. It is likely that some backwater classification work will be needed, but some of this work may have already been done (Julien et al. 2008) or is well underway (Donnelly 2009). It is likely that chemical/physical and biological characteristics of backwaters may vary naturally with the environmental setting which may include factors such as size, age, ecoregion (see Chapman et al. 2004) or other analogous phenomena such as connectivity and proximity to the main channel, origin or type (e.g., oxbows, delta, natural cutoff, chute cutoff, engineered cutoff, etc.), flood pulses, and water temperature. Conditions in backwaters can also change over time due to lateral migration of the mainstem and changes in flooding and sedimentation regimes (Wren et al. 2008). In fact, changes in the flood-pulse duration and extent (more restricted) are thought to affect the temperature of flood waters (i.e., cooler) which can affect sport-fish reproduction and recruitment (Schramm et al. 2004).

Quantile Regression

Has quantile regression been considered as a method for developing HSIs? Applications of quantile regression and habitat analyses in relation to certain stream species (e.g., Fayram and Mitro 2008) has been used to identify limiting habitat factors. In the Fayram and Mitro (2008) study on trout in Wisconsin the results suggest that trout density and a cold water fish assemblage measure could be enhanced simultaneously especially when there are some habitat features that are differentially limiting between
assemblage measures such as the cold water fish IBI and trout density. A similar result for bluegill, for example, could influence the concept as bluegill as a surrogate or other species or the fish assemblage as a whole.

11. Does the model effectively allow for reasonable variation of variables critical to the intended uses (i.e., application of the model during planning of water resource and restoration activities)?

Comment from Dennis McCauley  Comment Significance: Medium
Absolutely; the model allows the user to input a wide range of scenarios that would be directly applicable to a wide range of planning projects.

Comment from Chris Yoder  Comment Significance: Medium
The addition of an assemblage perspective would be advantageous when evaluating variation in and among habitat variables during both design planning and restoration assessment. Variation within a specific habitat variable within a single species HSI model may well be of lesser importance to other backwater species that are reflected in assemblage based responses. As such this would broaden the design considerations and benefit more than the target species and its closest taxonomic associates.

12. Comment on the precision and accuracy of the model outputs and identify which variables/factors have the greatest impact on model precision and accuracy.

Comment from Dennis McCauley  Comment Significance: High
I entered several data sets into the model and found it to be very accurate. I did notice a slight difference between this model and the Stuber model output when identical data sets were entered, but that difference was very small and likely attributable to a rounding error in the Stuber model. As with the Stuber et al. model (1982), the water quality variable, specifically dissolved oxygen, has the greatest impact on the model and rightfully so. The winter modification defaults to the water quality HSI when water quality HSI is less than 0.4. Current velocity inputs will also have a significant affect on the output. I found it interesting that the current velocity variable is limited to 10 cm/sec in the winter modification, while the spring and summer adult, embryo, fry and juvenile inputs for water velocity will accept values up to 20 cm/sec. I assumed water velocities in the UCMR backwaters seldom exceed 10 cm/sec.

Comment from Chris Yoder  Comment Significance: Medium
As mentioned in some of the other comments, certain aspects of habitat features (e.g., cover quality) may not be adequately represented in the current set of input variables. If they are indeed important and not part of the current inputs, this could limit the accuracy of the model outputs.

13. Comment on sensitivities of the model and identify the variables/factors to which the model is most sensitive.

Comment from Jason Weiss  Comment Significance: Unassigned
The model adjusts to changes in the input variables as long as none of the sub-categories have an HSI of 0. Any changes to the input variables are immediately apparent on the output variables. Sensitivity to specific variables is being performed by other on the review team.

Comment from Dennis McCauley  Comment Significance: Medium
Again, the model is correctly sensitive to water quality changes and water velocity changes. The winter modification could be made to be more sensitive to winter cover changes by adding other variables and perhaps by placing greater emphasis on side channel connectivity to the main channel.

Comment from Chris Yoder  Comment Significance: Medium
As stated in a prior comment, some description of the sensitivity of the models input variables would be helpful to understand the sensitivity of the model. This does not seem to be described in any detail.
14. Are the input requirements of the model evident to the user (i.e., types as well as accuracy and precision)?

Comment from Jin Huang Comment Significance: Medium

* The 'enter condition' and 'enter year' is not clear to the user what to enter. It would be nice to give options or instructions on that.

* In the "Habitat" column it's not clear to the first-time user what 'R' and 'L' represent.

Comment from Jason Weiss Comment Significance: Medium

The inputs are labeled and limited guidance is given in roll-over information boxes. The model assumes that the analyst has the required knowledge (such as a fisheries biologist) to understand and provide the correct inputs. Inputs outside of an acceptable range are not allowed, however no information is given to the user to indicate the acceptable range.

The following items were noted during evaluation of the model and spreadsheet:

- Description for Isolation (cell E44) is very subjective, especially in comparison to the other variables in the model. Suggest refining definition to reduce subjectivity.

- Description for variable Vd is not clear in comparison to the documentation (January 1990 paper), which specifies that velocity is for areas with an average depth greater than 4 feet.

- Variable for water temperature, Vc (cell E38), appears artificially limited to less than or equal to 4 degrees c. Documentation (January 1990 paper) does not indicate an upper limit, but says 4 degrees c is optimal.

Comment from Dennis McCauley Comment Significance: High

Very much so. The model does not allow the user to input erroneous values and instructs the user to the range of data that is acceptable.

Comment from Chris Yoder Comment Significance: Medium

The input variables are explicit by their description only. There is no explicit or otherwise stated need to collect new data to use the model.

15. Is it evident to the user how the inputs are used by the model?

Comment from Jin Huang Comment Significance: Low

Yes, the formula imbedded in the spreadsheet show how the inputs are used for calculating the HSI.

Comment from Jason Weiss Comment Significance: Unassigned

Yes. The model adjusts to changes in the input variables as long as none of the sub-categories have an HSI of 0. Comment boxes provide the formulas that are used to calculate the HSI for the sub-categories and overall output. Additional information can be derived by reviewing the formulas used to define the HSI values.

Comment from Dennis McCauley Comment Significance: Medium

Yes, especially when the reviewer reviews the background information on the process to fit equations (i.e., the FWS Smallmouth Bass model) and the background information given by the author.

Comment from Chris Yoder Comment Significance: Low

Yes, by the explanations and formulae used in the model.
16. Are assumptions critical to valid application clearly identified and characterized such that violation of a critical assumption would become apparent?

Comment from Jason Weiss  Comment Significance: Unassigned

Highlights of violations of assumptions were not noted during the review. The model does not allow violations of input ranges.

Comment from Dennis McCauley  Comment Significance: Medium

Yes, the model input does not allow the user to input erroneous values.

Comment from Chris Yoder  Comment Significance: High

No, except for the 'disclaimer' explanation in the 1982 document, which is necessarily general. This actually implies that new data and information would be collected in a wide number of areas as the HSI is applied, but in reality given that monitoring and assessment can be viewed as 'expendable' in many programs a more assertive description of sound monitoring practices as providing more than follow-up validation seems in order.

17. Comment on the degree to which model assumptions might invalidate the model’s use for specific applications.

Comment from Dennis McCauley  Comment Significance: Low

The winter habitat modification may not be used in conditions when the current velocity exceeds 10 cm/sec.

Comment from Chris Yoder  Comment Significance: Low

The HSI is fairly robust because it is comprised of multiple variables and each share some redundancy with other variables, hence it is unlikely that its application would be invalid unless it is applied well beyond its intended logic. This seems unlikely in capable hands.

18. Comment on the degree to which the model facilitates/accommodates uncertainty and risk analyses.

Comment from Jason Weiss  Comment Significance: Medium

The model does not incorporate uncertainty or risk analysis, nor does the documentation provide any guidance or methods to account for it. Computationally such changes would be fairly easy to implement using spreadsheet add-ons such as @Risk.

Comment from Dennis McCauley  Comment Significance: Medium

The greatest uncertainty I as see it in the winter modification is the estimation of % pool greater than 4 feet. These data seem to be generated largely from GIS mapping of the lock and dam system and may be difficult to estimate during ice cover. Other sources of variability to the model may be the frequency, spatial distribution and accuracy of the water quality measurements input to the model. For instance, the frequency and depth where dissolved oxygen measurements are taken to characterize the water body are very important considerations. Single near surface dissolved oxygen measurements will most likely misrepresent the water quality variable. Dissolved oxygen and temperature stratification could greatly skew the HSI results if not accounted for in the field measurement. Another source of uncertainty is that the models assumptions for bluegill are often based on life requisites for other Centrarchids (i.e., largemouth bass), which may or may not have the same over-winter/ice cover requirements.

Comment from Chris Yoder  Comment Significance: Low

There is nothing readily apparent about how to deal with uncertainty, but the applicability of the model is fairly well stated and any shortfalls in knowledge and/or untested assumptions are readily acknowledged.
19. Comment on the degree to which the model can be used as a tool to forecast conditions anticipated to occur during the design lifecycle of a water resource and restoration activities project (i.e., from 1 to 50 years).

*Comment from Jason Weiss  Comment Significance: Medium*

The model currently only evaluates one condition at a time and the assessment of lifecycle changes must be completed external to the model.

*Comment from Dennis McCauley  Comment Significance: Medium*

The model allows the user to input a wide variety of scenarios that could be used to forecast conditions and/or the affect of management activities over a long period of time.

*Comment from Chris Yoder  Comment Significance: High*

The HSI is mostly an empirically derived model that should be continually refined as data related to the results of restoration projects is collected and assessed. Ecological systems are dynamic and we are collecting data in an ongoing (hopefully) to capture what we expect to happen (e.g., response to restoration) as well as potentially unrelated changes (e.g., exotic species invasions, climate change). These types of models grow stronger by continuing to collect adequate data in a standardized manner and then reassessing the relative importance of these stressors over time. As we have seen in water quality studies conducted in a like manner over the past 30 years some impacts have lessened in response to targeted management actions, while “new” and previously unassociated impacts such as alien invasions have become more prevalent (particularly in large and great rivers) and climate change is not only looming, but may already be taking place. The direction of change in habitat, flow, and nutrient regimes is uncertain as much of it now depends on agricultural, land use, and environmental policies (CWA, Farm Bills, shifting to energy crops, etc.). As such these models should be data driven as much as is possible and will need to be continuously (or at least periodically) re-evaluated with a broader emphasis on habitat and assemblage wide responses. Fortunately, many of the required data attributes are already part of the LTRMP and with some enhancements and additions it should provide the systematic monitoring that is needed to undergird the modification of the current models and overall management responses as a result.

20. Comment on the degree to which the model delivers information adequate for the purpose of supporting determinations of compensatory mitigation.

*Comment from Jason Weiss  Comment Significance: Unassigned*

The model does not deliver information adequate for the purpose of supporting determinations of compensatory mitigation.

*Comment from Dennis McCauley  Comment Significance: Low*

The model could be used to demonstrate the impact of a specific management scenario on backwater habitat areas and used to model existing conditions specific to bluegill habitat. To that end, the model output could be used to support compensatory mitigation if and when backwaters are determined to have been damaged due to some anthropogenic source.

*Comment from Chris Yoder  Comment Significance: Low*

It would seem from the examples that mitigation actions designed to the HSI for bluegill has indeed delivered positive results in selected UMR backwaters.
21. Are the formulas used in the model(s) correct? Are model computations adequately documented? Are model computations correct throughout the document? Are model computations (mathematical logic) appropriate?

Comment from Jin Huang  Comment Significance: Medium

As a spreadsheet auditor, I checked whether the formula used in the spreadsheet matched with those in the technical documentation. Here are some comments:

1. The comment to cell D28 is incorrect for Lacustrine's formula. The denominator should be 4 rather than 5. So the formula should be: \( Cf=(V2\times V3\times V5\times V7)^{1/4} \). However the actual calculation in cell F28 is correct.

2. The comment to cell D41 is incorrect in the formula. Instead of \( C_{w-wq}=(2V_b+2V_c)/3 \) it should be \( C_{w-wq}=(2V_b+V_c)/3 \). However the actual calculation in cell F41 is correct.

Comment from Dennis McCauley  Comment Significance: High

In each instance the model computations appear to be correct and accurate. My review was limited to the input of various data sets into the model and by a comparison of known model outputs with other models. For example, I entered three data sets from Stuber et al (1982) into this model and the results were nearly identical.

Comment from Chris Yoder  Comment Significance: Medium

The formulas and computations appear to be correct and the accompanying certification states the extent of testing and QA checks. Models such as the HSI seem inherently additive and the individual curves may take into account the non-linearity that is not always apparent in an arithmetic processing of the model's variables. The concept of weighting may require more exploration.

22. Comment on the degree to which the model is inconsistent with USACE policies and accepted procedures.

Comment from Jason Weiss  Comment Significance: Medium

The model does not meet the current Corps policy of incorporating risk and uncertainty into analyses. The analyst would be required to run multiple scenarios to estimate the impacts of uncertainty on the results.

Corps plan formulation procedures require the use of average annual values to account for changes over the planning period. As stated in the kick-off meeting, the analyst must complete models runs for different intervals over the planning period to account for changing conditions. The results of these model runs are then annualized using a separate spreadsheet (not part of the model being reviewed). Although this information was provided during the presentation at the kick-off meeting, it is not clear that other analysts would know what procedures would need to be followed to determine an average annual value.

Comment from Dennis McCauley  Comment Significance: Low

As I understand it, this information was developed for the model certification process, which is a requirement for the Corps as stated in EC 1105-2-407, “Planning Models Improvement Program: Model Certification.” This documentation: A Modification of US Fish and Wildlife Service’s Habitat Suitability Index Model for Bluegill (Lepomis macrochirus) for Winter Conditions for Upper Mississippi River Backwater Habitats, appears to follow the guidance provided in the July 2007 Protocols for Certification of Planning Models, Planning Models Improvement Program, ER-PCX White Paper: Recommendations to Headquarters, U.S. Army Corps of Engineers on Certification of Ecosystem Output Models (May 2008), and Interim Guidance for Planning Centers of Expertise (PCX) to Proceed with Model Certification (7 September 2006).
None that are apparent.

23. **Comment on the degree to which the model is configured to accept modified assumptions and inputs regarding future global events such as, but not limited to, global climate change?**

**Comment from Jason Weiss  Comment Significance: Unassigned**

The model currently only evaluates one condition at a time and the assessment of lifecycle changes must be completed external to the model.

**Comment from Dennis McCauley  Comment Significance: Medium**

The original model and the winter habitat modification could be easily modified to accept various assumptions and inputs because of its relatively simple spreadsheet design.

**Comment from Chris Yoder  Comment Significance: Medium**

Provided the models are periodically updated with data from recent and systematic monitoring they should be able to respond to future events; sustained monitoring is the key. The explicit integration of assemblage level data as a monitoring tool that brings along potential changes due to climate change and exotic species would strengthen these models (see prior related comments - attachment 1).

24. **Comment on the degree to which the model has been tested for errors.**

**Comment from Jin Huang  Comment Significance: Low**

As far as I have tested, there are no errors that significantly affect the HSI calculation in the spreadsheet.

**Comment from Jason Weiss  Comment Significance: Medium**

Model certification documentation stated that testing for errors was performed on the model; however, the results of the testing were not provided.

Spreadsheet glitches were found while evaluating model. Cells with % values get tripped-up when value outside of acceptable range is entered. For example, if 110 is entered for variable V2 (cell E9) an error message appears to say the value is outside of acceptable range, however spreadsheet will not accept a correct value unless you also enter a % after the value (e.g., must enter “45%” as opposed to just “45”)

**Comment from Dennis McCauley  Comment Significance: Medium**

Others are reviewing the accuracy of the spreadsheet equations, however, the model consistently provided accurate results when I input known and previously tested data sets. I previously mentioned the slight differences in the HSI output when I had input the same datasets from the Stuber (1982) model, but those differences appear to be simple rounding differences between the two models (e.g., the Stuber model input data to one significant digit and the output to two significant digits).

**Comment from Chris Yoder  Comment Significance: Low**

Unsure. There seems to be a ready acknowledgment that certain assumptions remain untested. Still, it seems the robustness of the HSI would minimize the propagation of major errors to the point where design requirements are completely misleading.

25. **Comment on the capacity of the model to inform users of erroneous or inappropriate inputs.**

**Comment from Jin Huang  Comment Significance: Low**

The spreadsheet was able to give warning messages when the input data are outside the allowed range. But it would be nice if the available range of each variable could pop out when the user click on corresponding cells.
Comment from Jason Weiss  Comment Significance: Unassigned

Erroneous inputs outside of the input range are not allowed to be entered; however, the user is not provided with guidance on the proper range or variable types that are required. Users would benefit from guidance on the range of the input variables.

For variable inputs within the accepted range, the analyst must ensure that the data is correct.

Comment from Dennis McCauley  Comment Significance: High

The winter modification does not allow the user to input erroneous data. The drop boxes do a good job of reminding the user of the limitations and the appropriate data ranges.

Comment from Chris Yoder  Comment Significance: Low

Nothing other than the rejection of non-sensical input values and other error messages in the Excel software.

26. Are post-audits of model applications (i.e., statistical comparisons of post-implementation conditions to project planning model outputs) documented? If so, do validation results indicate that the model reasonably characterizes existing conditions and/or forecast future conditions? What model outputs deviate the most from actual conditions and, if possible, please comment on the likely cause.

Comment from Jason Weiss  Comment Significance: Unassigned

Certification documentation stated an audit was completed; however documentation was not provided.

Comment from Dennis McCauley  Comment Significance: High

Because the basis of the model is the Stuber 1982 model, and because the winter modification was first proposed in 1990 (Palesh and Anderson, 1990) and presumably tested against various data sets since then, suggests the model application is well documented. The ACOE also provided recent data sets that mostly support the model outputs as well (e.g., Knight et al, 1995 and 2008, Gents et al, 1995 and Bartels et al, 2008).

Comment from Chris Yoder  Comment Significance: Low

The use of follow-up assessment of post-mitigation relative abundance changes in bluegill and two other Centrarchidae is evident. However, it was not apparent that the construction of the model variables are ground-truthed with empirically derived data, thus it is difficult to answer the latter questions. I would say that the improvement shown in catchable bluegill numbers is an overall validation of the input variables.

27. Comment on the model’s ease of use.

Comment from Jin Huang  Comment Significance: Medium

It will be easier to use if the spreadsheet can improve the following:

1. The 'enter condition' and 'enter year' is not clear to the user what to enter. It would be nice to give options or instructions on that. In addition, It seems these two entries don't affect the results at all.

2. When first opening this spreadsheet, I got a message. See the image in 'Warning message_openFile_Bluegill.doc'

3. Change the description in cell D33 to from 'HSI' to 'Summer HSI'. It's the same to Cell D28-32, i.e., add 'Summer' to each description. Maybe also put a title for the first panel of the table to indicate the first part is for summer HSI calculation.
Comment from Jason Weiss  Comment Significance: Unassigned
The model is easy to use – the inputs variables are labeled and contained on one page of spreadsheet. However, some of the cells in the “Comments” column were protected which limits the ability to enter notes on the results. Suggest removing protection for entire comment column.

Comment from Dennis McCauley  Comment Significance: Medium
The model was easy to use. It is a simple matter to enter and or delete data. A “clear field” option would be beneficial.

Comment from Chris Yoder  Comment Significance: Low
Seems very easy to use.

28. Comment on the model’s practicality and application/input requirements.

Comment from Dennis McCauley  Comment Significance: Low
I agree with the author that the model outputs are directly relevant to support ACOE decisions on project alternatives and benefits.

Comment from Chris Yoder  Comment Significance: Low
Very practical and again easy to use. Little input required.

29. Comment on the availability of the data required by the model.

Comment from Jason Weiss  Comment Significance: Unassigned
The inputs would require data specific to the particular study area, which can be determined through either field work or other data sources (e.g., state databases on lakes in region).

Comment from Dennis McCauley  Comment Significance: Medium
I agree with the author that, in most cases, the model uses data that is readily available (e.g., acquisition of data from field studies), however, when I attempted to apply the field data from four studies (Knight et al, 1995 and 2008, Gents et al, 1995 and Bartels et al, 2008), it was often difficult to glean all of the necessary data from the reports. In each instance, it was necessary to make an assumption on one or more of the parameters because not all of the data were report to wholly support the HSI model.

Second, the winter modification requires the summer data as well to complete the HSI calculation. Therefore, both summer and winter data are necessary to complete the model.

Comment from Chris Yoder  Comment Significance: Medium
In the case of the UMR the LTRMP certainly provides sufficient data, but is this available everywhere the model is intended? Would a complete recalibration be needed for Ohio River backwaters or the open channel sections of the Mississippi River (seems quite likely)? A more detailed and explicit description or methods documentation of not only what data is required, but the procedures by which it is to be collected seems in order. Again, this is available for the LTRMP, but it seems spread across many documents that potential users may not be aware of nor take the time to track down.

30. Comment on the understandability of model output(s).

Comment from Jin Huang  Comment Significance: Low
The output (i.e., HSI) is easy to understand and interpret.

Comment from Jason Weiss  Comment Significance: Unassigned
The primary output is a HSI value that must be evaluated by the analyst and incorporated into other models. The model and documentation do not provide specific guidance on the proper application of the
outputs. However, HSI is a commonly used metric in environmental studies and would be commonly understood.

Comment from Dennis McCauley  Comment Significance: Medium
The HSI is a common and accepted output for habitat modeling.

Comment from Chris Yoder  Comment Significance: Unassigned
The accompanying model documentation was easy to read and understand as are the model outputs.

31. Comment on the transparency of model output(s).

Comment from Jin Huang  Comment Significance: Low
The calculation process for the output (i.e., HSI) are transparent to the users.

Comment from Dennis McCauley  Comment Significance: High
I agree with the author that the Excel spreadsheet allows a user to view all calculations in the model and the resulting outputs. Also, as data are input to the model, the user may view the immediate effect of the variable on the HSI.

Comment from Chris Yoder  Comment Significance: Low
Excel spreadsheet format is very clear and understandable.

32. Comment on how useful the model is for characterization of near-term conditions.

Comment from Jason Weiss  Comment Significance: Unassigned
The model is not formatted to evaluate changing conditions and presents gross values only. Life cycle conditions must be evaluated outside of the model.

Comment from Dennis McCauley  Comment Significance: Medium
The inputs to the model may be temporary or established environmental variables. Consequently, the model output represents the point in time that the variables were measured or unique to a particular scenario. For example, winter dissolved oxygen concentrations may be considered a near-term condition and the model responds to that very nicely.

Comment from Chris Yoder  Comment Significance: Low
Very useful.

33. Comment on how useful the model is for characterization of future conditions

Comment from Jason Weiss  Comment Significance: Unassigned
The model is not formatted to evaluate changing conditions and presents gross values only. Life cycle conditions must be evaluated outside of the model.

Comment from Dennis McCauley  Comment Significance: Low
The model will provide HIS estimations for various scenarios and input parameter predictions. For example, if a long-term management plan is to dredge a backwater pool, connect backwaters to main channel, or change water movement patterns, etc., the HSI model would demonstrate the resulting HSI estimation.

Comment from Chris Yoder  Comment Significance: Low
Perhaps less certain than near term, but in a long range planning context it seems adequate to the task. This capacity would be enhanced by a continuous or periodic review and update of model input variables and their derivation with temporary conmonitoring data.
34. Comment on the usability of the model for selecting the best course/plan of action.

Comment from Jason Weiss  Comment Significance: Unassigned
The model provides important data to compare the impacts of various alternatives but that data must be evaluated using other tools to calculate average annual values and to perform incremental cost effective analyses.

Comment from Dennis McCauley  Comment Significance: Low
Both the Stuber (1982) model and the Winter Modification are clear in that the model outputs are not statements of proven cause and effect relationships, however, if the selection of a best course or plan of action requires the selection of several actions (e.g., dredging, channelization, water diversion, etc.) then I believe the model could be used in that capacity. For example, if we made deep side channels available, it would likely increase the HSI for that area.

Comment from Chris Yoder  Comment Significance: Low
Like any model output the 'best' course of action is not always apparent until post-hoc assessment is conducted to determine the overall outcome. Thus, in the case of the UMR, where a robust monitoring program is already in place it makes the model better in theory and its applications as a result.

35. Is user documentation user friendly and complete?

Comment from Jin Huang  Comment Significance: Low
There is currently no user documentation but only a model documentation. Due to the simplicity of this model, maybe a separate user documentation is not necessary. However the spreadsheet may need to add an instruction sheet to explain the steps.

Comment from Jason Weiss  Comment Significance: Unassigned
No user documentation provided/available.

Comment from Dennis McCauley  Comment Significance: Medium
Input to the model is relatively intuitive and the model prevents you from entering erroneous values. However, an attached “read me” file may be useful.

Comment from Chris Yoder  Comment Significance: Low
Yes, very user friendly and seemingly complete.

36. Are the models transparent and do they allow for easy verification of calculations and outputs?

Comment from Jin Huang  Comment Significance: Low
Yes. The calculation in the spreadsheet is easy to verify.

Comment from Jason Weiss  Comment Significance: Unassigned
It is possible to follow the formulas back though the spreadsheet to determine how calculations were performed.

Comment from Dennis McCauley  Comment Significance: High
Because the model is in an Excel spreadsheet format, all calculations and outputs are easily viewed and verified.
The documentation is sufficiently explanatory to understand the origin and derivation of the HSI variables. The spreadsheet is very easy to use and makes both the inputs and outputs likewise easy to assimilate.

37. Does model distinguish between habitat types that are relevant to Corps planning (e.g., wetland vs. upland)?

*Comment from Jason Weiss  Comment Significance: Unassigned*
Model designed specifically for habitat for bluegill and distinguishes between Riverine and Lustrine environments. It is not intended to be used for other purposes or habitats.

*Comment from Dennis McCauley  Comment Significance: Low*
No, the model is an aquatic model independent of wetland and upland habitat types.

*Comment from Chris Yoder  Comment Significance: Low*
No, the only habitat addressed herein are off main channel backwaters. However, the design of the HSI could be applied to these other ecotypes.

38. Is the model output appropriate for inclusion into other Corps planning models (e.g., IWR-Planning Suite)?

*Comment from Jason Weiss  Comment Significance: Unassigned*
The analyst would be required to post-process the HSI output into another form, such as habitat units, that can then be used in the other Corps planning models. HSI is a commonly used metric in environmental studies and would be widely understood.

*Comment from Dennis McCauley  Comment Significance: Low*
Yes, assuming backwater habitats are important to the Planning suite.

*Comment from Chris Yoder  Comment Significance: Low*
Potentially, although a better understanding of the purposes of those models would help. Another issue is that single species models do have important limitations for multiple purposes at some point.

39. Does the model output account for changes in benefits over the planning period?

*Comment from Jason Weiss  Comment Significance: Medium*
Life cycle conditions must be evaluated outside of the model.

*Comment from Dennis McCauley  Comment Significance: Low*
No or not applicable.

*Comment from Chris Yoder  Comment Significance: Low*
Potentially, provided that periodic monitoring is conducted to provide this type of feedback.

40. Is the model output value expected to change over time or is it presented as an average annual value?

*Comment from Jason Weiss  Comment Significance: Medium*
As stated in the kick-off meeting, the analyst must complete models runs for different intervals over the planning period to account for changing conditions. The results of these model runs are then annualized using a separate spreadsheet (not part of the model being reviewed). Although this information was
provided during the presentation at the kick-off meeting, it is not clear that other analysts would know what procedures would need to be followed to determine an average annual value.

*Comment from Dennis McCauley  Comment Significance: Low*
It is expected to change overtime with the seasons and perhaps years.

*Comment from Chris Yoder  Comment Significance: Low*
This is not entirely clear. It would appear that the HSI output is a fixed value that would change only as model input variables are altered. As a monitoring tool it would be expected to change as habitat and water quality conditions change.

41. **Does the model provide guidance on the appropriateness of the inputs or is the analyst required to determine?**

*Comment from Jin Huang  Comment Significance: Low*
The spreadsheet provides limited guidance on the range of the input data except those question with multiple choices. it would be nice to pop out the valid range for each variable when the user click on the corresponding cell.

*Comment from Jason Weiss  Comment Significance: Unassigned*
Erroneous inputs outside of the input range are not allowed to be entered; however user is not provided with guidance on the proper range or variable types that are required. For variable inputs within the accepted range, the analyst must ensure that the data is correct.

*Comment from Dennis McCauley  Comment Significance: Medium*
The model predetermines the appropriateness of the inputs and automatically combines the variables into specific winter and non-winter descriptions.

*Comment from Chris Yoder  Comment Significance: Low*
The HSI does set limits on ranges of some values, but user knowledge is an assumption for its proper use.

42. **Are values calculated as changes from the 'without project' scenario or as gross values?**

*Comment from Jin Huang  Comment Significance: Low*
N/A.

*Comment from Jason Weiss  Comment Significance: Unassigned*
The model is not formatted to evaluate changing conditions and presents gross values only.

*Comment from Dennis McCauley  Comment Significance: Low*
N/A

*Comment from Chris Yoder  Comment Significance: Low*
The HSI can be calculated based on any number of scenarios simply by entering different variables. One would have to assume that these could be surmised based on no intervention vs. a series of different designs. This would then yield different HSI values that could be used to support cost/benefit analyses. Whether these differences translate to actual biological consequences would need to be determined by examining a gradient of actual projects and habitats at a large number f locations. Using some of the analyses that I suggested previously would result in this type of assessment.
Appendix E: Comments and discussion of Model Review Panel During the Review teleconference

Participants

BK = Bruce Kish (USACE; IWR Alternative Technical Representative)
CY = Chris Yoder (Midwest Biodiversity Institute, Fish Ecologist)
DA = Dennis Anderson (USACE; Model Proponent)
DM = David Mitchell (Abt Associates, Project Manager)
DMc = Dennis McCauley (Great Lakes Environmental Center, Fish Ecologist)
JF = Jeff Trulik (USACE; Headquarters representative)
JH= Jin Huang (Abt Associates; Spreadsheet Auditor / Specialist)
JP = Jim Palardy (Abt Associates, Deputy Project Manager)
JS = Jodi Staebell (USACE; Planning Center of Expertise Point of Contact)
JW = Jason Weiss (URS; Plan Formulation Expert)
SK = Shawn Komlos (USACE; IWR Technical Representative)

FPC#1 Categorical Definitions for minimum DO, substrate composition, and isolation

DA: Agreed with desirability of getting explicit percentages for the variables, more doable for DO. Still feels that a lot best professional judgment in estimating future conditions for all three, although baseline data is probably. Regarding isolation – considered weak, get spatial distribution into model, distinguish between upper and lower part of pool.

CY: Understands response, generally. Suggests making accurate numbers from existing data, stresses need to be explicit in documentation for reports.

DMc: Concur re: spatial variable development & other variables using methods/data used by WI DNR. Difficult to put percentages for the various sub-habitat values.

CY: Would like explicit responses, rather than groupings

DMc: Believes final panel comment is most important for side-channel dredging

DA: An explanation of the subjective nature of some assignment of variables. Cites that best BPJ that is internalized in some potential choices within the model.

CY: Using datasets from LTRM program to get into categorical ranges of measurements, so why is this subjective?

DA: LTRM does not include substrate composition on mapping scale, only site-specific sediment characterization (could be for dredging?). LTRM is for long-term monitoring, but randomized station sampling, for a variety of purposes, fish, macroinvertebrates, projects, etc.

CY: Suggested Qualitative Habitat Assessment in rivers and streams for establishing substrate characteristics with biological community to allow prediction of percentiles. Impression
of HSI models is that they are based on individual studies, some dated. He is hoping that long-term monitoring datasets will allow better assessment, less reliance on HSI approach (general comments). Need to ensure that data is being collected for suitable variables.

JP: Getting back to issue of whether is it worthwhile putting % on the categories on DO, substrate, etc. to allow my objectivity when these studies are reviewed years from now.

SK: Suggested immediate fix - better documentation practice to allow understanding, long-term fix – come up with the classes of percentiles.

DMc: Not a great amount of value for getting %s, but agrees that better documentation is absolutely necessary.

CY: Agrees with DM.

CM: Isolation variable more important than any other variables for definitions. Exchange of water with backchannel pools very important, ice cover less important.

DA: Agreed with getting rid of contiguous category (not generally used)

DMc: As long as isolation choice is documented, removal is okay

CY: Agreed, No further comment on issue.

JP: Isolation term consensus – remove the contiguous term. Other variables, make sure to document the selection choice rationale so that same scale is used during follow-up.

FPC Comment #2. Continuous percent variables in Bluegill HSI Model

DA: Assignment largely based on qualitative assignment / BPJ call that considers habitat quality. They could expand habitat quality variables but it would take work.

CY: Terminology clarification – this is all qualitative, but there are “quantitative” measures – but the habitat quality aspects are important in general. Agreed with Dennis that it will take work – maybe 2-3 years effort (a comprehensive model – not just “tweaking”). Long-term, develop new variables.

DA: Generally agreed that model needs to be robust, updated and validated, but will take time and money.

SK: Reminder that monitoring is project-specific and project funding, few $$ to allow for research and development. Need to tie in recommendations to short-term and long-term efforts subject to data constraints and funding.

CY: Compared what they do for QHEI assessment, variables not too different from what Corps could monitor

SK: Incorporate suggestions as part of future long-term monitoring to incorporate specific variables to get datasets to address these.

CY: Long-term monitoring is a strategic investment that rarely gets done. NOAA provides a good model for federal agencies; pre- during, and post-implementation monitoring.

SK: Possible integration with required WRDA monitoring as future step.

DMc: Agrees with Chris, that habitat quality (QHEI) application to larger rivers would be a big project. Thinks Bluegill model sufficient for before and after considerations of project alternatives.
**FPC #3 Life requisite of winter cover (CW-C)**

DA:  This is admittedly weak parameter, would like to get spatial distribution of water depth. Like to adopt WI DNR and IA DNR.

DMc:  Thinks DA comment is sound (WI and IA DNR) and variable should be expended for ice depth and other cover types during winter

CY:  Agrees with WI DNR approach regarding 6 ft depth contours. Incremental thresholds are preferable to pass-fail approaches, but dependent on the available data.

BK:  Do other states’ agency (like WI DNR) have other approaches or variables that we should be considering?  

DMc:  Recommends inclusion of ice cover, light penetration, and other variables before pool depth.

JP:  Reviewers consensus is that the short-term fix is not appropriate and that adding variables is required.

**FPC #4 – Winter water temperatures < 4 Celsius.**

DA:  Agreed with the correction, just a mistake.

**FPC#5 – Documentation supporting model.**

DA:  Agreed that documentation needs updating, that materials are on-hand, but this would take time and money.

JW:  Increase the user documentation, need to identify the critical assumptions, and issue regarding AAHUs.

CY:  No disagreement

DMc:  No disagreement

JP:  Agreement that documentation requires updating, including addition of critical assumptions and potential issue of AAHUs.

**FPC#6 Lack of documentation on the use of the Bluegill HSI model output**

JP:  Example of approach suggested from diving duck

JW:  Agrees that diving duck example is a start. But also wants to have short introduction to make sure that practitioners can properly enter the data, conduct the model, and input the materials to arrive at the AAHUs. General concerns with replicability of results and consistency across projects and districts.

SK:  For short-term best practices, identification of experts/practitioners already familiar with model, mid-term fix - implementation of in-line guidance

JW:  Provide basic documentation – explanation of objectives, definition of variables, instruction and guidance for model. What happens when experts retire?
DMc: Was unfamiliar to model, but found it to be fairly easy to use, and applied some available datasets to run it and found results reasonable.

CY: Concurs with DM.

JP: Application between project alternatives vs. comparison between projects? <Consensus, only between project alternatives, not between projects>

JW: Looking it from engineering viewpoint, but he would have a tough time running the model and getting consistent results with others – probably a function of BPJ

DA: Incumbent upon the practioners to understand the model and the critical assumptions, but a short introduction and/or cribsheet (users guide) is appropriate.

JP: Consensus that additional documentation is necessary – including model limitations, assumptions, cribsheet, in-line comments.

FPC #7 Untested assumptions in model regarding HSI and carrying capacity.

JP: Model validation needs to be done, Corps concur and looking to state agency to help.

DA: Clarification – not looking at carrying capacity but habitat usage. Agreed with the need to validate model. Studies/data within the last 10 years should let them to be able to validate the model. Feels there is a positive feedback between model and ecosystem restoration project and good opportunity for cross-fertilization. Funding and support are needed.

CY: One short-term step is to ensure that right data are being collected by state agencies. Habitat attributes such as substrate composition or cover indexes should be included.

JP: Make sure that all the variables in the model should be tracked?

CY: Not just variables in the current model but others that might be included in future iterations of the model (e.g., ice cover, snow, light penetration). Reasonable to think that if we don’t measure certain habitat quality properties, they will never be incorporated in the model (sharpening the yardstick)

DMc: Concurs with CY’s comments regarding data collection, also feels that post-implementation monitoring is important. USACE needs to work with state agencies.

DA: Generally agrees with approach.

JW: No comment

DMc: Reminder that model requires a minimum of two visits, due to difference between summer and winter habitat characteristics.

DA: Corps go in the summer, send WI DNR in winter (good arrangement)

Additional Comments:

DA: Good suggestions, good citations, no further questions, would like input when he considered modification of variables.

JW: There is a lot of subjective BPJ, using same study area and have three experts evaluate it, a good way to identify what are the key variables that experts differ most – indicate limits of BPJ. Some sort of QA process.
DA: Noted differences in interpretation between practitioners, so round-robin testing may have value. USACE doesn’t operate in a vacuum, also connect with other agencies.

DMc: Agreed with Jason’s suggestion, used example of laboratory practice to get consistency and quality improvements.

CY: Similar experiences when applying models to different geographic regions (OH, OK)

SK, BK, JS, JT: No further comments
Bluegill HSI Model Certification

Final Panel Comment Discussion Meeting

April 6, 2011

James Palardy
• Introductions (Palardy)

• USACE Planning Model Quality Assurance Review Process (Komlos/Kish)

• Final Panel Comment Discussion (McCauley, Yoder, Weiss, Anderson, others)

• Summary and Next Steps (Palardy)
Bluegill HSI Model Review Panel

- Abt Associates
  - David Mitchell: Task Manager
  - Jim Palardy: Deputy Task Manager

- USACE
  - Shawn Komlos: IWR Technical Representative
  - Bruce Kish: Alt Tech. Rep
  - Dennis Anderson: Model Proponent
  - Jodi Staebell: PCX POC
  - Nathan Richards: alt. POC
  - Jeff Trulik: HQ

- Technical Experts
  - Jason Weiss: Plan Formulation Expert
    - URS Corporation
  - Jin Huang: Spreadsheet Auditor **
    - Abt Associates
  - Dennis McCauley - Fish Ecologist
    - Great Lakes Environmental Center
  - Chris Yoder - Fish Ecologist
    - Midwest Biodiversity Institute

What is “model certification”?
“… a corporate approval that the model is sound and functional.”

What is a planning model?
“…defined as any models and analytical tools that planners use to define water resources management problems and opportunities, to formulate potential alternatives to address the problems and take advantage of the opportunities, to evaluate potential effects of alternatives and to support decision-making. It includes all models used for planning, regardless of their scope or source, as specified in the following sub-paragraphs…”

What is a “certified” planning model?
“… A planning model reviewed and certified by the appropriate Planning Center of Expertise (PCX) in accordance with the criteria and procedures specified in this Circular.”

What criteria are used by the Planning Center of Expertise as basis for certification?

1) Technical Quality – Contemporary theory, consistent with design objectives, documented, tested

2) System Quality – Computational integrity, appropriately programmed, verified or stress-tested

3) Usability – Ease of use, availability of input, transparency, error potential, education of user
Your comments are critical to informing the Planning Center of Expertise of:

- Potential technical flaws or shortcomings of the model
- Appropriate uses and limitations of the model
- Potential for model to yield results of questionable quality during planning-related applications

Your recommendations are critical to informing the Planning Center of Expertise of:

- Potential near term remedies to identified concerns
- Potential long-term remedies to improve the reliability and usefulness of the model
- Potential remedies to expand the model’s range of applicability

What purposes will the review serve?

The review is intended to provide the Planning Center of Expertise with insights it needs to determine in what way (if any) the model should be applied during execution of planning-related activities.

The review comments and recommendations will be retained for potential future users of the model to inform their funding of model improvement activities, and to facilitate informed selection and application of planning models.
## Discussion: Final Panel Comments

### Final Panel Comment 1:

Categorical definitions for three variables: minimum dissolved oxygen (V8), substrate composition (V20), and isolation (not numbered), must be made explicit to ensure model output is based upon objective data.

### Recommendation for Resolution:

Explicitly define category thresholds for these three habitat variables to minimize the amount of subjectivity present in overall HSI output.

### Response:

Concur: terms within DO and substrate composition should be better defined. It would be possible to define these terms (e.g., *seldom*, *usually*, *often* for DO; *present*, *scarce* for substrate composition) based on percentiles. However, assigning more precise values would be highly subjective. Note: even with good baseline databases, professional judgment is required to estimate the future without action and with various action alternatives.

The two isolation scenarios (i.e. isolated or contiguous with other bluegill habitat) could be improved. There is on-going work assessing the spatial distribution and extent of over-wintering habitat in a pool. Developing a spatial variable would greatly assist in selecting locations for habitat creation and in quantifying benefits. I am not aware of any time that the bluegill model was used with the scenario of having contiguous bluegill overwintering habitat. Hopefully we can modify the model to account for this spatial attribute (see response to comment 7).
## Final Panel Comment 2:

Continuous “percent” variables in the Bluegill HSI model are unlikely to capture important qualitative characteristics habitat. A discrete, qualitative component should be added to these variables to capture important measures of habitat quality.

## Recommendation for Resolution:

Add qualitative criteria to the following existing variables: percent cover of logs & brush (V2) and vegetation (V3), and percent backwater depth > 4 feet (Va). An approach similar to that used by the Qualitative Habitat Evaluation Index (QHEI; Rankin 1989, 1995; Ohio EPA 2006), the approach of Wakeley (1988), or another suitable approach, should be used to implement qualitative aspects of these continuous variables.

## Response:

The variables do attempt to do some qualitative assignment of importance. Expanding these variables, including development of habitat indices to encompass more attributes for cover, would be good. The cited QHEI was developed for smaller rivers and adaption to large floodplain rivers would require significant modification.
Discussion: Final Panel Comments

### Final Panel Comment 3:

The life requisite of winter cover (CW-C) is limited to a single variable of backwater depth greater than 4 feet (Va). The level of data supporting this variable appear to be limited. Effort should be made to validate this variable, and possibly incorporate other relevant variables such as ice cover or vegetation.

### Recommendation for Resolution:

Obtain field data to validate and modify the relationship between percent backwater depth > 4 feet and bluegill habitat quality. Alternatively, incorporate additional variables such as ice cover (assuming sufficient literature references can be found) to modify the existing life requisite component of winter cover.

### Response:

Concur: The water depth variable is one of the weakest in the winter modifications and I agree it could use modification. Ice and snow cover can affect water quality conditions, which changes throughout the winter season. Generally we assume late season conditions (February) when predicting minimum DO for the model. 2-3 foot deep areas can be important habitat early in the winter season, with 4 feet providing habitat mid-winter habitat and depths greater than 4 feet for late winter and/or for winters with heavy snow/ice cover. Based on WDNR’s late fall fish surveys, there also appears to be a species preference for water depth with largemouth bass congregating in areas with 6 feet or greater. The model could benefit by assigning an index value similar to QHEI based on spatial distribution of depths rather than a percent, as well adding other cover variables like vegetation. I believe we can work with the resource agencies to modify the winter cover variable (see response to comment 7).
Final Panel Comment 4:
The winter modification for the Bluegill Habitat HSI model artificially limits model application to areas with winter water temperatures (VC) below 4°C. This limitation does not appear to be based upon either data or theory and should be removed.

Recommendation for Resolution:
This model limitation appears to be an oversight since Bluegill thrive in warm winter waters in the Southern United States. Unless data show that winter temperatures > 4°C are prohibitive for populations of Bluegill, all data > 4°C should be assigned a habitat-variable HSI of 1.0.

Response:
Good catch. The model was intended to assign any value of > or = 40°C an HSI value of 1.0. The spreadsheet will be modified. Modifications to the spreadsheet to address comment 21 in Appendix D (correcting formulas in comments) will also be made.
Final Panel Comment 5:

Documentation matching the current spreadsheet-based model should be assembled and include information from the original USFWS model (Stuber et al 1982), the winter modification (Palesh and Anderson 1990), all applicable LTRMP methodologies used to obtain input data, and a methodology for conducting uncertainty analyses.

Recommendation for Resolution:

Assemble complete model documentation, including LTRMP methodologies and a methodology for conducting uncertainty analysis.

Response:

Concur that this would improve the utility of the model and we propose to work on this over the next year (see response to comment 7).
Final Panel Comment 6:

There is currently no documentation that provides guidance on the use of Bluegill HSI output. Relevant documentation and a spreadsheet template should be distributed within the Bluegill HSI model to ensure calculated benefits for total project life are correct.

Recommendation for Resolution:

Reviewers recommend that documentation be developed that outlines the steps necessary to perform uncertainty analysis and to ensure annualized outputs are generated in a manner that conforms with Corps policies and procedures. Such a document, and an associated spreadsheet template, should be disseminated with the Bluegill HSI Model. Reviewers believe that these documents would substantially improve the probability that model output conforms to Corps policy.

Response:

It is assumed/recommended that model users will be familiar with process for using the model outputs for planning use/analysis. Guidance on how target years are established (which are project specific depending on construction schedule, estimated future changes in habitat conditions, etc), estimation of average annual habitat unit, incremental analysis, etc. are documented in the user manuals for IWR-Plan at [http://www.pmcl.com/iwrplan/](http://www.pmcl.com/iwrplan/) and the FWS's 1980 Habitat Evaluation Procedures Handbook at [http://www.fws.gov/policy/ESMindex.html](http://www.fws.gov/policy/ESMindex.html). IWR has a certified model that can be used to annualize benefits and costs. It can be downloaded at the site above along with a user manual.
During the teleconference, there was broad agreement among model reviewers that additional information providing guidance for using HSI model output is necessary. It was agreed that a short paragraph of instructions that provided hyperlinks to suitable documentation (e.g., blue book, instructions for incremental cost effectiveness analysis, etc.) would address reviewer concerns. Overall, consensus was reached that ER-PCX should explore the development of a crib-sheet or short instruction document that would be made available to all users of the Diving Duck HSI model.
Final Panel Comment 7:
There are untested assumptions in the model with respect to relationships between HSI and the carrying capacity of bluegill. Model validation should occur to ensure model output is useful.

Recommendation for Resolution:
Reviewers recommend that model relationships be validated through regular monitoring of project sites that have undergone remediation. Additionally, data from the LTRMP may exist to explicitly test these relationships.

Response:
Concur with recommendation, and note:
- Regular monitoring of Habitat Rehabilitation and Enhancement Projects under the Environmental Management Program is currently undertaken.
- WDNR data will allows us to look at the quality of the fisheries in relationship to water quality, water depth distribution, vegetation, and other factors.
- IDNR is also just completing an extensive fish use study of couple of Environmental Management Program HREPs that will also add to the database.

These data should allow some level of validation of the model and predicted variable values and fish response. It will also allows us to see if there are any fish species related trends.

There is great interest in the part of EMP partners to make use of LTRM data in HREP planning and this would seem like a good opportunity to try to make more use of this data to refine the Bluegill HSI model. If funding allows, we could work with the interagency Fish and Wildlife Work Group over the next year to complete this evaluation and refine the model.
Discussion: Final Panel Comments

• Other Questions or Comments??
## Bluegill HSI Model Review Schedule

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<th>Event</th>
<th>Deadline/Condition</th>
<th>Date</th>
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<tr>
<td>Conduct kick-off conference call with model reviewers and Model Proponents</td>
<td>Kick-off conference call date</td>
<td>10-Dec</td>
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<tr>
<td>Model review team submits comments to Contractor</td>
<td>Within 21 calendar days of kick-off call with model review team</td>
<td>31-Dec</td>
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<tr>
<td>Draft Model Review Report</td>
<td>Within 24 days of completing the review</td>
<td>7-Feb</td>
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<tr>
<td>USACE provides comments on DMRR</td>
<td>Within 15 days of DMRR submittal</td>
<td>1-Mar</td>
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<tr>
<td>Teleconference meeting with USACE to discuss the Draft Model Review Report</td>
<td>Within 4 days of receipt of USACE comments</td>
<td>4-Apr</td>
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<tr>
<td>Final Model Review Report</td>
<td>Within 7 days of conference call on USACE draft report comments</td>
<td>13-Apr</td>
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Summary and Next Steps

- Abt Associates will summarize the discussion and clarify questions with respect to Final Panel Comments

- Within 7 working days, Abt will issue the final Model Review Report (fMRR)