Appendix B

Comparison of Habitat Evaluation Methods

(Richard Stiehl)

Comparison of Evaluation Methods for Assessing Potential Environmental Impacts on the Upper River

Richard Stiehl

Wildlife Habitat Appraisal Guide (WHAG)

WHAG is comprised of a set of Habitat Suitability Index (HSI) models modified to improve reliability under Missouri field conditions. It was developed in 1991 by the Missouri Department of Conservation (MDOC) as a regional modification of the Habitat Evaluation Procedures. The WHAG format was adapted from US DOI Resource Publication No. 133 (1980), with draft (HSI) models applied to MDOC wildlife management areas (WMA), annual wildlife survey routes and other areas. None of the models were statistically validated, and all habitat characteristics are scored by visual estimation.

WHAG is organized into Habitat Matrices with the general classifications of Wetland and Upland. The Wetland matrix may be applied in four wetland habitat types: nonforested wetland, bottomland hardwoods-wetland, cropland-wetland, and grassland-wetland. Twelve species are included in the matrix (mallard, Canada goose, least bittern, lesser yellowlegs, muskrat, king rail, green-backed heron, wood duck, beaver, American coot, northern parula warbler, and prothonotary warbler), but the program allows changing of the species used in each habitat matrix. The species representation in each habitat matrix is not even. Nonforest wetlands have the highest species representation (8), followed by bottomland hardwood-wetland (6). Two species (mallard and Canada goose) represent cropland-wetland and Canada goose alone represents grassland-wetland habitat.

The wetland matrix is described by 54 habitat variables, although none of the variables may be applied to all four wetland habitats. Nonforested wetlands are described by evaluating 32 variables, while bottomland hardwoods-wetland has 27 variables. Cropland-wetland and grassland-wetland have 13 and 7 variables, respectively, perhaps reflecting the fewer species associated with each habitat.

Each habitat variable is scored by placing it into one of several (usually 4 or 5) categories. The category produces a single value for a range of conditions for the variable. Each value is either considered a multiplier (weighted) or (more frequently) a limiting factor for the species, with all of the variables aggregated as an arithmetic mean to produce a 0 to 1 measure of suitability for the species.

Attributes of WHAG:

Positive:
1. Models are modified for Midwestern conditions.
2. Both game and nongame species represented.
3. New models and custom matrices may be created.
4. Some acceptance in Midwest.
5. Uses HSI type variable input.

Negative: 1. Variable categories do not allow continuous variation.
2. New models or model modification must conform to program constraints.
3. Arithmetic mean aggregation may not be biologically appropriate in all cases.
4. Calculation of future target year habitat values is data and time intensive.

Conclusions:

The WHAG evaluation engine would be acceptable, but new models would need to be developed for the Upper Mississippi application. Existing WHAG models would need to be modified to be biologically logical. Applying the results of the method to predict future habitat values for additional target years would be data and time intensive.

I do not recommend this method, mainly due to the aggregation constraints concomitant with the program. I do not accept the mathematical constraints of arithmetic mean aggregation. I believe that arithmetic mean aggregation of variables may be biologically sound only if the variables and their weightings are carefully considered on a species by species basis. The universal application of arithmetic mean aggregation is unsound and may result in potentially undependable results.

Aquatic Habitat Appraisal Guide (AHAG)

AHAG was developed through the efforts of the U.S. Army Corps of Engineers Waterways Experiment Station and the U.S. Army Corps of Engineers Rock Island District as a tool to meet the habitat evaluation requirements associated with Habitat Rehabilitation and Replacement Projects (HREP) on the Upper Mississippi River System (UMRS). AHAG is particularly applicable to evaluate impacts from the removal of sediments from backwaters, the placement of water control structures to manage water levels in backwater areas, and restoring flows to side channels. AHAG is based on the concept of the Habitat Evaluation Procedures (HEP), uses HSI models, and follows the format of US DOI Resource Publication No. 133 (1980).

AHAG has three default matrices of sixteen habitat variables as they relate to eight fish species (white bass, emerald shiner, river darter, northern pike, smallmouth buffalo, walleye, largemouth bass and bluegill). Matrices may be used in current forms, or customized to meet specific needs by adding or deleting species, or modifying the variables, either by changes in value curves or relative importance in the model. AHAG requires user input of habitat values estimated from existing information or measured in the field. These field values are then converted to a numerical equivalent between 0.0 and 1.0 (as SI values in HSI models) and then aggregated to compute the HSI for each species. A matrix of variables (similar to the structure in WHAG) provides evaluation of several species from representatives developed from five reproductive guilds (lithophilos, pelagophilos, phytopylos, litho-psammophilos, and speleophilos) and five habitat guilds (lotic-large fishes, lotic-small fishes, lentic-large fishes, lentic-small fishes and generalists). Even with seven null cells, the eight evaluation species do not encompass all possible reproductive/habitat associations present.

Although the AHAG program may be modified, it permits a maximum of 30 habitat variables, three species and five life stages per species.

As in WHAG, each AHAG habitat variable is scored by placing it into one of several (usually four or five) categories. The category produces a single value for a range of conditions for the variable. Departing from WHAG, AHAG allows three forms of HSI aggregation. The suitability of the habitat for each species may be determined by the arithmetic-mean of all variable scores, or by the lowest variable score (limiting factor), or as an arithmetic mean of selected variable scores that are considered limiting. There is apparently no guidance as to which aggregation is more biologically correct, although the default matrix lists limiting factor and mean limiting factor as optional. The default matrix also proposes a Suitability Index Scoring Criteria as Excellent=1.0; Good=0.75; Fair=0.5; Poor=0.25; and Unusable=0.0.

Attributes of AHAG:

Positive:
1. Models are constructed for Midwestern conditions.
2. Both game and nongame species represented.
3. New models and custom matrices may be created.
4. Some acceptance in Midwest.
5. Uses HSI type variable input.

Negative:
1. Variable categories do not allow continuous variation.
2. New models or model modification must conform to program constraints.
3. Aggregation methods may not be biologically appropriate in all cases.

Conclusions:

The AHAG evaluation engine is unacceptable. Although the existing AHAG models may be biologically sound, an engine that allows three different aggregation methods using the same input data is fundamentally flawed. Any model has both implicit and explicit assumptions. A model converts these biological assumptions into a mathematical form. To conclude that three different mathematical aggregations have the ability to convert these biological assumptions with similar biological accuracy suggests that either at least some assumptions are being violated, or the models are so general they are inaccurate. The existing AHAG models would need to be modified to be biologically and mathematically logical. I strongly question the Suitability Index Scoring Criteria values as inherently not scientific, undependable, and without a biological basis.

I strongly recommend against this method. The “user choice” of the aggregation of HSI values in the program suggests a possibility of more serious biological errors. An acceptable evaluation method must be both biologically and mathematically sound. Allowing several alternative HSI values from one data set suggests that any HSI value is acceptable. This is not what an evaluation method should do. Rather, a method should produce a value that is biologically accurate and logically defendable. I suggest that AHAG is unsound and may result in potentially undependable results.

Instream Flow Incremental Methodology (IFIM)

Instream flow methods have been developed predominantly by biologists and hydrologists working for agencies having regulatory responsibility related to water development and management to provide detailed ecological studies leading to a significant growth in the understanding of the relations between stream flow and aquatic habitats. Most of the empirical evidence gathered to date has focused on fish and benthic macro-invertebrate habitat requirements, with recent emphasis on the relation between stream flow and woody riparian vegetation and river-based recreation. Water management problem solving has matured from setting fixed minimum flows with no specific aquatic habitat benefit to incremental methods in which aquatic habitats are quantified as a function of stream discharge. Collectively, the efforts led to a general class of instream flow assessment techniques (models) meant to help reserve a specific amount of water within the channel for the benefit of fish and other aquatic life.

Methods capable of quantifying the effect of incremental changes in stream flow to evaluate a series of possible alternative development schemes led to the development of habitat versus discharge functions developed from life-stage-specific relations for selected species, that is, fish passage, spawning, and rearing habitat versus flow. Corroborating research took the form of analyses correlating the general well-being of fish populations (usually in terms of measured standing crop) with various physical and chemical attributes (water velocity; minimal water depths; instream objects such as cover, bottom substrate materials with particular emphasis on the amount of fines in the interstitial spaces within coarse bed elements; water temperature; dissolved oxygen; total alkalinity; turbidity; and light penetration through the water column) of the stream flow regime and its interaction with the stream channel structure. IFIM unfolded against the backdrop of minimum flow standards, quantitative impact analyses, water budgets, and interdisciplinary analyses. The specific impetus was the National Environmental Policy Act that mandated all federal water resource agencies to consider alternative water development and management schemes. This requirement placed increased responsibility on natural resource agencies for methods, evaluations, and recommendations related to reservoir storage and release and stream channel depletions. IFIM was developed by an interdisciplinary team and was founded on a basic understanding and description of the water supply and habitats within stream reaches of concern.

IFIM has been designed for river system management by providing an organizational framework for evaluating and formulating alternative water management options. It has been built on the philosophical foundation of hydrological analyses to understand the limits of water supply. Analysis offers a description, evaluation, and comparative display of water use throughout a river system. Emphasis is placed on the display of usable habitat across several years to capture the variability in both water supply and habitat. Such comparative information enhances negotiations in the planning and management of the riverine resources. Sharing limited water during drought cycles and the management of timed releases contribute to compatibility between instream and out-of-stream user groups and allow for rapid recovery of aquatic populations during favorable conditions.

Tools that can be used to show the relation between the amount of habitat and stream flow fall into two groups. The first uses statistical analyses to correlate environmental features of a stream with fish population size. A Habitat Quality Index (HQI) is developed by regressing several habitat variables against the standing crop of fish. This procedure is stream-specific, and the recommendations are related to critical low flows. The second group of tools links open channel hydraulics with known elements of fish behavior. Examples include the Physical Habitat Simulation System (PHABSIM). An important explicit element of PHABSIM and HQI is an analysis of water supply. A water supply analysis should accompany any standard-setting technique to answer the question: What is the likelihood that water will be available to meet the standard? Many people confuse IFIM with PHABSIM. Where IFIM is a general problem solving approach employing systems analysis techniques, PHABSIM is a specific model designed to calculate an index to the amount of microhabitat available for different life stages at different flow levels. PHABSIM requires the collection of field data on stream cross sections and habitat features, hydraulic simulation to evaluate habitat variables at different flows, and species suitability criteria to calculate stream characteristics with available habitat at alternate flows. Depending on the complexity of the proposed project and the complexity of the stream under study, the collection of field data ranges from inexpensive and quick to costly and time consuming. Using PHABSIM enables the investigator to inform decision makers about the impacts on fish habitat of different flows for different life stages. Attention is typically given to the life stages of fish species that are of special concern for management, or that are thought to be most sensitive to change. The resulting relation between flow and habitat, generated by linking species criteria with flow-dependent stream channel characteristics, aids in negotiation by more clearly depicting the effect that less-than-optimum flow will have on habitat.

IFIM is one process designed to accomplish this intricate research based on knowledge of fish response to habitat features. In an approach such as IFIM, these predictions will typically require hydrologic analyses, habitat models, sediment transport, water quality, and temperature analyses, as well as trophic level studies, validation of species criteria, studies of biomass, and population dynamics.

Conclusions:

Based on the overall impacts of the proposed project, the use of IFIM is not the most appropriate tool to measure the impacts of any changes in the flows at the project sites. The second "I" of IFIM is incremental. The proposed projects will not alter the ability to regulate the flow incrementally. Although IFIM may be used on a large river system, the Mississippi River is at the upper limit of IFIM model reliability. If the primary function of a project would provide the capability of manipulating flow, then IFIM use would be appropriate on a large river system. I conclude that as the project will not effectively control the flows on the Mississippi River, the use of IFIM/PHABSIM would be inappropriate.

Habitat Evaluation Procedures (HEP)

HEP is a method that was developed to rate the quality and quantity of habitat in order to quantify the impacts of changes made through land and water development projects. It can also be used as a tool to document baseline information on habitats as a gauge for future habitat modification. HEP may be adapted to many different uses including project planning, impact assessment, mitigation and compensation, and habitat management by providing information for two types of wildlife comparisons: (1) the relative value of different areas at the same point in time, and (2) the relative value of the same area at future points in time.

Habitat suitability index models are used in HEP to estimate the value of the habitat within the study area for the selected evaluation species. By definition, any model is an abstraction of reality. Models are tools that can be used to improve our understanding of, and predictive capability about, functioning systems. In HEP, the "functioning system" is the relationship of a species to its habitat.

Documented models are used in HEP to determine the quality portion in the formula used in the calculation of Habitat Units (HUs). HUs are the basic accounting unit used in HEP. An index of habitat suitability is simply a ratio determined by comparing a value of interest to some standard. In HEP, this index is determined by comparing existing habitat conditions for a species to optimal habitat conditions for the species. By definition, then, the range of an HSI must fall within the range of 0.0 to 1.0. On this scale, 0.0 represents no habitat suitability, and 1.0 represents optimum suitability.

A model is an abstraction of reality. The extent to which a given model mimics the "reality" being modeled depends on several factors, including the complexity of the situation, the understanding of the system being modeled (i.e., the available information base, and the effort expended in model development. A model is intended to be used as a tool to help increase the understanding of a specified system in order to make a more informed decision. There are at least six reasons for using documented models in applications of HEP:

(l) Models document the process used in an evaluation.
(2) Models may establish credibility of an evaluation.
(3) Models provide permanent records of the basis for decisions.
(4) Models function as an effective communications tool.
(5) Models synthesize habitat information.
(6) Models provide a framework from which to make improvements.

The advantages are not unique to HSI models; in fact, all models provide these advantages. Models that produce an index of habitat suitability (or whose outputs can be converted to such an index) are required in HEP. Existing models with different outputs (e.g., population measures) can be converted to an index of habitat suitability if the "optimum" population condition can be defined.

There are about 240 HSI models published as “blue books” by the U.S. Fish and Wildlife Service. Although the models are about evenly divided between aquatic and terrestrial species, the number that may apply to the Mississippi River project is significantly fewer. As both AHAG and WHAG model constructions are based on an HSI structure, I am confident that any model in either WHAG or AHAG could be put into the HEP format.

A major advantage that HEP/HSI has over WHAG and AHAG is the flexibility it has in the type of SI transformation it allows, and the type of aggregations of the SIs into a final HSI. The structure of the method demands sound biological decisions, which should result in defendable results. Further, I can develop a Spreadsheet of the evaluation species (SHEP) which will allow future habitat projections, under various scenarios to be quickly and easily compared. Additionally, the IREM (a GIS-HSI interface) is compatible with HSI format models. Although IREM does not demand HSI models, its sensitivity to special variables and predictive power would be under-utilized with the lowered sensitivity of both AHAG and WHAG.

Attributes of HEP:

Positive :
1. Both game and nongame species well represented.
2. New models and custom matrices may be created.
3. Some acceptance in the Midwest, and other areas.
4. Uses HSI models generally, but other models (regression, abundance, etc.) may be used also.
5. Compatible with SHEP and IREM.

Negative:
1. Some agency distrust of the method.
2. New models must be constructed for species not in HSI format.

Conclusions:

I suggest that HEP is the most appropriate tool for this project. I suggest that there will be some development time necessary if SHEP is to be incorporated into the process, but that the development time associated with SHEP will be less than the time needed to provide a broad base for decision making. Additional time will be needed to integrate HEP and IREM, but again the capability of the application to address complex future scenarios, with graphical output will, in my opinion, be highly worthwhile.