Habitat Evaluation Procedures (HEP)

ESM 102

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Washington, D.C.

Preface

Since 1974 the U.S. Fish and Wildlife Service (USFWS) has been developing a habitat-based evaluation methodology entitled the Habitat Evaluation Procedures (USFWS 1976) for use in impact assessment and project planning. This work has culminated in the development of three documents. The first document, entitled "Habitat as a Basis for Environmental Assessment" (101 ESM), addresses the justification for a habitat-based technique and discusses the conceptual approach to habitat assessment.

This document, the "Habitat Evaluation Procedures" (102 ESM), is the second of the three documents and serves as a further refinement of the Habitat Evaluation Procedures (HEP) first developed in 1976. This document describes how the concepts outlined in the first document can be implemented in a standardized procedure for conducting habitat evaluations in the field. The Procedures provide a quantification of wildlife habitat that is based on two primary variables: 1) the Habitat Suitability Index (HSI); and 2) the total area of available habitat.

Two major changes have occurred in the Procedures since 1976 and are presented in this document. The first involves determining an HSI by use of documented habitat models. The second major change involves analyses of individual evaluation species, rather than habitat types (cover types) throughout the analysis. Concepts discussed in "Habitat as a Basis for Environmental Assessment" provide a rationale for this change.

The third document, "Standards for the Development of Habitat Suitability Index Models for Use with the Habitat Evaluation Procedures" (103 ESM), provides guidance in the development of habitat models. Together, the three documents provide the user with a useful tool for habitat evaluations.

The current HEP methodology has been developed primarily for application to terrestrial and inland aquatic habitats. HEP has not been extensively applied to estuarine systems. However, the concepts of habitat evaluation may be equally applicable in those systems. The USFWS is conducting further tests and research to determine what changes may be necessary to fully apply HEP to estuarine systems.

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1. Introduction

HEP is a method which can be used to document the quality and quantity of available habitat for selected wildlife species. HEP provides information for two general types of wildlife habitat 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. By combining the two types of comparisons, the impact of proposed or anticipated land and water use changes on wildlife habitat can be quantified. This document describes HEP, discusses some probable applications, and provides guidance in applying HEP in the field.

The HEP is based on the assumption that habitat for selected wildlife species can be described by a Habitat Suitability Index (HSI). This index value (from 0.0 to 1.0) is multiplied by the area of available habitat to obtain Habitat Units (HU's), which are used in the comparisons described above. The reliability of HEP and the significance of HU's are directly dependent on the ability of the user to assign a well defined and accurate HSI to the selected evaluation species. Reliability is greatly increased when documented criteria for determining HSI's are available. Guidance for the development of criteria is found in the "Standards for the Development of Habitat Suitability Index Models for Use with the Habitat Evaluation Procedures" (103 ESM).

The user must determine the applicability of HEP to a particular study (Chapter 2). Figure 1-1 shows the steps to be followed if HEP is applicable to the study. The first step generally involves defining the study limits, including delineating the study area, determining cover types, and selecting evaluation species. The next step is to describe baseline conditions in terms of Habitat Units. The third step of HEP is the projection of future habitat conditions in terms of Habitat Units. These steps provide the basic approaches for habitat assessments and are described in greater detail in Chapters 3-5. Chapter 6 describes a methodology for including value judgments in evaluating alternative actions. Chapter 7 discusses the concepts of the application of HEP to compensation studies. Finally, Chapter 8 provides a detailed example of an application of HEP using the Forms in Appendix A. Appendix B provides guidelines for the development of sampling.

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[1]The term "wildlife" is used in this document to refer to both aquatic and terrestrial animal species.

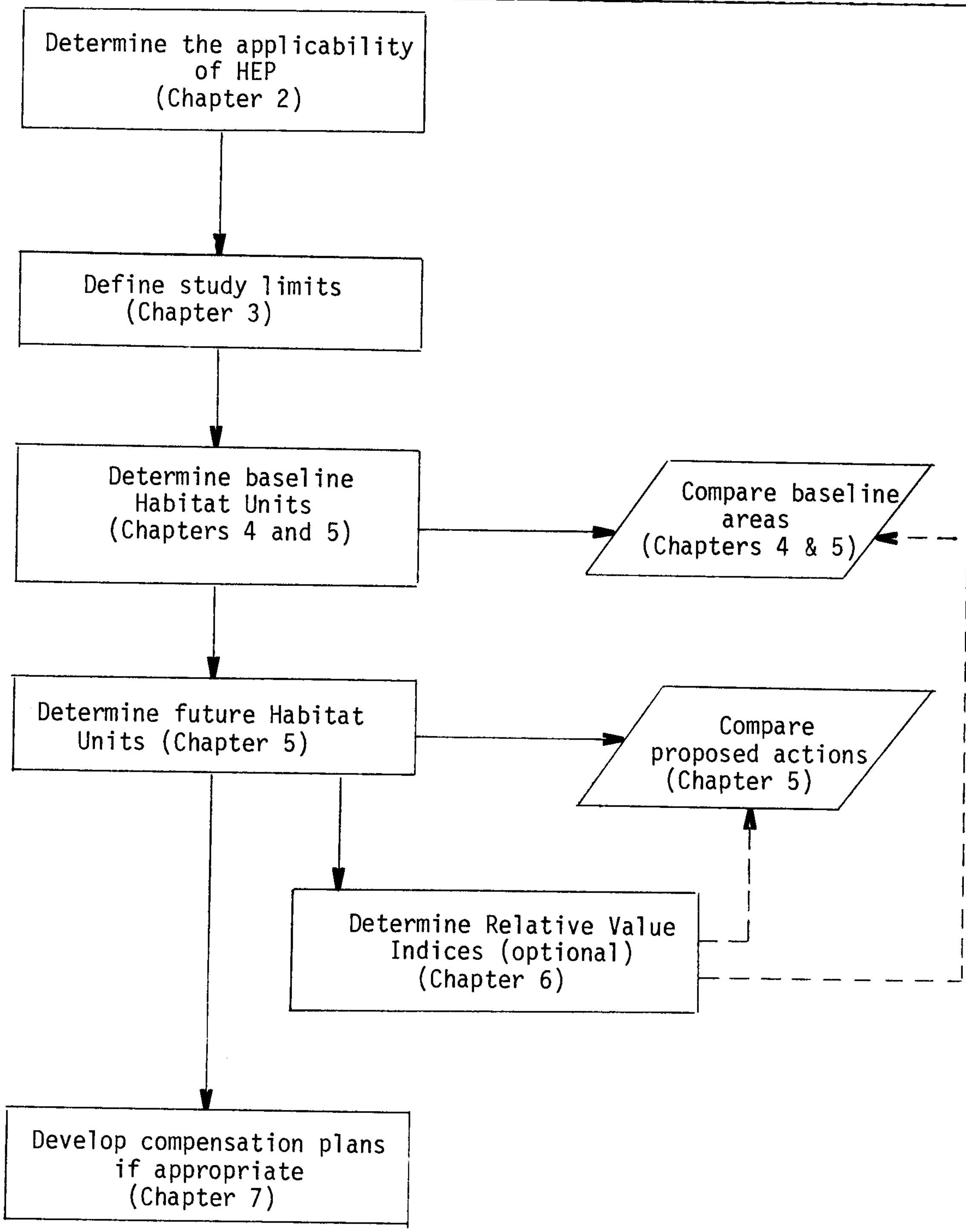

Figure 1-1. Generalized evaluation process using HEP

2. Determination of the Applicability of HEP to a Wildlife Planning Effort

Wildlife resource planning is a very general term used to define a number of activities concerned with optimizing the supplies of wildlife to meet some stated objective(s). Whether the planning effort is directed at a wildlife problem, such as land and water resource planning, or is a result of other resource problems, such as mineral extraction, there are several common activities involved.

The Habitat Evaluation Procedures may be used in three distinctly separate, but related, planning activities: 1) wildlife habitat assessments, including both baseline and future conditions; 2) trade-off analyses; and 3) compensation analyses. HEP data also may be used in the Human Use and Economic Evaluation (104 ESM).

An important consideration in deciding whether or not to use HEP is the cost and time involved. Although HEP may technically be suited for a particular planning activity, time and budget constraints may not permit its use. There are several major factors that are directly related to the time needed for, and costs of, a HEP application including the size of the study area, the number of cover types, the number of evaluation species, and the number and types of proposed actions. The intensity of the HEP application must be compatible with the stage of planning. In early planning stages, the study design can be generalized to require low levels of data collection and analysis. Time and associated costs may be minimal for such preliminary HEP applications. However, the intensity of data collection and analyses can be expanded as more extensive data are required for decision-making. Judgment must be used to adjust the level of HEP application to mesh with data needs; gathering site-specific information for studies not requiring such data will greatly increase costs.

2.1 Cost estimation for a HEP application. Any specific application of HEP will have its own unique features and the following estimates of study costs should serve only as a general guide. The guidelines provided in this chapter will aid in the calculation of time and associated costs for a HEP application, but do not include related study activities, such as the time needed for study coordination and reporting responsibilities. A HEP application can be completed in several days or may take as long as several months. The following estimates are for an average high intensity HEP application to a water resource development project.

A. Pre-field costs. Costs associated with the pre-field stage of a HEP analysis are related to mapping and development of habitat models. Mapping costs include obtaining aerial photographs of the study area and delineating cover types. Cost and time estimates for these tasks are highly variable and depend on the quality of aerial photography, the level of resolution required, and the availability of photogrammetric equipment. A mid-range estimate for mapping from aerial photographs is about one person-day per 4,000 acres. Aquatic habitat mapping may require supplemental information, such as water gaging station records.

Time required to develop habitat models for each evaluation species depends largely on the availability of information. The time required for this task will be minimal if previously developed models are appropriate for the analysis. A minimum of two person-days per species should be allotted for development of basic models in word format (Chapter 4 and 103 ESM).

B. Field costs. Field time depends on the numbers of evaluation species and cover types identified for habitat analysis and the data requirements of the habitat models used. Cover types are identified for purposes of species selection, data collection and analysis and as a convenient means to simplify the habitat evaluation. The amount of time required for data collection and analysis generally corresponds to the number of cover types selected.

The actual number of samples required will depend on the desired reliability of the habitat analysis, the variability of field data collected, and the type of habitat model used. For terrestrial studies, the minimum number of samples per cover type is three, and experience indicates that 10 to 15 sample sites per cover type are usually sufficient to obtain reasonably reliable data. Four to six sites, on the average, can be sampled per day. Therefore, sampling of each cover type will take an average of two to three days if 10 to 15 evaluation species are included in the study and the habitat models for those species require individual site sampling.

C. Analysis of data. Documentation of impact assumptions and data analysis should average from 8 to 14 person-days per proposed action. About half (four to seven person-days) of this time is required to develop and document land use assumptions and record data on HEP forms; the remaining half is required for manual calculations. If HEP computer software is used for analysis, the total time can be reduced to four to seven person-days per proposed action, with the addition of two to four days to enter into the computer the data for all proposed actions.

D. Summary of costs. A detailed water resource study, consisting of a manual application of HEP that considers 3 proposed actions, 20 evaluation species, 5 cover types, and a total area of 20,000 acres, would require approximately 70 to 110 work days according to the guidelines presented in this chapter. A computer assisted application would reduce this time by 12 to 21 days.

3. Definition of Study Limits

The first step of a HEP application consists of: 1) defining the study area; 2) delineating cover types; and 3) selecting evaluation species.

3.1 Definition of the study area. Definition of the study area should consider the purposes of the study, significant changes that may occur in existing habitat, and the interrelationships of species within the biological community that presently exist or could exist there in the future.

The study area should include those areas where biological changes related to the land or water use proposal under study are expected to occur. This area should include areas that will be affected, either directly (e.g., engineering structures) or indirectly (e.g., human use trends) by the proposed use. Additionally, the study area should include contiguous areas with significant biological linkages to the area where actual physical impacts are expected to occur. For example, reservoir inundation might affect a stream fishery through both the loss of habitat and the isolation of populations from upstream spawning areas. The study area boundaries may require revision after cover type delineation and selection of evaluation species have been completed.

3.2 Delineation of cover types. A HEP analysis of the study area requires the delineation of cover types. The level of delineation of cover types generally depends on mapping constraints and the detail required in the analysis. It is doubtful that any single cover type classification system would be applicable to all studies in all parts of the country. Therefore, biologists should select a regionally accepted classification system that is compatible with available mapping resources.

Cover types should be delineated on an accurate base map (e.g., U.S. Geological Survey topographic sheet). Maps generated from remotely sensed data (scale 1:20,000 to 1:60,000) usually permit acceptable resolution for terrestrial habitat evaluations. Color infrared photography generally provides the best separation of vegetative structure, which forms the basis for terrestrial cover types. Aquatic cover types should be described by characteristics such as size and temperature. These characteristics have proven to be fairly good estimators of the number (Barbour and Brown 1974; Magnuson 1976) and kinds (Lotrich 1973) of fish species in aquatic systems in restricted geographical areas. Specific definitions of cover type descriptors are provided in 103 ESM.

Cover types serve three basic functions in HEP. First, cover types facilitate the selection of evaluation species (Subsection 3.3). Second, extrapolation of data from sampled areas to unsampled areas can be done with some confidence if the study area is divided into relatively homogeneous areas, thus reducing the amount of sampling necessary. Finally, separation of the study area into cover types facilitates treatment of HEP data (Chapter 4).

3.3 Selection of evaluation species. Evaluation species, both terrestrial and aquatic, form the basis of a HEP analysis. An evaluation species can be a single species, a group of species, species life stage, or a species life requisite. Evaluation species are used in HEP to quantify habitat suitability and determine changes in the number of available HU's. Therefore, a HEP assessment is directly applicable only to the evaluation species selected. The degree to which predicted impacts for these species can be extrapolated to a larger segment of the wildlife community depends on careful species selection.

There are at least two basic approaches to the selection of evaluation species: 1) selection of species with high public interest, economic value, or both; and 2) selection of species to provide a broader ecological perspective of an area. The choice of one approach in lieu of the other may result in a completely different outcome in the analysis of a proposed land use. Therefore, the objectives of the study should be clearly defined before species selection is initiated. If the objectives of a study are to base a land use decision on potential impacts to an entire ecological community, such as a unique wetland, then a more ecologically based approach is desirable. If, however, a land or water use decision is to be based on potential impacts to a public hunting or fishing area, then species selection should probably favor animals with a tangible economic value. In actual practice, species should be selected to represent both economic and ecological views because planning efforts incorporate objectives that have economic, social, and ecological aspects. Species selection always should be approached in a manner that will optimize contributions to the stated objectives of the planning effort.

Most land use decisions are strongly influenced by the perceived impacts of the proposed action on human use. Since economically or socially important species have clearly defined linkages to human use, they should be included as evaluation species in all appropriate land use studies. They must be used if a Human Use and Economic Evaluation (104 ESM) is to be included in the habitat assessment process.

An analysis based only on those species with directly identifiable economic or social value may not be broad enough to adequately describe all of the ramifications of a land use proposal. If it is desirable to increase the ecological perspective of an assessment, the following types of species should be considered:

1) Species known to be sensitive to specific land use actions. The species selected with this approach serve as "early warning" or indicator species for the affected wildlife community.

2) Species that perform a key role in a community because of their role in nutrient cycling or energy flows. These species also serve as indicators for a large segment of the wildlife community, but may be difficult to identify.

3) Species that represent groups of species which utilize a common environmental resource (guilds). A representative species is selected from each guild and predicted environmental impacts for the selected species are extended with some degree of confidence to other guild members.

The procedures for selecting terrestrial and aquatic species described in detail below consider all three types of species with emphasis on guilds. Species of high public interest should be included in the appropriate guild process because in many cases such species do serve as ecological indicators as described above.

A. Terrestrial guild development. The recommended procedure for selecting terrestrial species involves categorizing vertebrate species in an ecological community according to their feeding and reproductive guilds. Feeding guilds are defined in terms of feeding mode (e.g., carnivore, herbivore, or omnivore) and strata locations in the ecosystem where the foods are obtained (e.g., canopy, shrub layer, or surface). Reproductive guilds are defined only in terms of strata locations where reproduction occurs. Figure 3-1 illustrates an example of the possible subdivisions of feeding modes and Figures 3-2 and 3-3 illustrate possible subdivisions for strata locations. Locational descriptors in Figure 3-2 can be used in any terrestrial system and the locational descriptors in Figure 3-3 provide the additional descriptors needed to define guilds for wetland species. For example, a forested wetland may contain location descriptors from both Figure 3-2 and Figure 3-3.

Development of guilds for the selection of species involves several successive steps: 1) construction of matrices that define feeding and reproductive guild cells; 2) selection of species from each cover type that meet guild definitions; and 3) selection of species from each guild to act as study evaluation species. These steps are discussed in the appropriate order below.

(1) Step 1. Construction of matrices. Both a feeding matrix and a reproductive matrix must be constructed for each cover type in a study area. The feeding matrix is created by entering feeding modes horizontally across the top and locational descriptors (strata) down the left side of the matrix (Figure 3-4). The reproductive matrix is constructed similarly, except there is only one reproductive category across the top. The descriptors used to construct the feeding matrix depicted in Figure 3-4 were level

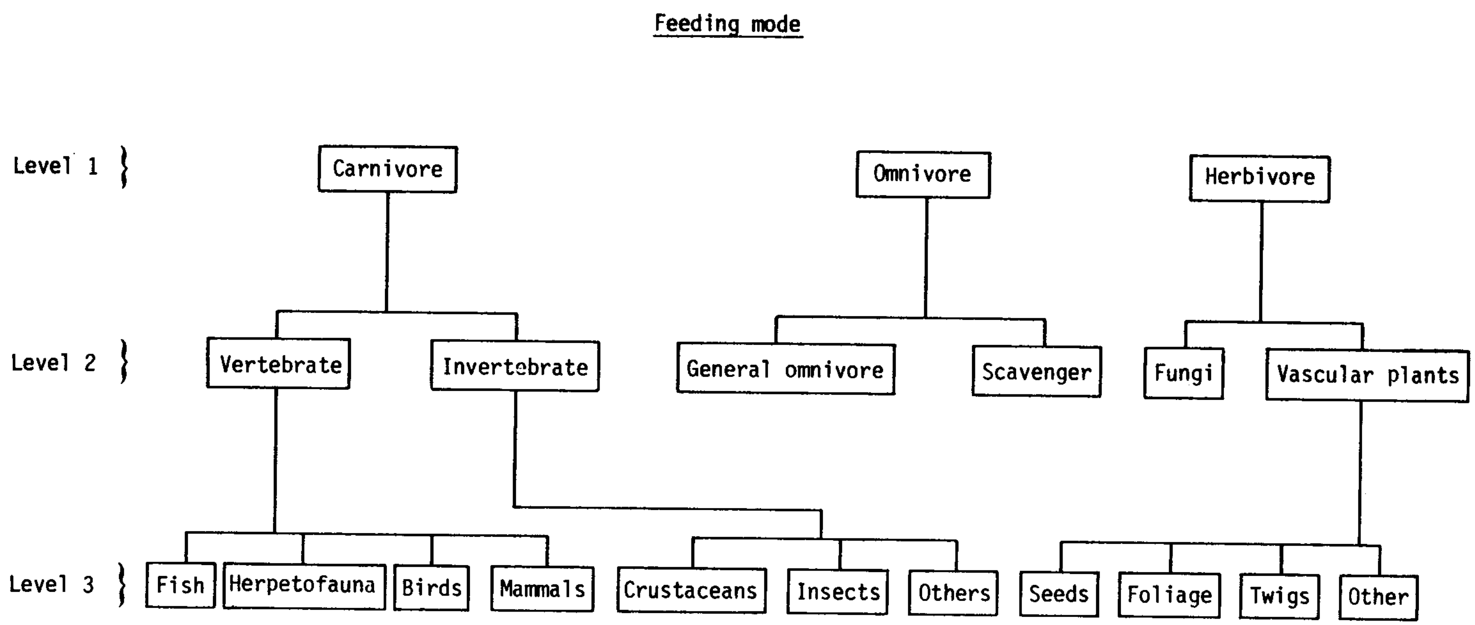

Figure 3-1. An example of the development of feeding mode descriptors through various levels (1-3) of detail.

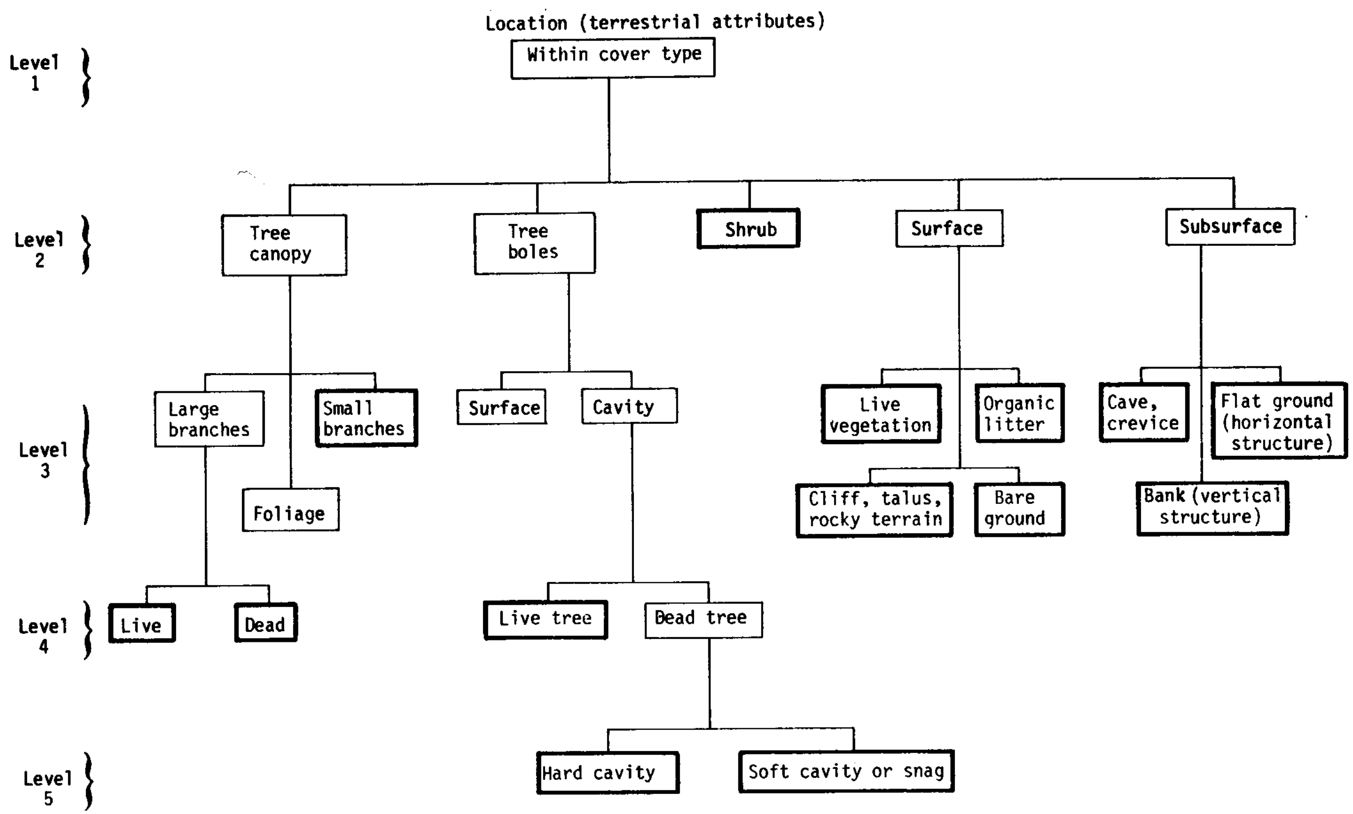

Figure 3-2. An example of terrestrial locational descriptors for selection of evaluation species through guilding.

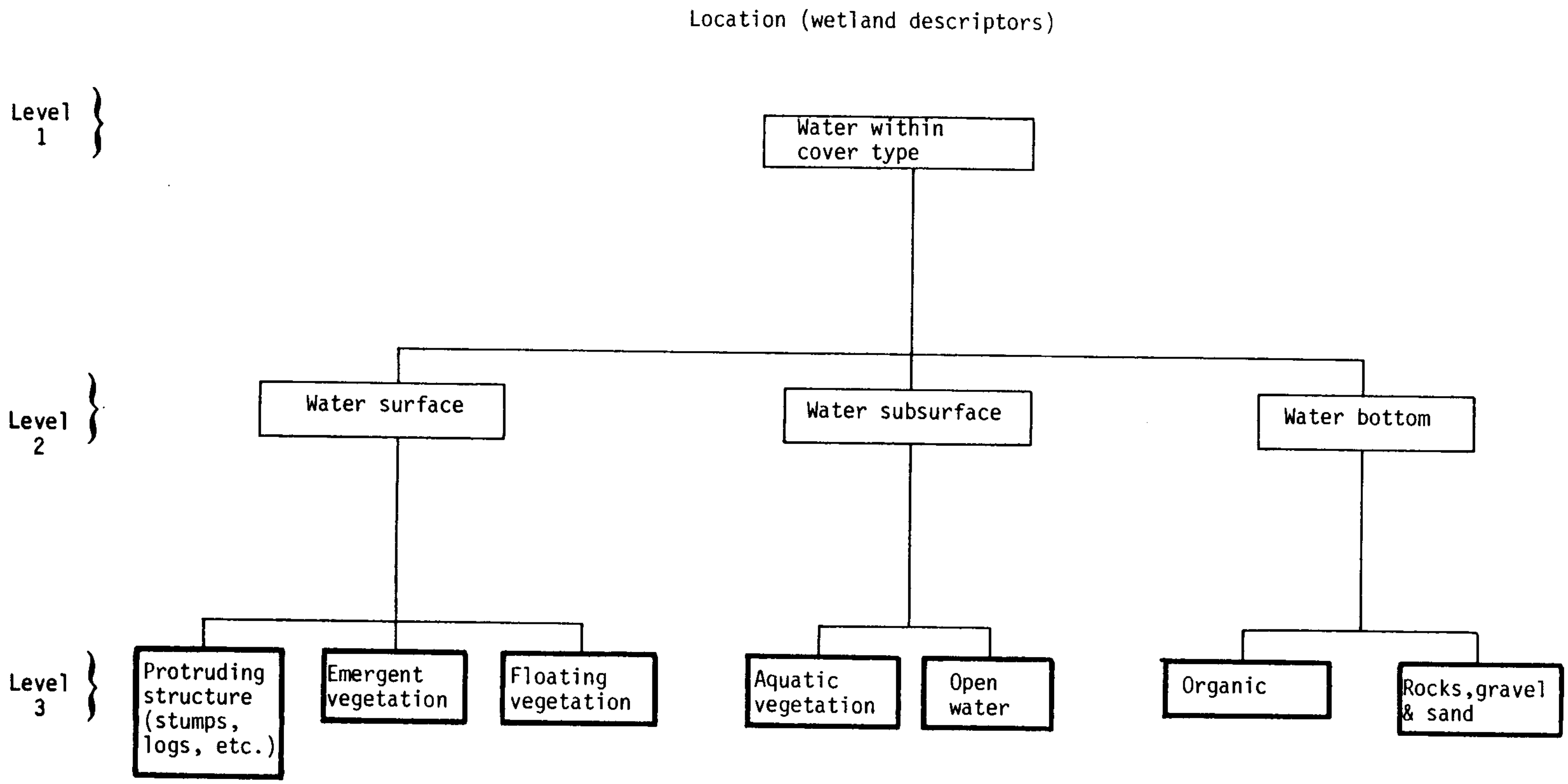

Figure 3-3. Terrestrial locational descriptors for guilding at various levels of detail (wetland descriptors).

Cover type: Deciduous forest	Feeding mode					
	Vertebrate carnivore	Invertebrate carnivore	General omnivore	Scavenger	Herbivore (fungi)	Herbivore (vascular plants)
Tree canopy		Hairy woodpecker				Fox squirrel Gray squirrel
Tree boles		Hairy woodpecker	Pileated woodpecker Carolina chickadee			
Shrub layer						White-tailed deer Eastern cottontail Eastern woodrat
Terrestrial surface	Bobcat Red-tailed hawk Red-shouldered hawk Barred owl	Nine-banded armadillo	Gray fox Raccoon			White-tailed deer Eastern cottontail Eastern woodrat Golden mouse Fox squirrel
Terrestrial subsurface						

Figure 3-4. An example of terrestrial feeding guilds in a deciduous forest in the south-central United States.

2 locational (Figure 3-2) and level 2 feeding (Figure 3-1) descriptors. The reproductive matrix shown in Figure 3-5 was constructed using locational descriptors from the levels indicated by bold-line squares in Figure 3-2.

The descriptors used to construct these matrices were selected to produce guild cells similar to those contained in the wildlife species data base being developed by Short, 1980. Extensive literature reviews indicated that these descriptors result in guilds which contain species similar in terms of habitat utilization for impact assessment purposes. Descriptors at other levels of detail can be used for a HEP analysis.

The guilding concept is somewhat arbitrary because no two species are precisely the same in terms of habitat utilization and responses to land use changes. The best level of detail for guilding for a particular study allows the maximum generalization about species similarities while maintaining acceptable homogeneity within the individual guilds. There will always be a compromise between the number of guild cells and the degree of similarity between species in any guild. The number of guilds that should be identified is constrained by the time and funds available for a study. More detail in the guild descriptors results in the identification of a greater number of potential evaluation species. The matrices in Figures 3-4 and 3-5 contain 44 cells collectively. If one species were selected to represent each cell for each cover type in a study area, there would be a large number (44 times the number of cover types) of potential evaluation species. However, in practice the number of actual species would be lower for several reasons:

1) Nonapplicable cells. There may be several cells for which no species can be identified. For example, there may be no identifiable species that feeds on fungi in the tree canopy.

2) Nonapplicable strata. Some cover types may not contain all the strata identified. For example, grassland cover type matrices will not include feeding or reproductive guilds that are defined by tree canopy and tree bole strata.

3) Land use changes being studied. It may be possible to ignore certain guild cells and still select species most likely to be impacted by land use changes. A given study need only

Cover type: Deciduous forest	Reproductive
Tree canopy	
Small branches	Red-eyed vireo
Large live branches	Fox squirrel, gray squirrel, red-tailed hawk, red-shouldered hawk
Large dead branches	
Tree boles	
Live tree cavity	Fox squirrel, gray squirrel, raccoon, hairy woodpecker, Carolina wren, barred owl
Dead hard cavity	Raccoon, barred owl, pileated woodpecker, hairy woodpecker, Carolina wren
Dead soft cavity	Raccoon, barred owl, pileated woodpecker, Carolina chickadee, hairy woodpecker, Carolina wren
Shrub	White-tailed deer, gray catbird, indigo bunting, mourning dove
Surface	
Live vegetation	White-tailed deer, eastern cottontail, eastern woodrat, bobwhite, turkey
Organic litter	
Cliff, talus, rocky terrain	
Bare ground	
Subsurface	
Cave, crevice	Eastern woodrat, bobcat, gray fox
Flat ground	Eastern woodrat
Bank	Eastern woodrat, gray fox, nine-banded armadillo

Figure 3-5. An example of terrestrial reproductive guilds in a deciduous forest in the southcentral United States.

consider those strata impacted by a particular land use change. For example, only the terrestrial surface and shrub layers may need to be analyzed if a land use proposal involves increased livestock grazing.

Given the above variables that influence the relationship between the number of guilds and the number of evaluation species, it is difficult to provide rigid guidelines for matrix construction. However, as a general rule, construct initial feeding and reproductive matrices with a combined number of guilds approximately four to five times the desired number of evaluation species. The matrices may be reconstructed at different levels of detail if either: 1) the actual number of species is too large; or 2) the guild categories are too general for study purposes.

(2) Step 2. Selection of species to meet guild descriptors. After the matrices have been developed, the next step is to categorize species into the guilds. The public interest species should be included in the guilds. Some judgment is required in determining the number of species that should be considered. In some cases, there may be several hundred vertebrate species in a study area. Various screening mechanisms can be used to reduce the list of candidate species. For example, habitat evaluation data bases, such as those under development by the USFWS and other agencies, might be consulted as a prescreening mechanism to identify those species for which adequate habitat information is available from which to develop habitat models. As a general guideline, enough species should be entered into the matrix to represent a reasonable cross-section of feeding and reproductive guilds. For very general descriptors, a small number of species might be sufficient to provide at least one species in each guild. Figures 3-4 and 3-5 contain examples of species categorized according to feeding and reproductive guilds.

(3) Step 3. Selection of species from each guild. If more than one species has been entered into any guild, at least one should be selected to represent the guild. This within-guild selection can be arbitrary or according to a ranking scheme. Suggested ranking criteria include anticipated sensitivity to proposed land use impacts, community role in nutrient cycling or energy flow, geographic range, cover type utilization, and the availability of habitat data. Each criterion may be subdivided into several categories for purposes of numerical weighting. For example, the data availability criterion might be subdivided and weighted as follows:

	Weight
Species-habitat relationships well known..............	4-5
Species-habitat relationships partially known	2-3
Species-habitat relationships not well known	1

As an example of within-guild selection, the two deciduous forest omnivores that feed on tree boles (Figure 3-4) are ranked according to: 1) availability of habitat information; and 2) perceived sensitivity to land use impacts (for example, a timber management practice). Habitat relationships for both the pileated woodpecker and the Carolina chickadee are reasonably well understood; the score for each would be 2.5. However, the pileated woodpecker is perceived to be more sensitive to the proposed timber management practice and would be rated at 4.0; the more tolerant Carolina chickadee would be rated at 1.0. The overall score for the pileated woodpecker (6.5) is higher than the overall score for the Carolina chickadee (3.5) and, therefore, the pileated woodpecker would be the first choice for an evaluation species to represent the omnivore- tree bole guild in deciduous forest. The ranking process may place a high value on an economically or socially important species; in such cases, the species will provide both economic and ecological perspectives. However, be cautious when selecting a game species to represent a guild because in many cases game species are "generalists" that adapt readily to change. Generalist species may not adequately represent other guild members in a habitat evaluation.

B. Aquatic guild development. Aquatic guilds can be developed to aggregate species into groups with similar habitat requirements. The guild structure can have several levels, and the number of descriptors within a level can vary. Guilds may be based on: 1) feeding habits (Leidy and Jenkins 1977); 2) reproductive habits (based on Balon 1975; Balon *et al*. 1977); 3) tolerance and response to temperature (Hokanson 1977); 4) preferred habitat; or 5) tolerance to the results of a potential habitat alteration, such as turbidity-siltation. In some studies, the user may find it useful to further divide the guild into several levels. For instance, Balon (1975) presents a detailed reproductive guild classification that would provide more resolution for delineating species into groups by their similar reproductive strategies. The various descriptors in the matrix need not be mutually exclusive. For example, a species such as smallmouth bass is commonly found in both riverine and lacustrine habitats and can be classified under both categories.

After the descriptors have been established, the aquatic species are listed and categorized by guild descriptor. The guild matrix presented in Figure 3-6 is one of several possible guild structures and serves only as an example. The number of levels and descriptors for the guild

Evaluation Species or Life Stage	Habitat preferences: Lacustrine: Small (< 50 ha)	Medium (50-200 ha)	Large (> 200 ha)	Near Shore	Off Shore	Riverine: Small (< 5 m wide)	Medium (5-30 m wide)	Large (> 30 m wide)	Low Velocity (pools, eddies)	High Velocity (riffles, runs)	Summer temperature optima: Cold (< 20° C)	Cool (20-28° C)	Warm (> 28° C)	Reproductive considerations: Simple Spawners a/	Complex Spawners b/	Temperature Range (C)	Season (Jan = 1, Dec = 12)
Smallmouth bass	X	X	X	X		X	X	X	X			X			Rb	13-20	5-7
Channel catfish	X	X	X	X	X		X	X	X				X		C	21-30	5-7
Sunfishes	X	X	X	X		X	X	X	X				X		PRg	>21°	5-8
Threadfin shad			X		X			X	X	X			X	P		>21°	4-8
Spotfin shiner								X		X		X		P		>15°	5-8

a/ Simple Spawner - B = buoyant or semi-buoyant, drifting eggs; P = eggs deposited primarily on plant materials, R = eggs deposited primarily on rocky-sandy substrates, PR = eggs deposited on either rocky-sandy substrate or plants.

b/ Complex Spawner - C = constructs or uses naturally occurring cavities as nests and guards nest, Rb = constructs nest in or on rocky substrate, Pg = constructs nest in or on plant materials and guards nest, PRg = constructs nest with either inorganic or organic materials and guards nest. Mg = constructs mound-shaped nest and guards nest.

Aquatic species matrix. Figure 3-6. Aquatic species matrix must be adapted to fit study needs. For example, if the stream bottom type is important, descriptors such as mud, sand, gravel, or rubble bottom could be added to the matrix.

It is most desirable to list all species in the study area and then select a species from each guild. However, in many cases time and budget constraints may require that a preliminary screening occur to reduce the number of species before attempting to place them in the guilds. Taxonomic classification at the family level has ecological significance and can provide a first level screening to reduce the number of species. The user should select at least one species in the study area from each taxonomic family and place them in the guilds. Species of high public interest should also be placed in the guilds so that the final list of species contains those of high public interest and species representing ecological diversity. An "x" is placed in the matrix cells in which each species belongs (Figure 3-6).

Evaluation species are selected by choosing one or more species from the matrix. When several species occur in one guild and the user determines that only one or two members of that guild are required for the evaluation, criteria must be developed to select species from within the matrix (See Steps 1-3 in Section 3.3A). Criteria such as availability of quantifiable habitat information, degree of public interest in the species, or other criteria can be used to make the final selection.

C. Compiling study area list of evaluation species. A composite list of species for the study area will contain every species chosen to represent their matrix in all cover types and species chosen for economic or social importance. If the number of evaluation species on this list exceeds study constraints, the list can be reduced by: 1) developing a more generalized matrix, and; 2) deleting entire cells from the existing matrices. Matrix cells can be deleted from consideration based on rating criteria as discussed in Step 3 [3.3 A(3)] of the terrestrial guilding process.

4. Calculating Study Area Habitat Units

A HEP analysis is structured around the calculation of Habitat Units (HU's) for each evaluation species in the study area. The number of HU's is defined as the product of the Habitat Suitability Index (quality) and the total area of available habitat (quantity). This chapter provides some basic guidelines for determining HSI and total available habitat area for evaluation species. Chapter 5 discusses the use of HU's in habitat assessments for both baseline and impact studies.

4.1 Calculating total area of available habitat. The total area of available habitat for an evaluation species includes all areas that can be expected to provide some support to the evaluation species. Total area of available habitat is calculated by summing the areas of all cover types likely to be used by the evaluation species. If the study area is not subdivided into cover types, the total area of available habitat is identical to the entire study area.

The objective of defining total area of available habitat is to delineate only those areas that require HSI determinations. The total area of available habitat will vary between evaluation species if cover type use patterns are different; therefore, HSI's for each evaluation species may apply to different subareas (i.e., available habitat).

4.2 Calculating a Habitat Suitability Index for available habitat. The fundamental step in determining HU's is to estimate or calculate HSI's for each evaluation species. The technique for determining HSI values must be clearly described in a HEP study in order to establish credibility, optimize the usefulness of the analysis in decisionmaking, provide a permanent record of the basis for a decision, and make future improvements in HSI models. Studies by Ellis *et al*. (1979) confirmed that such descriptions increase the repeatability in determining HSI values. Although repeatability does not mean that HSI values will be accurate, repeatability is a prerequisite to improved accuracy.

The recommended method of describing HSI values is through the use of HSI models. An HSI model may be in word or mathematical format but, regardless of the format, the model must clearly describe the rules and assumptions used to calculate an HSI. The process of calculating an HSI involves: 1) establishing HSI model requirements; 2) acquiring an HSI model; and 3) determining HSI for available habitat.

A. Establishing HSI model requirements. Habitat models used in HEP must be in index form. Inhaber (1976) defined an index as a ratio between some value of interest and a standard of comparison. For HEP purposes, the value of interest is an estimate of habitat conditions in the study area, and the standard of comparison is the optimum habitat condition for the same evaluation species. Therefore,

$$\text{Index value} = \frac{\text{Value of Interest}}{\text{Standard of Comparison}} \text{ ; or}$$

4. Calculating Study Area Habitat Units

$$HSI = \frac{\text{Study Area Habitat Conditions}}{\text{Optimum Habitat Conditions}}$$

where the numerator and denominator have the same units of measure. The HSI ranges between 0 and 1.0 and, as with any index, is dimensionless (i.e., the units for both the numerator and denominator must be the same and should be specified).

The ideal goal of an HSI model is to produce an index with a proven, quantified, positive relationship to carrying capacity (i.e., units of biomass/unit area or units of biomass production/unit area). This ideal model goal will often be unobtainable; consequently, a more easily obtainable but acceptable goal must be defined. The minimum acceptable goal for an HSI model might be, for example, an index that a recognized expert, knowledgeable about the habitat requirements of a species, believes is positively related to long-term carrying capacity.

The use of an HSI model within HEP places additional requirements on HSI values. The HEP mechanisms for comparing proposed actions and developing compensation plans are based on the assumption that HSI is a linear index; i.e., a change in HSI from 0.1-0.2 is the same magnitude as a change from 0.8-0.9. Even if the HSI model used has a proven, positive relationship to long-term carrying capacity, the relationship must be linear (or transformable to linear). It is not necessary to obtain a model that meets the ideal goal if assumptions concerning the linear relationships of the index to carrying capacity are acceptable.

B. Acquiring HSI models. In acquiring an HSI model for use in HEP, the ideal goal, as stated previously, is to use a model that has been proven to be linearly correlated with a defined measure of carrying capacity (e.g., biomass/unit area or biomass production/unit area). There are two basic categories of models that may be used with HEP: 1) HSI models that directly produce a unitless number between 0 and 1 that is believed (or assumed) to have a positive relationship with carrying capacity; or 2) HSI models with a predictable value of interest (i.e., the numerator is estimated in some specified units, such as lbs per acre).

(1) Existing habitat models. HSI models are under development by the USFWS[2] and several reservoir models are now available in Aggus and Morais (1979). Models have been described that can be converted

[2]Contact USFWS, Western Energy and Land Use Team, 2625 Redwing Road, Fort Collins, Colorado 80526.

to HSI format. The Aquatic Systems and Instream Flow Group has developed a method of assessing change in fish habitat potential in streams in response to change in stream flow or channel configuration (Bovee 1978; Stalnaker 1978; Stalnaker 1980). This method involves modeling habitat within selected stream reaches. Training and technical assistance in the use of this method is available from the Aquatic Systems and Instream Flow Group. Terrestrial habitat models that predict population densities based on statistical methods have been developed by Russell et al. (1980).[3] These models use conditional probability statements derived through habitat observations in areas of both high and low population densities.

Tested and scaled regression models relating habitat variables to population measures are available for reservoir fishes (Jenkins 1976; Leidy and Jenkins 1977; Aggus and Morais 1979) and some stream fishes (Binns and Eiserman 1979) and should be reviewed for potential HEP applications. In addition, certain species data bases are being developed by the U.S. Forest Service and other agencies and may be useful in HSI modeling.

If there are existing models, judgment may be required in adapting them for specific applications. Almost all models are developed around a specific set of assumptions that may or may not apply to a specific application area. An existing habitat model may be constructed around habitat variables (e.g., % canopy cover or tree height) that do not relate to habitat suitability in all regions of the country where the species occur.

The use of existing habitat models in HEP requires that model outputs be in a 0 to 1 index form. Models that output a measure of habitat suitability that are not a 0 to 1 index should be converted to an HSI as follows:

$$HSI = \frac{\text{Model Output (Study Area Habitat Conditions)}}{\text{Optimal Habitat Conditions}}$$

For example, the output of the model developed by the Aquatic Systems and Instream Flow Group is weighted useable area (WUA) for appropriate instream habitat types (spawning, fry, juvenile, adult). This information is displayed for selected stream reaches at monthly intervals (Stalnaker 1980). Suitability indices for each habitat type may be calculated as follows:

[3]The use of these models may require assistance from the Colorado Cooperative Wildlife Research Unit, Colorado State University, Fort Collins, Colorado.

$$SI_i = \frac{\text{Weighted Useable Area (WUA) of the Stream Reach Modeled}}{\text{Wetted Surface Area of the Same Stream Reach}}$$

where i = instream habitat type

SI_i = suitability index for a given stratified stream segment described by the representative reach samples.

These SI values must be aggregated into an HSI value. The physical habitat simulation model (PHABSIM) developed by the Aquatic Systems and Instream Flow Group can be used to predict WUA changes in stream environments under proposed alterations of streamflow or channel geometry. This model output can then be used to calculate future HSI values. The Instream Flow Group is currently preparing a detailed illustration of the application of the IFG Incremental Methodology in a HEP analysis.

The output of the model described by Russell et al. (1980) is a population density estimate. This estimate can be converted to an HSI as follows:

$$HSI = \frac{\text{Population Density Estimates (Model Output)}}{\text{Maximum Observed Population Density}}$$

(2) Development of HSI models. If an HSI model must be developed, 103 ESM should be consulted for full details of the model building process. The following discussion is a summary of the modeling process and is meant to be an aid to understanding how an HSI model may be constructed.

The general steps in the construction of a model are: 1) establish a model goal; 2) define the habitat variables that are related to the model goal; and, 3) define model relationships that combine measurements of the variables to achieve model goals.

Model goals include two general aspects: 1) output specifications and 2) a definition of potential variables the field biologist is able to measure. The ideal output for an HSI model is a measure of habitat suitability per unit area (e.g., biomass or biomass production/unit area). In order to provide a rapidly applicable assessment tool, habitat models for use in HEP should be based on easily measured physical, chemical, or vegetative variables. After reviewing the literature about the evaluation species, the proper variables to measure can usually be identified. States *et al.*

(1978) described variables commonly measured in aquatic and terrestrial systems, noted why variables were important, and discussed references on how to measure them.

The relationship between model variables can be defined in word or mathematical format. In word format, a definition of optimum habitat is developed through a written description of the best condition of habitat variables. A description of the habitat in the study area, based on the same variables, is developed and compared to the word model to determine the HSI. The data and logic used to determine the HSI must be described.

A mathematical format is a more rigorous approach and requires that the logic of the HSI calculation be mathematically defined. HSI values are determined by mathematical functions that combine habitat variable measurements. A mathematical format allows clearer statements of model relationships but is not necessarily any less subjective than a model in word format. The mathematical functions need not be complex, but should consider the biological interactions of variables.

Ideally, an HSI model should be calibrated to the desired output goal. Significant assumptions are required concerning the attainment of model output goals (e.g., number of animals/hectare) until the model has been tested and scaled by comparing it to a defined measure of habitat suitability.

C. Determining HSI for available habitat. After a habitat model is obtained, the model must be used in HEP to obtain an HSI for the available habitat. The HSI for available habitat is a function of the suitability of all cover types used by the evaluation species. The HSI for available habitat is calculated in one of several ways; the choice depends on the structure of the model. Figure 4-1 displays the various routes to calculating an HSI for available habitat. These routes are dependent on the structure of the model and can be defined by answering three questions about the model structure: 1) Does use of the model produce suitability indices (SI's) for the available habitat from individual cover type suitability indices?; 2) If cover type suitability indices are calculated, does the available habitat for the species consist of more than one cover type?; and 3) If the available habitat consists of more than one cover type, is interspersion between cover types important for the species?

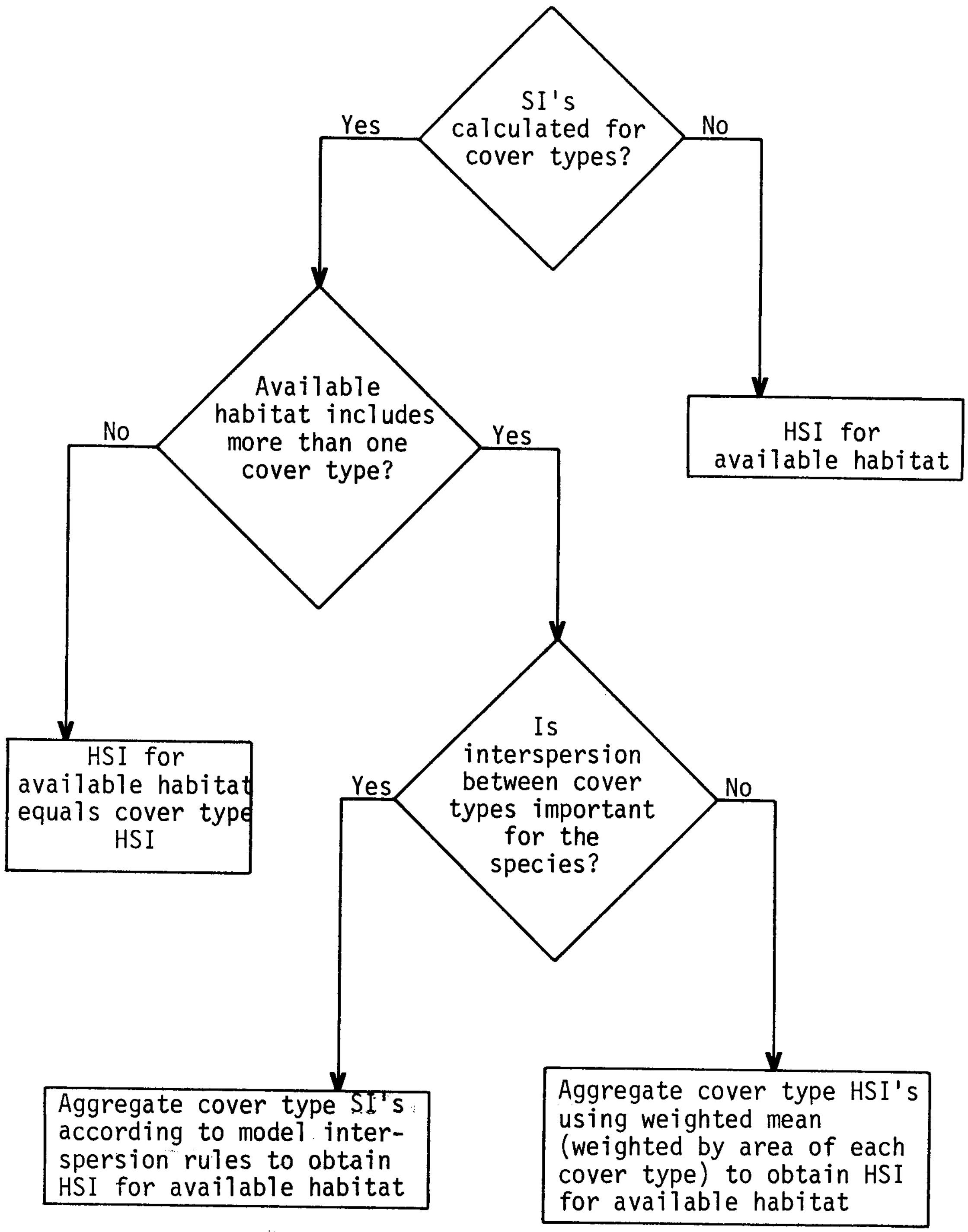

Figure 4-1. Options for calculating HSI for available habitat.

4. Calculating Study Area Habitat Units

In response to the first question in Figure 4-1, if the habitat model does not produce cover type suitability indices then all pertinent habitat variables, including interspersion, will be combined in one relationship. Examples of models of this type are provided by Russell et al. (1980). Different calculations are necessary if cover type suitability indices are produced by the model. Models that provide suitability indices for evaluation species by cover type are being developed by the Habitat Evaluation Procedures Group (USFWS, Fort Collins, Colorado) and are described in more detail in 103 ESM.

Each cover type within the available habitat is assigned a suitability index for only those resources provided by the cover type (e.g., food, reproductive cover). The indices applied to individual cover types are not necessarily habitat suitability indices because they may only apply to part of the species' habitat needs.

A second question is necessary if the model produces cover type indices: Does the available habitat for a species include only one cover type? If all habitat needs are met by one cover type, then the HSI for available habitat is equivalent to the cover type suitability index. If the available habitat consists of two or more cover types, then methods are required to aggregate cover type indices into an HSI for available habitat. The aggregation methods are defined by the third question in Figure 4-1. If interspersion between cover types is important, then the model should aggregate cover type HSI's into one HSI value. For example, optimum habitat conditions for species A might be a 2:1 ratio of cover type A (that provides suitable food) to cover type B (that provides suitable cover), with the added requirement that only those portions of the cover types which are within 300 m of each other should be considered as optimum habitat. If a species occurs in more than one cover type, but interspersion between cover types is not important (i.e., all habitat needs are provided by each cover type), then a different aggregation method is required. This latter aggregation method is a simple weighted mean of the suitability indices for the cover types (weighted by the area of each cover type).

All models have specific data requirements that influence data collection tasks. If a model is structured to compute cover type suitability indices, then data must be collected for each cover type. Baseline habitat conditions typically will be based on field data collection at several selected sites within each cover type. HSI's for future years typically will be based on a predicted average value of the habitat variables within each cover type, without the use of field sample sites. Spatial variables (interspersion of cover types) are best computed from maps. The same basic data collection options can also be used for other model types by sampling in the field to compute mean values of variables or estimating areawide average values of variables.

5. Habitat Assessments Using Habitat Units

Habitat assessments involve measurement and description of habitat conditions for baseline (present) assessments and impact (future with and without action) assessments. For baseline assessments, different areas can be compared in terms of HU's as a guide to further land use planning. Baseline assessments are point-in-time comparisons. For impact assessments, alternative future land use actions can be compared based on predicted future availability of HU's. The net impact of a proposed land use action is the difference in predicted HU's between the future with the action and the future without the action.

5.1 Habitat Unit analysis for one point in time - Baseline assessments. Baseline assessments are used to describe existing ecological conditions. The results of baseline assessments provide a reference point from which resource planners can: 1) compare existing conditions in two or more areas in order to define management capabilities or as a guide to future land use planning; 2) predict and compare changes that may occur without the proposed action, with the proposed action, or with compensation measures; and 3) design monitoring studies. Baseline assessments play a critical role in wildlife planning by identifying wildlife resource capabilities at one point in time so that proposed future actions can be directed toward or away from specific areas. A baseline assessment involves: 1) definition of the study limits, including definition of the study area, delineation of cover types, and selection of evaluation species (Chapter 3); and 2) characterization of the study area in terms of HU's (Chapter 4).

The objective in performing a baseline assessment is to calculate the number of HU's at one point in time for each evaluation species. The area of available habitat (Section 4.1) is multiplied by the mean HSI (Section 4.2) for each evaluation species to determine the total HU's for that species in the study area. The baseline HU's are evaluated and compared directly if the baseline assessment is designed to compare existing conditions in two or more areas. Additional calculations are required (Section 5.2) if the baseline data are to be used as a reference point for impact assessments.

5.2 Habitat Unit analysis for multiple points in time - Impact assessments. Impact assessments are performed by quantifying habitat conditions at several points in time throughout some defined period of analysis. Points in time (target years) can be selected at fixed intervals such as every year, or according to some other schedule.

The assessment of land use impacts is facilitated by dividing the study area into impact segments. An impact segment is defined as an area in which the nature and intensity of the future land use can be considered homogeneous, such as the flood pool area in a reservoir project, a recreational area, or the area of a particular agricultural practice. The advantage of dividing the study area into impact segments is that only one condition need be considered for each cover type within each impact segment. The effects of a particular action may be analyzed over a large area by assuming that the same condition exists throughout each impact-segment-cover-type zone.

Habitat Units must be calculated for the evaluation species at each of the future points in time for future-with and future-without project conditions; this process includes predicting total available habitat and HSI for each evaluation species, using the same HSI models that were used for the baseline year.

A. Use of target years for future predictions. The impact assessment can be simplified by selecting target years (TY's) for which habitat conditions can be reasonably defined. At a minimum, target years should be selected for points in time when the rates of loss or gain in HSI or area are predicted to change. Rates of loss or gain in HSI or area are assumed to occur linearly between target years.

There are several requirements for the selection of target years. The HU-time analysis must begin at a baseline year (TY-0). A baseline year is defined as a point in time before proposed changes in land and water use result in habitat alterations in the study area. In most cases, the baseline year will be existing or current year conditions. However, in some cases, current habitat conditions may reflect proposed action influences. For example, landowners or managers may begin clearing bottomland timber from flood prone sites located downstream from an anticipated flood control project before baseline studies can be initiated. In such cases, baseline year conditions will be those that existed in some previous year. Judgment is required in defining baseline year habitat conditions when present conditions reflect proposed action influences.

In addition to a baseline year, there must always be a target year 1 and an ending target year which defines the future period of analysis. Target year 1 is the first year land and water use conditions are expected to deviate from baseline conditions. The habitat conditions (HSI and area) described for each target year are the expected conditions at the end of that year.

B. Predicting future area of available habitat. For each proposed action, the area of available habitat must be estimated for future years. Some cover types will increase in total area, others will decrease, and in some cases new cover types will be created or existing ones totally lost under projected future conditions.

The user must constantly check to ascertain that the total area of the study does not vary from the baseline area. The recommended method for determining the future area of cover types is the use of cover type maps. The method of developing a cover type map for a future year is to overlay impact segment boundaries on the baseline cover map previously developed (Section 3.2). Baseline cover types will either be unaltered, altered (i.e., variables such as % vegetation cover may change), or converted to new cover types depending on such factors as land use within the impact segment, vegetation successional trends, and management. Areas converted to new cover types through succession or impacts are given a new cover type designation. Altered cover types are designated a subtype (e.g., deciduous forest altered by flooding). An overlay of impact segment boundaries may be required for each target year. Each proposed action requires its own series of overlays in order to determine changes in area of available habitat between selected target years. Figure 5-1 illustrates how a baseline cover type map could be used in conjunction with impact segments to produce cover type maps for future conditions.

C. Predicting future HSI. The same models that were used to determine baseline HSI values must be used to determine future HSI values. If, for example, a mathematical model was used to calculate baseline HSI, a related word model cannot be used to predict future HSI values, or vice versa.

Estimating HSI values for future years requires predictions of changes in the physical, vegetative, and chemical variables of each cover type. Impact segment overlays can be used as an aid in estimating these variables. For example, seasonal flooding could alter a forest understory but not the canopy closure. Changes in interspersion relationships due to creation of new cover types or conversion of existing cover types also can affect HSI model output and can be easily measured on future cover type maps (impact segment overlays).

D. Annualization of impacts. Most Federal agencies use annualization as a means to display benefits and costs, and the habitat analysis should provide data that can be directly compared to the benefit/cost analysis. The annualization process will be described in detail, although it is not the only mechanism with which to display future habitat changes. Federal projects are evaluated over a period of time that is referred to as the "life of the project" and is defined as that period between the time that the project becomes operational and the end of the project life as determined by the construction, or lead, agency. However, in many cases gains or losses in wildlife habitat may occur before the project becomes operational, and these changes should be considered in

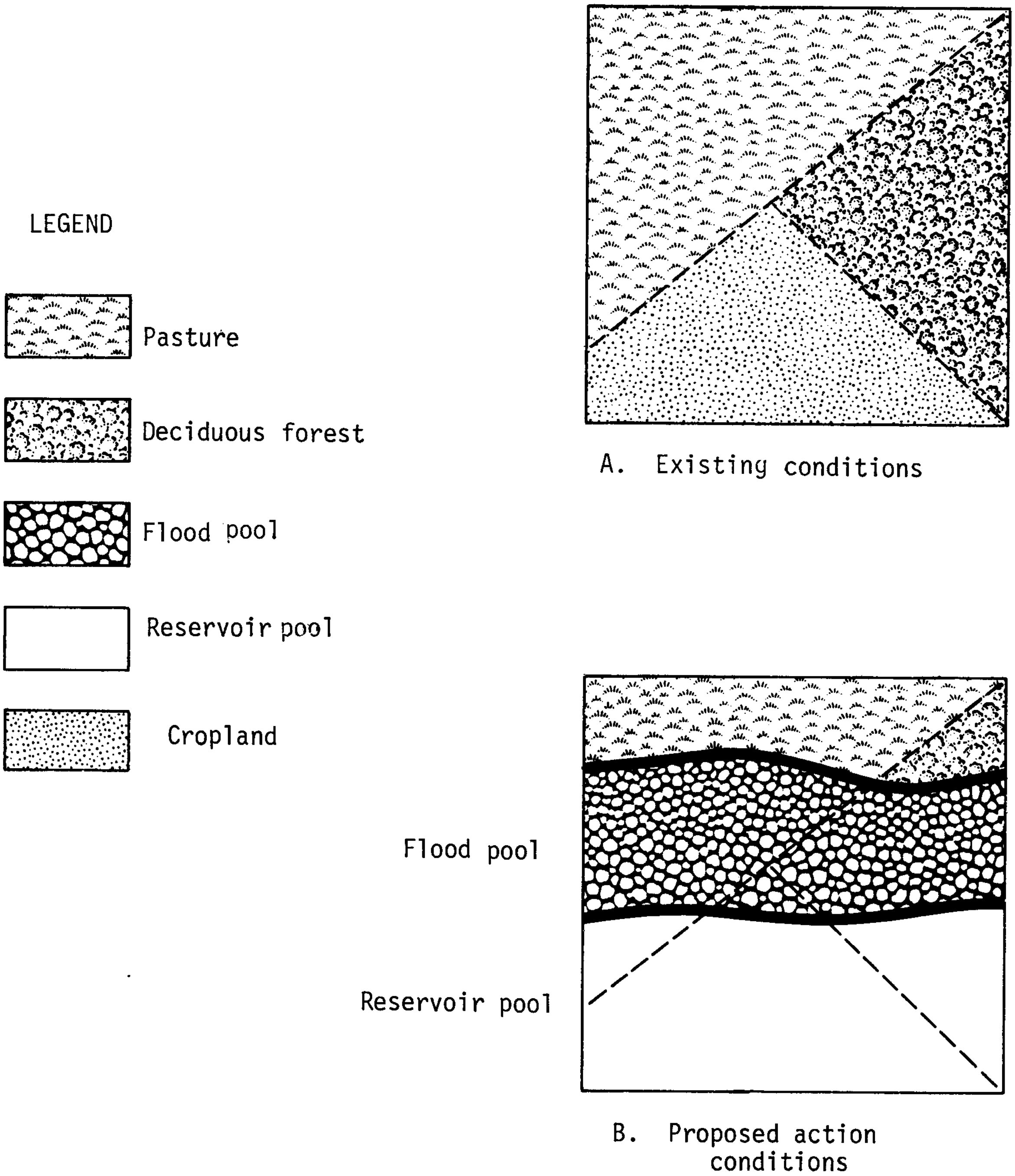

Figure 5-1. An example of a cover type map illustrating existing habitat conditions (A) and predicted conditions for target year 20 with a proposed action (B).

the impact analysis. Examples of such changes include construction impacts, implementation of a compensation plan, or other land use changes. The habitat assessment incorporates these changes by use of a period of analysis that includes prestart impacts (Figure 5-2). However, if no prestart changes are evident, then the life of the project and the period of analysis are the same.

Habitat Unit gains or losses are annualized by summing HU's across all years in the period of analysis and dividing the total (cumulative HU) by the number of years in the life of the project. In this manner prestart changes can be considered in the analysis. This calculation results in Average Annual Habitat Units (AAHU's).

The area of the shaded portion of the graph in Figure 5-3 represents the cumulative HU's for all years in the period of analysis and is calculated by summing the products of HSI and area of available habitat for all years in the period of analysis as follows:

$$\text{Cumulative HU's} = \sum_{i=1}^{p} H_i \, (A_i) \qquad (1)$$

where H_i = HSI at year i

A_i = area of available habitat at year i

p = the period of analysis (e.g., 100 years)

This is a generalized formula and requires that the HSI and area of available habitat be known for each year. However, a formula that requires only target year HSI and area estimates is:

$$\text{Cumulative HU's} = (T_2 - T_1)\left[\frac{A_1H_1 + A_2H_2}{3} + \frac{A_2H_1 + A_1H_2}{6}\right] \qquad (2)$$

where T_1 = first target year of time interval

T_2 = last target year of time interval

A_1 = area of available habitat at beginning of time interval

A_2 = area of available habitat at end of time interval

H_1 = HSI at beginning of time interval

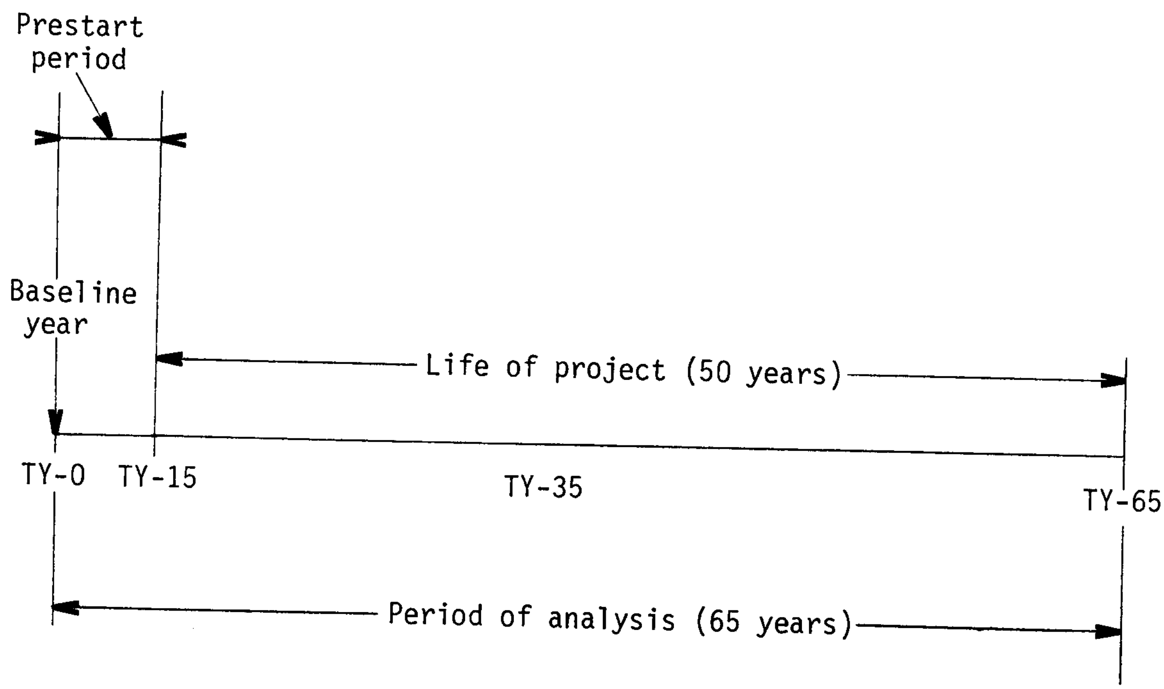

Figure 5-2. Relationship between the "life of the project" and the "period of analysis".

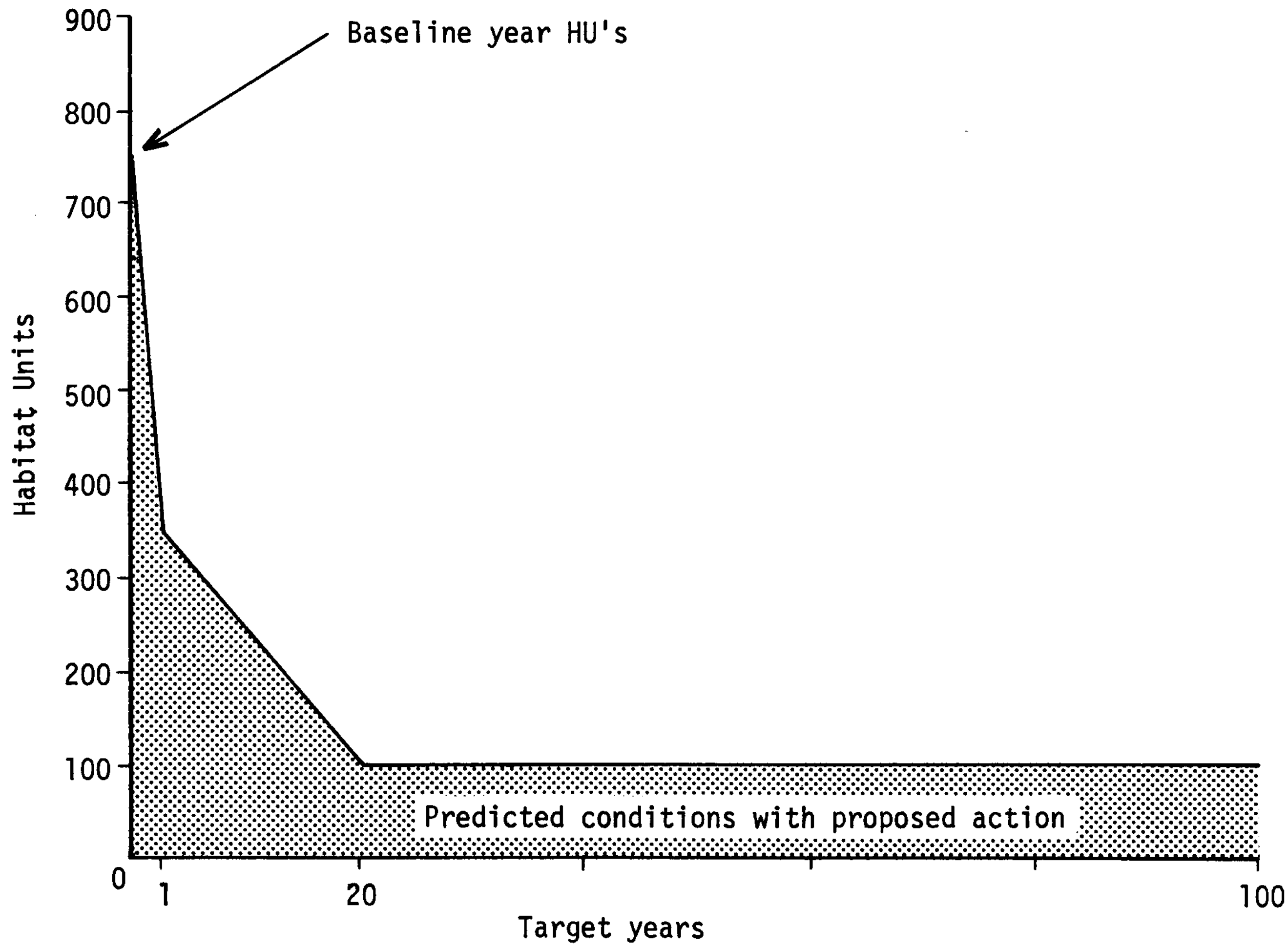

Figure 5-3. Change in white-tailed deer HU's for a hypothetical reservoir project. Shaded area represents the cumulative habitat availability with the proposed action.

H_2 = HSI at end of time interval

3 and 6 = constants derived from integration of HSI x Area for the interval between any two target years

Formula (2) is applied to the time intervals between target years. For the example in Figure 5-3, the formula must be applied for three time intervals: baseline to year 1, year 1 to year 20, and year 20 to year 100. The formula was developed to precisely calculate cumulative HU's when either HSI or area or both change over a time interval. The rate of change of HU's may be linear (either HSI or area is constant over the time interval), or curvilinear (both HSI and area change over the time interval); the formula will work in either case.

E. Calculating net impacts of a proposed action. The preceding example illustrates the calculation of AAHU's for one set of future conditions. However, determining the net impact of a proposed action requires that two future analyses be performed and compared to one another: 1) expected future conditions with the proposed action; and 2) the future without the proposed action. When comparing future conditions, the same baseline year and period of analysis must be used for each. Table 5-1 presents a hypothetical set of data for white-tailed deer habitat for the future with and the future without a proposed action.

Table 5-1. Target year habitat conditions for white-tailed deer for both the future with and the future without a proposed action.

Condition	Target year	Area (acres)	HSI value	Total HU
With proposed action	Baseline	1000	0.75	750
	1	500	0.70	350
	20	500	0.20	100
	100	500	0.20	100
Without proposed action	Baseline	1000	0.75	750
	1	1000	0.75	750
	20	900	0.60	540
	100	600	0.60	360

Using formula (2) for cumulative HU's, the AAHU calculations for the future with the proposed action are as follows:

Baseline - 1

A. $(1 - 0)\left[\frac{1000(0.75) + 500(0.70)}{3} + \frac{500(0.75) + 1000(0.70)}{6}\right] = 545.8$

Years 1-20

B. $(20 - 1)\left[\frac{500(0.70) + 500(0.20)}{3} + \frac{500(0.70) + 500(0.20)}{6}\right] = 4275$

Years 20-100

C. $(100 - 20)\left[\frac{500(0.20) + 500(0.20)}{3} + \frac{500(0.20) + 500(0.20)}{6}\right] = 8000$

Cumulative HU's = 545.8 + 4275 + 8000 = 12820.8

AAHU's = $\frac{12820.8}{100} = 128.2$

The AAHU calculations for the future without the proposed action are as follows:

Baseline - 1

A. $(1 - 0)\left[\frac{1000(0.75) + 1000(0.75)}{3} + \frac{1000(0.75) + 1000(0.75)}{6}\right] = 750$

Years 1-20

B. $(20 - 1)\left[\frac{1000(0.75) + 900(0.60)}{3} + \frac{900(0.75) + 1000(0.60)}{6}\right] = 12,208$

Years 20-100

C. $(100 - 20)\left[\frac{900(0.60) + 600(0.60)}{3} + \frac{600(0.60) + 900(0.60)}{6}\right] = 36,000$

Cumulative HU's = 750 + 12,208 + 36,000 = 48,958

AAHU's = $\frac{48,958}{100} = 489.6$

The net annual impact of the proposed action on white-tailed deer is calculated by using the formula:

$$\text{NET IMPACT} = \text{AAHU}_{\text{WITH}} - \text{AAHU}_{\text{WITHOUT}}$$

$$= 128.2 - 489.6$$

$$= -361.4 \text{ AAHU}$$

The net impact figure reflects in AAHU's the difference between future with and future without the proposed action conditions. An average of 361.4 fewer HU's will be available for deer every year during the life of the proposed action than would be available if the proposed action was not implemented. Figure 5-4 illustrates this relationship.

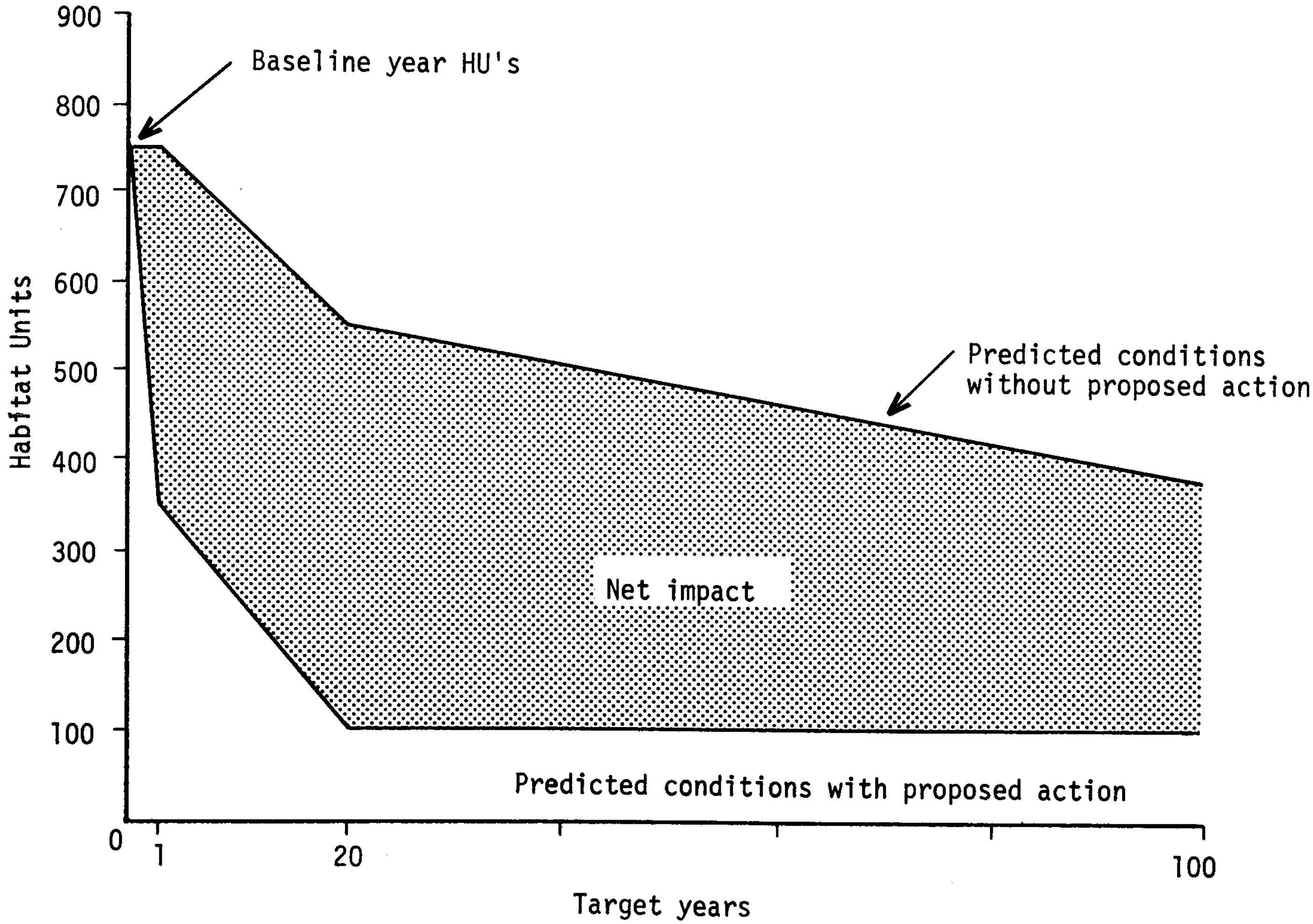

Figure 5-4. Relationship between baseline, conditions without a proposed action, conditions with a proposed action, and net impact.

6. Trade-off Analysis

The resource planner must often compare alternative proposed actions, each of which would result in HU changes for different evaluation species. Such comparisons involve value judgments which oftentimes appear subjective and unrealistic to the public or to decisionmakers. This chapter presents a methodology which uses Relative Value Indices (RVI's) to document value judgments made during a resource planning effort. This discussion of trade-off analysis does not imply that trade-offs are desirable, but rather recognizes that most proposed actions, which would alter habitat conditions, will result in both gains and losses of different wildlife resources.

Trade-off decisions, if made, must be based on identified resource management goals, administrative policy, or both. Management goals for different evaluation species can be incorporated and evaluated through the use of RVI's. In practice, RVI's are applied as weighting values to the HU's calculated for each evaluation species. These weighting values are determined by a user-defined set of socioeconomic and ecological criteria. Examples of such criteria are presented in Table 6-1. After HU's have been modified by RVI's, they no longer directly relate to habitat potential (carrying capacity) because they include value judgments.

6.1 Calculation of Relative Value Indices (RVI). The calculation of RVI values is performed in three steps: 1) defining the perceived significance of RVI criteria; 2) rating each evaluations species against each criterion; and 3) transforming the perceived significance of each criterion and each evaluation species' rating into a RVI.

The first step in RVI calculation involves the application of relative weights to each criterion to numerically define its perceived importance to the user. The suggested weighting technique is to use pairwise comparisons in which each criterion is compared to every other criterion, and a decision is made about which criterion of any pair is more important.

In the simplest application of a pairwise comparison, the options when comparing one criterion to another are to assign a value of: 1) one, which implies that the criterion is more important; 2) a zero, which implies the criterion is less important; or 3) a one-half, which implies that the criteria are of equal importance or that a decision cannot be made due to lack of information. This all or none (1 vs. 0) approach may be replaced by a proportional approach. In the latter case, the values assigned to each criterion may range from 0 to 1 with the total of each comparison equaling 1, such as 0.2 vs. 0.8 or 0.4 vs. 0.6. A dummy criterion is always included in the pairwise comparison analysis to ensure that all criteria will have some weighted value is always assigned a value of zero. When the first

Table 6-1. Examples of Relative Value Index Criteria for Evaluation Species

Criteria	Definition	Range of value
1. Abundance or scarcity	The population within the geographic area of concern relative to the other evaluation species. If population data are not available, habitat information can be substituted.	0.1 - most abundant 1.0 - least abundant
2. Vulnerability	The probability that the populations (or habitat) of the particular evaluation species will be adversely impacted in the future without condition.	0.1 - lowest probability 1.0 - highest probability
3. Replaceability	Populations of evaluation species can be increased relatively easily through creation of additional habitat or management of existing habitat, or both.	0.1 - easily increased 1.0 - little or no opportunity to increase populations
4. Aesthetic value	A general perception of the aesthetic value attributed to the evaluation species.	0.1 - low value 1.0 - high value
5. Management efforts	The amount of effort/money expended by organizations, agencies, and institutions to preserve or enhance conditions for the evaluation species.	0.1 - little or none 1.0 - large amounts by many groups

criterion has been compared to all other criteria, the second criterion is compared to the third, fourth, fifth, and others. These comparisons can be easily made in a simple matrix.

In Figure 6-1, the all or none approach is used to compare RVI criteria to obtain relative weights. Criterion 1 (scarcity) is compared to the criteria in each column. Comparison values are entered into the matrix cells. For example, if a decision is made that Criterion 1 (scarcity) is more important than Criterion 3 (replaceability), a value of 1 is placed in the cell where the scarcity row intersects the replaceability column. Then, a value of 0 is placed in the cell where the replaceability row intersects the scarcity column (see Appendix A, Form E, for further information on completing pair-wise comparison matrices).

To obtain relative weights for each criterion, all entries for each criterion are added horizontally to obtain a total. These individual criterion totals are then added vertically to obtain a grand total (Figure 6-1). The grand total is divided into each criterion total, and the resulting value becomes the relative weight of each criterion. The relative weight represents the user determined importance of each criterion (Figure 6-1).

The second step in RVI calculation involves rating each evaluation species against each criterion. This step does not involve a partitioning of values between two choices, but rather involves an individual judgment for each evaluation species and each criterion (Figure 6-2). The user must determine what value between 0.1 and 1.0 is appropriate for each evaluation species and criterion. For example, in Figure 6-2 the white-tailed deer is rated against criterion 1, scarcity. If this evaluation species was known to be extremely scarce in the area, a value of 1.0 would be assigned; if it was moderately abundant, a value in the mid-range would be assigned; and if it was extremely abundant, a value of 0.1 would be assigned. In this example, white-tailed deer were considered moderately abundant and assigned a value of 0.5 (Figure 6-2). In practice, this process would continue until all evaluation species were rated against all criteria.

The final step in RVI calculation involves multiplication of the relative weight of each criterion determined in Step 1 by the value assigned each evaluation species in Step 2, to obtain a relative value and subsequent RVI. Figure 6-3 illustrates this process. The relative weight of each RVI criterion determined by pairwise comparison (Figure 6-1) is multiplied by the value assigned each evaluation species when compared to each criterion (Figure 6-2), and a product obtained. All products for an evaluation species are then summed to obtain a relative value. The relative value of each evaluation species is then divided by the highest relative value obtained for any evaluation species to determine each RVI. In Figure 6-3, relative

Ranking criteria	Ranking criteria				Total	Relative weight
	(1) Scarcity	(2) Vuln.	(3) Replac.	Dummy		
(1) Scarcity	NA[1/]	0	1	1	2	0.33
(2) Vulnerability	1	NA	1	1	3	0.5
(3) Replaceability	0	0	NA	1	1	0.17
Dummy	0	0	0	NA	0	0.0
Grand total					6	1.0

1/ NA = Not applicable

Figure 6-1. Pairwise comparison matrix for example data to determine relative weight of each ranking criteria.

Evaluation species	Criteria		
	(1) Scarcity	(2) Vul.	(3) Replac.
White-tailed deer	0.5	0.8	0.2
Ruffed grouse	0.8	0.9	0.4
Red squirrel	0.1	0.1	0.1
Red fox	0.6	0.2	0.3
Yellow-rumped warbler	1.0	1.0	1.0

Figure 6-2. Rating each evaluation species for each criterion.

Evaluation species	Criteria (1) Scarcity 0.33	Criteria (2) Vul. 0.5	Criteria (3) Replac. 0.17	Relative value	Relative Value Index
White-tailed deer	0.5	0.8	0.2		
Product	0.17	0.4	0.03	0.6	0.6
Ruffed grouse	0.8	0.9	0.4		
Product	0.26	0.45	0.07	0.78	0.78
Red squirrel	0.1	0.1	0.1		
Product	0.03	0.05	0.02	0.10	0.10
Red fox	0.6	0.2	0.3		
Product	0.20	0.1	0.05	0.35	0.35
Yellow-rumped warbler	1.0	1.0	1.0		
Product	0.33	0.5	0.17	1.00	1.00

Figure 6-3. Evaluation species Relative Value Indices

values and RVI's for each evaluation species are identical because of the perceived importance of the yellow-rumped warbler (it has a relative value of 1.0); in actual practice, this may not be the case.

6.2 Use of RVI's. In summary, RVI can be used to adjust HU data by taking into account value judgments. After this occurs, HU's no longer are directly related to carrying capacity because value judgments have been made. However, the adjusted HU values can be used to compare base-line areas and proposed actions to determine where the greatest impact would occur. RVI can be used to adjust HU data by multiplying the net impact of a proposed action (W AAHU's) by the RVI for each evaluation species (Table 6-2). The adjusted HU values also can be used to develop alternative compensation plans (Chapter 7).

Caution is required when using RVI values in the development of compensation plans. The rules of ratio mathematics will not necessarily be upheld by this approach. Therefore a species with an RVI of 1.0 may not be precisely twice as important as a species with an RVI of 0.5. However, with some interpretation the resource manager should be able to develop a reasonably sound set of RVI scores.

Table 6-2. Aggregation of Habitat Unit data by use of Relative Value Indices.

Evaluation Species	Change in Average Annual Habitat Units	Relative Value Index	Adjusted Value (HU x RVI)
White-tailed deer	-722	0.6	-433
Ruffed grouse	-400	0.78	-312
Red squirrel	-300	0.10	-30
Red fox	-120	0.35	-42
Yellow-rumped warbler	-550	1.00	-550
Total			-1,367

7. HEP Application to Compensation Analysis

Compensation studies identify measures that would offset unavoidable HU losses due to a proposed action. Compensation occurs by applying specified management measures to existing habitat to effect a net increase in HU's. The existing habitat may or may not be located in the "impact" study area. In order to obtain compensation, the HU losses due to the proposed action must be fully offset by the specified acquisition and/or management measures.

The compensation process is depicted in Figure 7-1. A compensation study is initiated by identifying a list of evaluation species for which compensation is desired. The list may contain a single species or several species which represent an entire community.

The compensation study must have specific objectives and defined management goals. One specific objective should be to identify a list of target species for which habitat gains can be used to offset habitat losses. The list of target species does not have to be identical to the list of impacted species. The target species are partially determined by the specified compensation goal. Essentially there are three possible compensation goals.

1) <u>In-kind (no trade-off)</u>. This compensation goal is to precisely offset the HU loss for each evaluation species. Therefore, the list of target species must be identical to the list of negatively impacted species. The ideal compensation plan will provide, for each individual species, an increase in HU's equal in magnitude to the HU losses. A mathematical expression of this goal is:

$$\sum_{i=1}^{n} (M_i + I_i)^2 = 0 \qquad (3)$$

where M = Habitat Units gained through compensation for a target species

I = HU losses for same species

i = species number

n = the total number of identified species

2) <u>Equal replacement (equal trade-off)</u>. This compensation goal is to precisely offset the HU losses through a gain of an equal number of HU's. With this goal, a gain of one HU for any target species can be used to offset the loss of one HU for any evaluation species. The list of target species may or may not be identical to the list of impacted species. The mathematical expression of this goal is:

7. HEP Application to Compensation Analysis

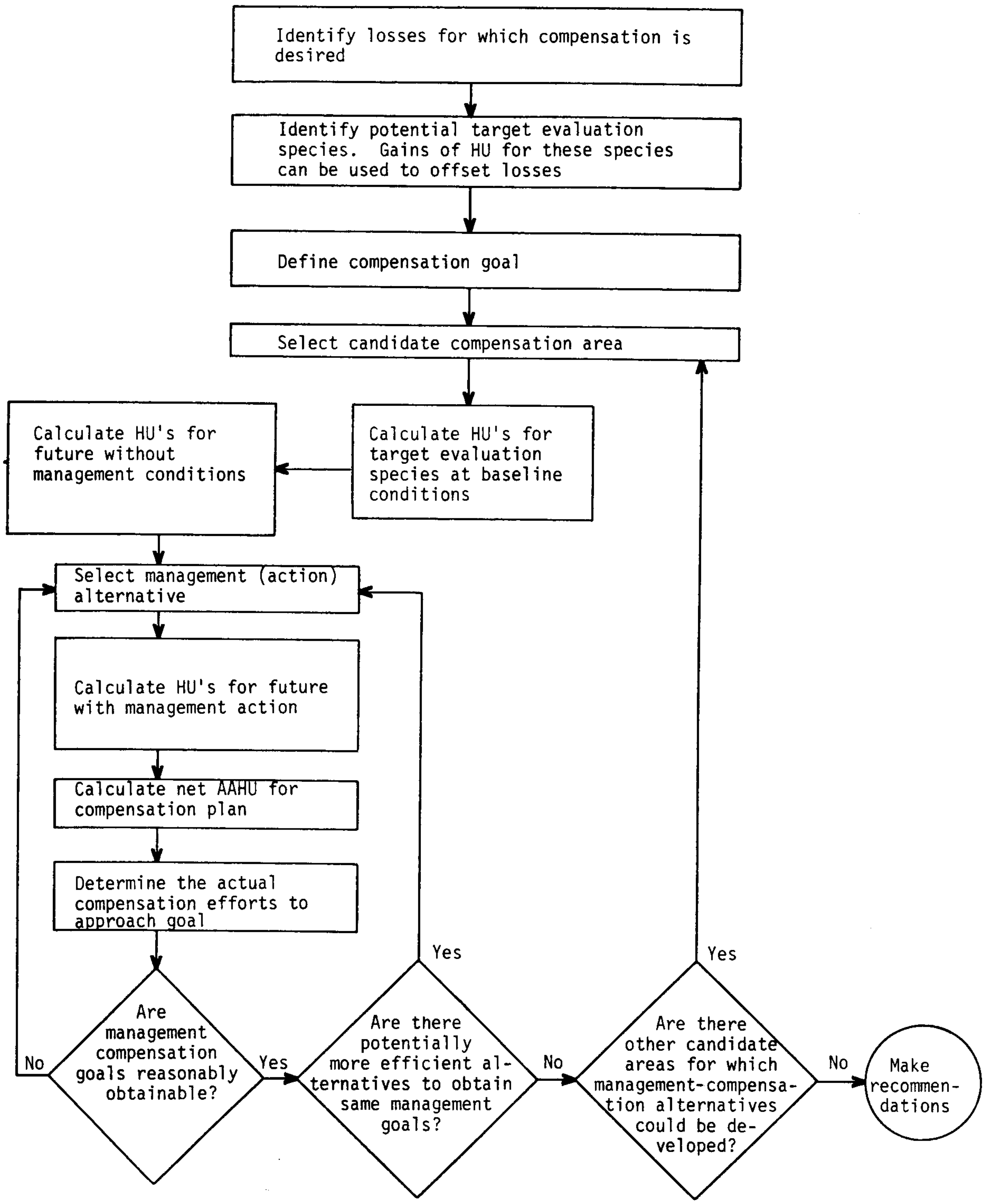

Figure 7-1. The compensation process.

$$\sum_{i=1}^{n} M_i + \sum_{i=1}^{m} I_i = 0 \qquad (4)$$

where M, I, and i conform to previous usage

n = total number of target species

m = total number of impacted species

3) Relative replacement (relative trade-off). With this goal, a gain of one HU for a target species is used to offset the loss of one HU for an evaluation species at a differential rate depending on the species involved. The trade-off rates can be defined by RVI values for each species. For example, if the RVI values for white-tailed deer and ruffed grouse are 1.0 and 0.5 respectively, one white-tailed deer HU can be used to offset two ruffed grouse HU's. The lists of target and evaluation species can differ. The mathematical expression of this goal is:

$$\sum_{i=1}^{n} M_i(RVI_i) + \sum_{i=1}^{m} I_i(RVI_i) = 0 \qquad (5)$$

where M, I, n, m, and i conform to previous usage

RVI = Relative Value Index for the species

The above compensation goals may be further clarified by specifying the type of habitat(s) that must be managed for compensation. This specification would be desirable when the loss of a specific community (e.g., a forested wetland) is to be compensated.

After the compensation objectives are set, the compensation analysis is the same as that used to identify project impacts. The steps in the process, as depicted in Figure 7-1, are to:

1) Select a candidate compensation study area. The area can be of any size but must be at least large enough to be a manageable unit for the target species. Develop a cover type map and determine the area of each cover type.

2) Conduct a baseline habitat assessment for each target species as described in Chapter 5. Baseline data for individual species in the "impact" area may be used if the candidate compensation area is similar in terms of HSI values. If this is not the case, additional field work to determine HSI's will be necessary in the compensation study area.

3) Determine the AAHU's for the compensation study area assuming no future proposed action.

4) Identify a proposed management action that will achieve specified goals. Specify the management measures (e.g., prescribed burning, selective timber cutting, and others) that will be used to increase the HU's for target species in the candidate compensation area.

5) On the compensation area, contrast the HU's without management to the HU's with proposed management measures and determine the net increase in HU's.

The process defined above is identical to the process used to assess the net impacts of any proposed action (i.e., an estimate of the net AAHU changes for a specified future action).

The next step in the process is calculating the actual size of the management area that will be required to fully offset losses. The previously stated size requirement was only that the compensation study area be large enough for a manageable unit; thus, in all probability, the area will not be large enough to meet compensation goals. The calculation of area requirements is best illustrated with an example.

The compensation data for a hypothetical study, depicted in Table 7-1, will be used to analyze the effectiveness of a proposed management plan for offsetting HU losses to five evaluation species. A 1,000 acre compensation study area was arbitrarily chosen for analysis. Based on the data in Table 7-1, compensation for each evaluation species varies from 970 acres to fully offset ruffed grouse habitat losses to 13,750 acres to fully offset yellow-rumped warbler habitat losses. The actual area that is chosen for compensation will depend on the selected goal. The area calculations are provided below for each of three goals specified earlier:

1) <u>In-kind (no trade-offs)</u>. This compensation goal specifies that compensation should precisely offset the HU losses for each species. If hypothetical management plan A fully met this goal, the areas in Table 7-1 would be the same. If 975 acres were managed, the only species that receives full habitat compensation is the ruffed grouse. If 13,750 acres are used for the management plan, habitat for every species, with the exception of the yellow-rumped warbler, will more

Table 7-1. Examples of HU data for compensation anaylsis.

Evaluation Species	Change in Habitat Units (a) Proposed Action	Change in Habitat Units (b) Management Plan A	Ratio of (a) to (b)	Area Needed for Compensation Ratio x Area*
White-tailed deer	-722	250	2.88	2,880
Ruffed grouse	-400	410	0.97	970
Red squirrel	-300	210	1.42	1,420
Red fox	-120	50	2.4	2,400
Yellow-rumped warbler	-550	40	13.75	13,750

*Size of area initially selected for analysis; 1,000 acres in this example.

than offset HU losses. There is no mid-range management area figure that would equally compensate HU losses for all species. However, there is one mid-range area that will optimize the achievement of the in-kind goal. This area minimizes the total HU over-compensations and under-compensations by a sum of squares technique and is calculated by formula (6):

$$\text{Optimum Compensation Area} = -A\left[\frac{\sum_{i=1}^{n} M_i I_i}{\sum_{i=1}^{n} M_i^2}\right] \qquad (6)$$

where M, I, i, and n conform to previous usage

A = size of candidate compensation study area

The size of the candidate compensation area selected will not affect the size of the optimum compensation area as calculated with this formula. For the example in Table 7-1, the best compensation area under management plan A is:

$$\text{Optimum Compensation Area} = -1{,}000 \quad \frac{(-722)(250) + (-400)(410) + (-300)(210) + (-120)(50) + (-550)(40)}{(250)^2 + (410)^2 + (210)^2 + (50)^2 + (40)^2}$$

$$= -1{,}000 - \frac{435{,}500}{278{,}800}$$

$$= 1{,}562 \text{ Acres}$$

With 1,562 acres used for the specified management plan A, habitat for the yellow-rumped warbler, white-tailed deer, and the red fox will not be compensated but habitat for the other species will be over-compensated. The calculated area of 1,562 acres is the best compromise figure to satisfy the compensation goal. The degree to which the compensation plan achieved the in-kind (no trade-off) goal can be calculated with formula (3) by increasing the "M" values by a factor of 1.562, i.e., 1562/1000, as follows:

$$\sum_{i=1}^{n} (M_i + I_i)^2 = [(250 \times 1.562) - (722)]^2 + [(410 \times 1.562) - (400)]^2$$

$$+ [(210 \times 1.562) - (300)]^2 + [(50 \times 1.562) - (120)]^2$$

$$+ [(40 \times 1.562) - (550)]^2$$

$$= 465{,}712.3$$

The value 465,712.3 has meaning primarily as a reference to which other alternative management plans can be compared. A more balanced plan with respect to in-kind goals would have a lower number ("0" is ideal). Other alternative management schemes should be developed if possible to more closely meet the in-kind compensation goal. The test of a better plan would be one that more equally offsets losses to each species.

2) Equal replacement (equal trade-offs). This compensation goal specifies that the gain of one HU can be used to offset the loss of one HU for any species. In the current example, the trade-offs can be between any of the five species. The actual area that should be chosen for compensation to achieve this goal is determined by:

$$\text{Compensation Area} = -A \left(\frac{\sum_{i=1}^{n} I_i}{\sum_{i=1}^{m} M_i} \right) \quad (7)$$

where A, M, I, i, m, and n conform to previous usage.

For the example, the compensation area will be:

$$\text{Compensation Area} = -1{,}000 \left(\frac{-2{,}092}{960} \right)$$

$$= -1{,}000 \ (-2.179)$$

$$= 2{,}179 \text{ Acres}$$

The equal replacement goal can always be met precisely by managing the specified area.

3) Relative replacement (relative trade-offs. This compensation goal specifies that the gain of one HU can be used to offset the loss of one HU at a differential rate depending on the species involved. The RVI values in Figure 6-3 will be used to determine the differential trade-off rates. The area needed for compensation is calculated by:

$$\text{Compensation Area} = -A \left[\frac{\sum_{i=1}^{n} I_i(RVI_i)}{\sum_{i=1}^{n} M_i(RVI_i)} \right] \quad (8)$$

where A, I, M, n, m, and i conform to previous usage

RVI = Relative Value Index for a species

For the example, the compensation area will be:

$$\text{Compensation Area} = -1{,}000 \; \frac{(-722)(0.6) + (-400)(0.78) + (-120)(0.35) + (-300)(0.1) + (-550)(1.0)}{(250)(0.6) + (410)(0.78) + (50)(0.35) + (210)(0.1) + (40)(1.0)}$$

$$= -1{,}000 \; - \frac{1367.2}{548.3}$$

$$= 2{,}493 \text{ Acres}$$

The relative replacement goal will always be met by managing the calculated area.

The foregoing compensation calculations are provided as illustrations of the use of HEP and should not imply that actual studies must conform precisely to the examples. There may be other ways that a compensation study can be performed. However, there are two factors that should always be considered. The first of these is the development of alternative compensation plans, if possible, no matter what goals are defined. The best compensation plan is one that not only meets Habitat Unit (biological) goals but also is socially acceptable and cost efficient. Determining the social acceptability of a particular plan is a function of planning and cannot be fully covered in this document. However, there are fairly simple guidelines for determining economic efficiency. Among a set of alternative compensation actions, the most economically efficient plan is the one that will meet the objectives at the lowest cost. Costs may include land acquisition, development, and continuing management costs. These cost figures should be developed for every compensation alternative that is analyzed.

The second consideration for a compensation analysis is the inclusion of species that may be negatively impacted by the management plan. The biological acceptability of a particular compensation alternative may be influenced by these losses. Potentially negative impacts of a compensation plan can be included in an analysis, even if only subjectively, and can be mathematically included using formulas (3) through (8).

8. Example of a HEP Application

The purpose of this chapter is to illustrate the use of HEP forms (Appendix A) in the development and subsequent use of HEP data in three separate but related planning activities: 1) wildlife habitat assessments, including both baseline and future conditions (Chapter 5); 2) trade-off analyses (Chapter 6); and 3) compensation analyses (Chapter 7). Example applications of these planning activities are discussed separately, in the order mentioned, to illustrate the different processes required. This order is approximately the same chronology followed in most land and water use studies because each planning activity is a prerequisite to the next. For example, baseline studies must precede impact assessments, impact assessments must precede trade-off analyses, and trade-off analyses precede compensation studies.

The example study involves a proposed alteration of a medium-sized warmwater stream segment, and the predicted alterations in adjoining terrestrial habitat resulting from hydrological changes and changes in ownership and management.

8.1 Habitat assessments. Habitat assessment using HEP involves the determination or prediction of HU's for selected evaluation species (Chapter 5). There are two steps in the assessment process: 1) baseline determinations that produce measures of HU's at one point-in-time; and 2) future assessments which project the net changes in HU's for a specified future period of time.

A. Baseline assessments. Baseline assessments are used to describe existing habitat conditions (Section 5.1) and normally involve development of a cover type map of the study area. Example cover type-area data that would be derived from a map are presented in Table 8-1.

Table 8-1. Cover types and area data for example study.

Cover type	Area (acres)
Deciduous forest	1,000
Coniferous forest	1,500
Grassland	500
Residential woodland	800
Medium-sized warmwater stream	50

Both socioeconomic and ecologically important species were selected for this example through a combination of techniques discussed in Chapter 3. Table 8-2 identifies the eight evaluation species selected for this example and indicates cover type usage by each.

Table 8-2. Example study area evaluation species and cover types.

	Cover types				
Evaluation species	Deciduous forest	Coniferous forest	Grassland	Residential woodland	Medium-sized warmwater stream
White-tailed deer	X	X	X		
Ruffed grouse	X				
Red fox	X	X	X		
Yellow-rumped warbler	X			X	
Spotfin shiner					X
Channel catfish					X
Sunfishes (*Lepomis* spp.)					X
Smallmouth bass (stream)					X

Area and HSI values for all evaluation species were determined and entered on an appropriate Form B (Figure 8-1) to determine HU's. However, in some situations, supplementary Forms A-1 and A-2 may be required in order to complete Form B.

If a suitability index is calculated at individual sample sites within each cover type, Form A-1 is used to record site scores and to calculate

8. Example of a HEP Application

1. Study
EXAMPLE

2. Proposed action
Baseline condition

3. Target year
Baseline (1980)

4. Evaluation species	5. Area of available habitat	6. Evaluation species' mean Habitat Suitability Index in available habitat	7. Habitat Units in study area
White-tailed deer	3000	0.6	1800
Ruffed grouse	1000	0.7	700
Red fox	3000	0.4	1200
Yellow-rumped warbler	1800	0.4	720
Spotfin shiner	50	0.4	20
Channel catfish	50	0.3	15
Lepomis spp.	50	0.6	30
Smallmouth bass (stream)	50	0.8	40
		Total	8. 4525

Figure 8-1. Form B displaying baseline data.

1. Study EXAMPLE	**2. Proposed action** Plan A
3. Target year Baseline	**4. Cover type or subarea** Warmwater stream-Riffle
5. Area 30	**6. Date** July 1, 1980

7. Evaluation species	**8. HSI of sample sites** 01	02	03	04	05	06	07	08	09	10	**9. Mean HSI in cover type**
Spotfin shiner	0.2	0.2	0.4	0.4							0.3
10. Site scores	0.2	0.2	0.4	0.4							**11. Mean** 0.3

Figure 8-2. Sample site HSI values for the spotfin shiner in riffle subareas. (Form A-1)

8. Example of a HEP Application

1. Study EXAMPLE	**2. Proposed action** Plan A
3. Target year Baseline	**4. Cover type or subarea** Warmwater stream-Pool
5. Area 20	**6. Date** July 1, 1980

7. Evaluation species	**8. HSI of sample sites** 01	02	03	04	05	06	07	08	09	10	**9. Mean HSI in cover type**
Spotfin shiner	0.6	0.6	0.4	0.4							0.5
10. Site scores	0.6	0.6	0.4	0.4							**11. Mean** 0.5

Figure 8-3. Sample site HSI values for the spotfin shiner in pool subareas. (Form A-1)

1. Study	2. Proposed action
EXAMPLE	Plan A
3. Target year: Baseline	4. Cover type or subarea: Deciduous forest
5. Area: 1000	6. Date: January 1980

7. Evaluation species	8. HSI of sample sites 01	02	03	04	05	06	07	08	09	10	9. Mean HSI in cover type
White-tailed deer (fall/winter food)	0.5	0.6									0.55
White-tailed deer (cover)	0.7	0.7									0.70
Red fox (reproductive)	0.3	0.5									0.40
Ruffed grouse	0.8	0.8									0.80
10. Site scores	0.57	0.65									11. Mean 0.61

Figure 8-4. Sample site HSI scores for deciduous forest. (Form A-1)

8. Example of a HEP Application

1. Study: EXAMPLE	2. Proposed action: Plan A
3. Evaluation species: Yellow-rumped warbler	4. Sample dates: January 1980 — 5. Target year: Baseline

6. Cover type or subarea	7. Area	8. Mean HSI of area	9. Available Habitat Units (Block 7 x Block 8)
Deciduous forest	1000	0.5	500
Residential woodland	800	0.3	240
	10. 1800		11. 740

12. Mean HSI for available habitat = $\frac{\text{Block 11}}{\text{Block 10}} = \frac{740}{1800} = 0.41 = 0.4$

Figure 8-5. Determination of weighted mean HSI for the yellow-rumped warbler. (Form A-2) mean suitability indices. Figures 8-2 and 8-3 illustrate the use of Form A-1 for the spotfin shiner in two different subareas of the stream cover type. Figure 8-4 illustrates the use of Form A-1 for white-tailed deer and red fox, two species for which HSI models supply only partial suitability scores (i.e., not all life requisites are supplied by deciduous forest), and the ruffed grouse.

The HSI for available habitat must be aggregated if the study area is divided into cover types or subareas for analysis purposes. The aggregation technique depends on the species habitat use patterns. If interspersion between cover types is not important, Form A-2 may be used to aggregate cover type indices. The yellow-rumped warbler is an example of a species found in two cover types--deciduous forest and residential woodland (Table 8-2). Each cover type provides all life requisites and interspersion between the two is not a significant consideration for any individual warbler. The HSI of available habitat for the yellow-rumped warbler becomes a simple weighted mean (i.e., weighted by area of each cover type) for the two cover types (Figure 8-5). Figure 8-6 represents the same process for the spotfin shiner which uses subareas of a single aquatic cover type. Area and HSI values from each subarea (Figures 8-2 and 8-3) were combined on Form A-2 to obtain a weighted mean HSI value of 0.4 for the spotfin shiner. Data obtained in this manner from Form A-2 were entered on Form B. If interspersion between cover types is important, the habitat model must contain the aggregation method.

Baseline HU data are used: 1) to make point in time comparisons; 2) as a reference point for impact assessments; or 3) for entry into the Human Use and Economic Evaluation (104 ESM). Baseline assessments may involve the comparisons of two or more areas; either the HU or HSI data for evaluation species may be used, depending upon study objectives. If, for example, the study objective is to select an area for development in order to minimize the impact on an evaluation species such as white-tailed deer, then the user would select that area with the least number of white-tailed deer HU's for development. If the study objective is to prevent losses of optimum habitat, then the user may evaluate the HSI values to determine which area is of highest quality.

When impact assessments are desired, the baseline year HU data becomes the common reference point on which future comparisons are based (Chapter 5). The relationship (assumed or proven) between HU and carrying capacity provides an entry point into Human Use and Economic Evaluation (104 ESM). Habitat Unit data, based on sustained yield and harvest rates, are used to determine upper limits of human use; an example of this relationship is found in Section 4.1, 104 ESM.

8. Example of a HEP Application

1. Study: EXAMPLE		2. Proposed action: Plan A	
3. Evaluation species: Spotfin shiner		4. Sample dates: July 1, 1980	5. Target year: Baseline

6. Cover type or subarea	7. Area	8. Mean HSI of area	9. Available Habitat Units (Block 7 x Block 8)
Pool	20	0.5	10
Riffle	30	0.3	9
	10. 50		11. 19

12. Mean HSI for available habitat = $\frac{\text{Block 11}}{\text{Block 10}} = \frac{19}{50} = 0.38 = 0.4$

Figure 8-6. Determination of weighted mean HSI for the spotfin shiner. (Form A-2)

B. Impact assessments. An impact assessment requires an analysis of the net impacts of a proposed action in terms of change in HU's through a specified period of time. Net impacts are obtained by comparing predicted future conditions without any action (e.g., current land and water use trends continue) with expected future conditions resulting from the proposed action. Therefore, two separate analyses of habitat changes through time are required.

To illustrate the impact assessment process, 7 target years were selected over a 115 year analysis period. In practice, a Form B, and appropriate supplemental Form A's, would be completed for each target year. All target year HSI and area data are compiled on a separate Form C for each evaluation species. However, only data for the smallmouth bass (stream) are presented to illustrate the calculation of AAHU's on Form C. Each evaluation species would be treated by the same process in an actual impact assessment. The proposed stream alteration is expected to affect both HSI and area for the smallmouth bass (Figure 8-7). Land acquisition, and accompanying land use changes which alter HSI, are predicted to begin at target year 1 and to continue until target year 10. Additional land use changes affecting both HSI and area are predicted to occur during target year 11. Construction during target year 15 is predicted to further alter HSI and area. Life of the project for benefit/costs analyses begins at target year 15 and continues for 100 years. Target years 50 and 115 reflect predicted changes in HSI and area that result from natural recovery processes within the stream.

The calculations on Form C (Figure 8-7) indicate that for the smallmouth bass (stream) 18.8 AAHU's would be available with the proposed action. The net impact to habitat for this evaluation species is calculated by comparing Form C data for the future with a proposed action (Figure 8-7) and the future without the proposed action using Form D. The completion of each Form C requires prior completion of the appropriate Form B's and supplemental Form A's.

Figure 8-8 presents the smallmouth bass (stream) data for future-with and future-without the proposed action, plus comparable example data for all other evaluation species obtained (in practice) from their respective Form C's. Net impacts to smallmouth bass habitat (stream) can be expressed as 26.0 AAHU's per year for the life of the project. Completion and analysis of one Form D for each proposed action under consideration completes the impact assessment. Alternative actions can be compared on: 1) the relative magnitude of HU changes for any species or set of species; and 2) the species impacted since these may differ between alternatives. When different species are impacted by different alternatives, interpretations are required.

1. Study name	2. Study area	3. Proposed action
EXAMPLE		Plan A

4. Evaluation species	5. HSI and area by target year (TY)													
	Baseline		TY 1		TY 10		TY 11		TY 15		TY 50		TY 115	
	HSI	Area	HSI	Area	HSI	Area	HSI	Area	HSI	Area	HSI	Area	HSI	Area
Smallmouth Bass (Stream)	0.8	50	0.7	50	0.6	50	0.4	48	0.2	45	0.3	46	0.4	48

6.

$$\text{Total number of HU years} = (T_2 - T_1)\left[\left(\frac{A_2H_2 + A_1H_1}{3}\right) + \left(\frac{A_1H_2 + A_2H_1}{6}\right)\right]$$

where: T_1 = First year of time interval
T_2 = Last year of time interval
A_1 = Habitat area at first target year
A_2 = Habitat area at second target year
H_1 = HSI at the first target year
H_2 = HSI at the second target year

	Calculations	7. Habitat Units between target years
6A.	$1\left[\left(\frac{50 \times 0.7 + 50 \times 0.8}{3}\right) + \left(\frac{50 \times 0.7 + 50 \times 0.8}{6}\right)\right] = 1\ (25 + 12.5)$	37.5
6B.	$9\left[\left(\frac{50 \times 0.6 + 50 \times 0.7}{3}\right) + \left(\frac{50 \times 0.6 + 50 \times 0.7}{6}\right)\right] = 9\ (21.7 + 10.8)$	292.5
6C.	$1\left[\left(\frac{48 \times 0.4 + 50 \times 0.6}{3}\right) + \left(\frac{50 \times 0.4 + 48 \times 0.6}{6}\right)\right] = 1\ (16.4 + 8.1)$	24.5
6D.	$4\left[\left(\frac{45 \times 0.2 + 48 \times 0.4}{3}\right) + \left(\frac{48 \times 0.2 + 45 \times 0.4}{6}\right)\right] = 4\ (9.4 + 4.6)$	56.0
6E.	Total from additional target years 399 + 1072.5	1471.5
	Sum of Habitat Units	8. 1882.0

9. Life of project	10.
100	Block 8 ÷ Block 9 18.8

Figure 8-7. Determination of AAHU's available for a smallmouth bass (stream) under plan A. (Form C)

8. Example of a HEP Application

1. Study EXAMPLE	2. Proposed action Plan A		
3. Evaluation species	**4. Average Annual Habitat Units**		**5. Change in** Average Annual Habitat Units
	a. Future with action	**b. Future without action**	
White-tailed deer	1278	2000	-722
Ruffed grouse	300	700	-400
Red fox	1000	1120	-120
Yellow-rumped warbler	150	700	-550
Spotfin shiner	25	22	+3
Channel catfish	13	16.5	-3.5
Lepomis spp.	26	33	-7.0
Smallmouth bass (stream)	18.8	44.8	-26.0
		Total	**6.** -1825.5

Figure 8-8. Determination of net change in AAHU's resulting from plan A. (Form D)

The use of HEP focuses on evaluation species. However, these data can be projected from evaluation species to a larger segment of the wildlife community if adequate care is given to the species selection process (Chapter 3). For example, if habitat for a species representing a particular guild is altered, inferences about other species within that guild can be made.

8.2 Trade-off analysis. Trade-off analysis is an optional treatment of data, and occurs after Forms B through D, plus any necessary Forms A-1 and A-2, are completed for the proposed action being analyzed. Examples of completed Forms A-1 through D were provided earlier and are not repeated here. Forms E, F, and G-1 are completed for those evaluation species for which a trade-off analysis is desired. In this example, the decision was made to undertake a separate trade-off analysis for terrestrial and aquatic species. Therefore, two sets of Forms E, F, and G-1, one for terrestrial and one for aquatic species, would be completed. Figures 8-9, 8-10, and 8-11 illustrate the use of Forms E, F, and G-1, respectively, for terrestrial evaluation species only.

Trade-off analyses combine value judgments (RVI's) with a biological index (AAHU's) to display relative AAHU's. These relative AAHU's display, from the standpoint of user-defined socioeconomic and environmental criteria, which evaluation species are most impacted. In this example, the greatest impact, in terms of relative AAHU's, would occur to the yellow-rumped warbler (Figure 8-11).

8.3 Compensation analysis. Compensation studies identify measures that would offset unavoidable HU losses due to a proposed land use action. This section illustrates the evaluation of four management plans to meet specific compensation goals (Chapter 7). Prior completion of Forms B (plus supplementary Forms A-1 and A-2 if appropriate), C, and D are required for the proposed action (Plan A) and each management plan.

A. Goal 1. In-kind Compensation. In-kind compensation is intended to replace losses of AAHU's, for an evaluation species, with equal gains in AAHU's for that same species. Goal 1 (in-kind, no trade-off) may be impossible to completely achieve; it is usually necessary to develop several plans to determine which one best meets this compensation goal. Two plans, Stream Management Plan 1 (Figure 8-12) and Stream Management Plan 2 (Figure 8-13), are provided for management of the stream to meet Goal 1. Both plans are based on a decision by the user to only attempt to compensate in-kind (Goal 1, Chapter 7). Relative Value Indices are not used in this case; Form H is completed by using data from a Form D for the proposed action, and a Form D for the management plan under evaluation. When trying to meet Goal 1, only species negatively impacted by the proposed action are listed on Form H. If Stream Management Plan 1 is implemented, 24 acres of stream habitat would

1. Study

EXAMPLE (Terrestrial only)

2. Ranking criteria	3. Ranking criteria (1)	(2)	(3)	(4)	(5)	(6)	Dummy	4. Sum	6. Relative weight
(1) Scarcity	XXXXX	0	1				1.0	2.0	0.33
(2) Vulnerability	1	XXXXX	1				1.0	3.0	0.50
(3) Replaceability	0	0	XXXXX				1.0	1.0	0.17
(4)				XXXXX			1.0		
(5)					XXXXX		1.0		
(6)						XXXXX	1.0		
Dummy criteria	0	0	0	0	0	0	XXXXX	0.0	0.00
								5. Total 6.0	7. Total weight 1.0

Figure 8-9. Example ranking of RVI criteria for terrestrial Evaluation Species. (Form E)

8. Example of a HEP Application

1. Study EXAMPLE

2. Evaluation species	3. Relative weight of ranking criteria						5. Relative value	6. Relative Value Index
	1	2	3	4	5	6		
	0.33	0.50	0.17					
	4. Relative importance of each ranking criterion to each evaluation species.							
White-tailed deer	0.5	0.8	0.2					
Product	0.17	0.4	0.03				0.60	0.60
Ruffed grouse	0.8	0.9	0.4					
Product	0.26	0.45	0.07				0.78	0.78
Red fox	0.6	0.2	0.3					
Product	0.2	0.10	0.05				0.35	0.35
Yellow-rumped warbler	1.0	1.0	1.0					
Product	0.33	0.50	0.17				1.0	1.0
Product								
Product								
Product								
Product								
Product								
Product								

Figure 8-10. Determination of RVI's for terrestrial Evaluation Species. (Form F)

8. Example of a HEP Application

1. **Study** EXAMPLE		2. **Proposed action** Plan A	
3. **Evaluation species**	4. **Change in** Average Annual Habitat Units	5. **Relative** Value Indices	6. **Change in relative** Average Annual Habitat Units
White-tailed deer	-722	0.6	-433
Ruffed grouse	-400	0.78	-312
Red fox	-120	0.35	- 42
Yellow-rumped warbler	-550	1.000	-550
		Total change in relative Average Annual Habitat Units.	7. -1337

Figure 8-11. Determination of change in relative AAHU's for terrestrial Evaluation Species. (Form G-1)

8. Example of a HEP Application

1. Study: EXAMPLE	2. Proposed action to be compensated: Plan A
3. Proposed management plan: Stream Management Plan 1	4. Size of management area: 20 Acres

5. Evaluation species	6. Change in (total or relative) Average Annual Habitat Units due to proposed action	7. Change in (total or relative) Average Annual Habitat Units due to management plan	8. Column 7 squared	9. Ratio of Column 6 to Column 7	10. Column 6 times Column 7	11. Evaluation species compensation need (Block 4 x Column 9)
Channel catfish	- 3.5	+ 2.0	4.0	1.75	- 7.0	35
Lepomis spp.	- 7.0	+ 1.0	1.0	7.00	- 7.0	140
Smallmouth bass (stream)	-26.0	+22.0	484.0	1.182	-572.0	23.64
	12. Total -36.5	13. Total 25.0	15. Total 489		16. Total -586.0	17. Compensation requirement 24 Acres
	14. Ratio of 12 to 13 -1.46					

Figure 8-12. Calculation of compensation requirements for plan A under stream management plan 1. (Form H)

8. Example of a HEP Application

1. Study	2. Proposed action to be compensated
EXAMPLE	Plan A

3. Proposed management plan	4. Size of management area
Stream Management Plan 2	30 Acres

5. Evaluation species	6. Change in (total or relative) Average Annual Habitat Units due to proposed action	7. Change in (total or relative) Average Annual Habitat Units due to management plan	8. Column 7 squared	9. Ratio of Column 6 to Column 7	10. Column 6 times Column 7	11. Evaluation species compensation need (Block 4 x Column 9)
Channel catfish	- 3.5	+ 1.0	1.0	3.5	- 3.5	105.00
Lepomis spp.	- 7.0	+ 4.0	16.0	1.75	- 28.0	52.50
Smallmouth bass (stream)	-26.0	+19.0	361.0	1.368	-494.0	41.04
[illegible]	[illegible]	[illegible]				

12. Total	13. Total	15. Total	16. Total	17. Compensation requirement
-36.5	24.0	378	-525.5	42

14. Ratio of 12 to 13
-1.52

Figure 8-13. Calculation of compensation requirements for plan A under stream management plan 2. (Form H)

need to be managed to best meet Goal 1 (Figure 8-12, Block 17). If Stream Management Plan 2 is implemented, 42 acres of stream habitat would need to be managed according to the management plan to best meet Goal 1 (Figure 8-13, Block 17). The degree to which either of these plans meet Goal 1 can be determined by application of formula (3), Chapter 7. The number of HU's gained through compensation for an evaluation species, the M_i in formula (3), is obtained by multiplying the value in Column 7, Form H, by the ratio of the compensation requirement (Form H, Block 17) divided by the size of the management area (Form H, Block 4). The application of formula (3), to data presented in Figures 8-12 and 8-13, results in a value of 35 for Stream Management Plan 1 and a value of 7 for Stream Management Plan 2. These values indicate that Stream Management Plan 2 best meets the management goal of in-kind compensation because the value of 7 is closer to zero than is the value of 35.

B. Goal 2. Equal replacement. This goal specifies that the gain of one AAHU can be used to offset the loss of one AAHU for any evaluation species. Relative Value Indices are not required for these analyses. Prior completion of Form B is required for both the proposed action and the management plans.

Stream Management Plan 3 was designed to meet Goal 2. Evaluation species with either gains or losses in AAHU's, as a result of implementation of the proposed action, are listed on Form H (Figure 8-14). Analyzing these data with the use of Form H results in the determination that the management of 33.5 acres (Block 17, Figure 8-14) would be required to fully meet Goal 2.

C. Goal 3. Relative replacement. Relative replacement makes use of RVI's to determine the relative values of evaluation species for compensation (see Chapter 7). Reservoir Management Plan 1 was designed to compensate for losses of stream habitat by management of smallmouth bass habitat in the reservoir by control of water levels during the spawning season. A Form D is needed for Reservoir Management Plan 1, in addition to Forms B, C, and D for the proposed action. Note that Columns 4a and 4b of Form D (Figure 8-15) lack data for certain species because the HSI models used for those species were unable to detect changes in HSI as a result of the implementation of the management plan. In such circumstances, it is unnecessary to complete Form B and C for the management plan for those evaluation species.

Reservoir Management Plan 1 was developed to meet the goal of relative replacement; therefore RVI's must be determined for the evaluation species by use of Forms E and F (Figures 8-16 and 8-17, respectively). The RVI's from Form F (Figure 8-17) are entered on Form G-1 for both the proposed action and management plan (Figures 8-18 and 8-19) to adjust the AAHU's data to accommodate socioeconomic and environmental considerations. After the AAHU's have been adjusted, they no longer directly represent carrying capacity.

8. Example of a HEP Application

1. Study: EXAMPLE	2. Proposed action to be compensated: Plan A
3. Proposed management plan: Stream Management Plan 3	4. Size of management area: 20 Acres

5. Evaluation species	6. Change in (total or relative) Average Annual Habitat Units due to proposed action	7. Change in (total or relative) Average Annual Habitat Units due to management plan	8. Column 7 squared	9. Ratio of Column 6 to Column 7	10. Column 6 times Column 7	11. Evaluation species compensation need (Block 4 x Column 9)
Spotfin shiner	+ 3.0	0.0	0	NA	0	NA
Channel catfish	- 3.5	2.0	4.0	1.75	- 7.0	35
Lepomis spp.	- 7.0	1.0	1.0	7.00	- 7.0	140
Smallmouth bass (stream)	-26.0	22.0	484.0	1.182	-572.0	24
	12. Total -33.5	13. Total 25.0	15. Total 489		16. Total -586	17. Compensation requirement -(20)x(-1.34) =26.8
	14. Ratio of 12 to 13 -1.34					

Figure 8-14. Calculation of compensation requirements for plan A under stream management plan 3. (Form H)

1. Study EXAMPLE		**2. Proposed action** Reservoir Management Plan 1	
3. Evaluation species	**4. Average** Annual Habitat Units		**5. Change in** Average Annual Habitat Units
	a. Future with action	**b. Future without action**	
Spotfin shiner	-	-	0
Channel catfish	-	-	0
Lepomis spp.	-	-	0
Smallmouth bass (stream)	-	-	0
Smallmouth bass (reservoir)	2,000	1,950	+50
		Total	**6.** +50

Figure 8-15. Determination of net change in AAHU's resulting from reservoir management plan 1. (Form D)

1. **Study**

EXAMPLE - (Aquatic only)

2. **Ranking criteria**	3. Ranking criteria (1)	(2)	(3)	(4)	(5)	(6)	Dummy	4. **Sum**	6. **Relative weight**
(1) Regional scarcity	XXXXX	1.0	1.0	1.0	1.0		1.0	5.0	0.333
(2) Vulnerability	0.0	XXXXX	0.5	1.0	1.0		1.0	3.5	0.233
(3) Replaceability	0.0	0.5	XXXXX	1.0	1.0		1.0	3.5	0.233
(4) Aesthetic value	0.0	0.0	0.0	XXXXX	0.0		1.0	1.0	0.067
(5) Management efforts	0.0	0.0	0.0	1.0	XXXXX		1.0	2.0	0.133
(6)						XXXXX	1.0		
Dummy criteria	0	0	0	0	0	0	XXXXX	0.0	0.00
								5. **Total** 15.0	7. **Total weight** 0.999

Figure 8-16. Example ranking of RVI criteria for aquatic Evaluation Species. (Form E)

1. Study EXAMPLE								
2. Evaluation species	**3. Relative weight of ranking criteria**						**5. Relative value**	**6. Relati Value Index**
	1	2	3	4	5	6		
	0.333	0.233	0.233	0.067	0.133			
	4. Relative importance of each ranking criterion to each evaluation species.							
Spotfin shiner	0.5	0.2	0.1	0.1	0.1			
Product	0.167	0.047	0.023	0.007	0.013		0.257	0.257
Channel catfish	0.4	0.6	0.5	0.2	0.7			
Product	0.133	0.14	0.117	0.013	0.093		0.496	0.496
Lepomis spp.	0.1	0.1	0.3	0.4	0.4			
Product	0.033	0.023	0.07	0.027	0.053		0.206	0.206
Smallmouth bass (stream)	1.0	1.0	1.0	1.0	1.0			
Product	0.333	0.233	0.233	0.067	0.133		0.999	1.0
Smallmouth bass (reservoir)	0.3	0.3	0.2	0.2	0.5			
Product	0.1	0.07	0.047	0.013	0.067		0.297	0.297
Product								
Product								
Product								
Product								

Figure 8-17. Determination of RVI's for aquatic Evaluation Species. (Form F)

1. **Study** EXAMPLE		2. **Proposed action** Plan A	
3. **Evaluation species**	4. **Change in** Average Annual Habitat Units	5. **Relative** Value Indices	6. **Change in relative** Average Annual Habitat Units
Spotfin shiner	+3.0	0.257	+0.771
Channel catfish	-3.5	0.496	-1.736
Lepomis spp.	-7.0	0.206	-1.442
Smallmouth bass (stream)	-26.0	1.0	-26.0
Smallmouth bass (reservoir)	0.0	0.297	0.0
		Total change in relative Average Annual Habitat Units.	7. -28.4

Figure 8-18. Determination of change in relative AAHU's for aquatic Evaluation Species under plan A. (Form G-1)

1. Study EXAMPLE		**2. Proposed action** Reservoir Management Plan 1	
3. Evaluation species	**4. Change in** Average Annual Habitat Units	**5. Relative** Value Indices	**6. Change in relative** Average Annual Habitat Units
Spotfin shiner	0	0.257	0.0
Channel catfish	0	0.496	0.0
Lepomis spp.	0	0.206	0.0
Smallmouth bass (stream)	0	1.0	0.0
Smallmouth bass (reservoir)	+50	0.297	+14.85
		Total change in relative Average Annual Habitat Units.	**7.** +14.85

Figure 8-19. Determination of change in relative AAHU's for aquatic Evaluation Species under reservoir management plan 1. (Form G-1)

The data developed in Form G-1 are then entered on Form H (Figure 8-20) to determine compensation. Note that in this proposed compensation plan, all evaluation species AAHU's lost in the stream are compensated by a gain in smallmouth bass (reservoir) AAHU's at a rate adjusted by the Relative Value Indices. Data developed by use of Form H for Reservoir Management Plan 1 indicate that a reservoir of 1,912 acres would need to be managed, according to the management plan, to compensate for losses of habitat for all evaluation species. Other management plans for the reservoir could increase or decrease the acreage required for management, or the user may determine that 100% compensation is not required. The final evaluation of the plan should reflect these considerations.

The examples in this chapter only provide an analysis of how "good" a selected plan is, based on a certain set of assumptions, and how many acres of habitat are needed to best meet the compensation goal. Use of HEP requires that the assumptions be stated. Final choice of compensation goals would depend on socioeconomic, environmental, and administrative considerations inherent to each proposed action.

8. Example of a HEP Application

1. Study EXAMPLE	2. Proposed action to be compensated Plan A
3. Proposed management plan Reservoir Management Plan 1	4. Size of management area 1,000

5. Evaluation species	6. Change in (total or relative) Average Annual Habitat Units due to proposed action	7. Change in (total or relative) Average Annual Habitat Units due to management plan	8. Column 7 squared	9. Ratio of Column 6 to Column 7	10. Column 6 times Column 7	11. Evaluation species compensation need (Block 4 x Column 9)
Spotfin shiner	+0.771	0	0	NA	0	NA
Channel catfish	-1.736	0	0	NA	0	NA
Lepomis spp.	-1.442	0	0	NA	0	NA
Smallmouth bass (stream)	-26.0	0	0	NA	0	NA
Smallmouth bass (reservoir)	0.0	+14.85	220.5	0	0	0
	12. Total -28.4	13. Total 14.85	15. Total 220.5		16. Total 0	17. Compensation requirement -(1000)(-1.912) 1,912
	14. Ratio of 12 to 13 -1.912					

Figure 8-20. Calculation of compensation area requirements for a proposed action with a proposed management plan. (Form H)

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Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.1 General instructions. The following forms are designed to aid in the performance of three types of assessment activities: 1) calculation of Habitat Units for one or more study areas under existing conditions or future conditions, or both, caused by one or more proposed actions (Figure A-1); 2) comparison of the change in Habitat Units for one or more different study areas due to one or more proposed actions (Figure A-2); and 3) calculation of how large an area needs to be managed to compensate for losses in productivity of selected evaluation species (Figure A-3).

Before attempting to use these forms, determine which of the three types of activities is (are) pertinent to the study, then use the proper flow chart(s) (Figures A-1, A-2, and A-3) to determine which forms need to be completed. Special terms used on the forms are defined in the Glossary. All three types of assessment activities require the completion of Form B. The completion of a Form B may require the completion of Forms A-1 and A-2 as documentation of how the values on Form B were derived. Figure A-4 illustrates when the completion of Forms A-1 and A-2 is necessary.

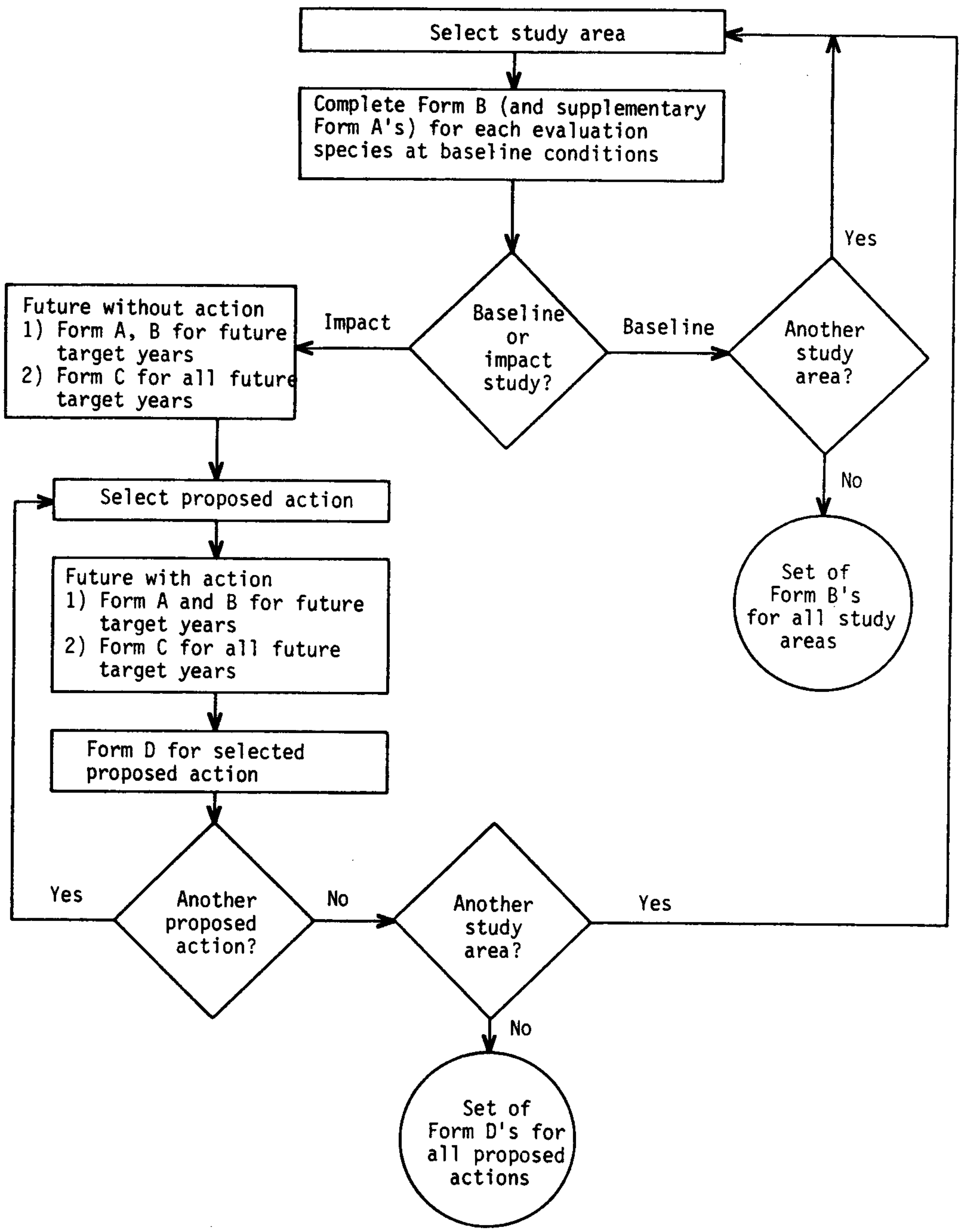

Figure A-1. Calculation of HU's for different study areas and proposed actions (Forms A, B, C, and D).

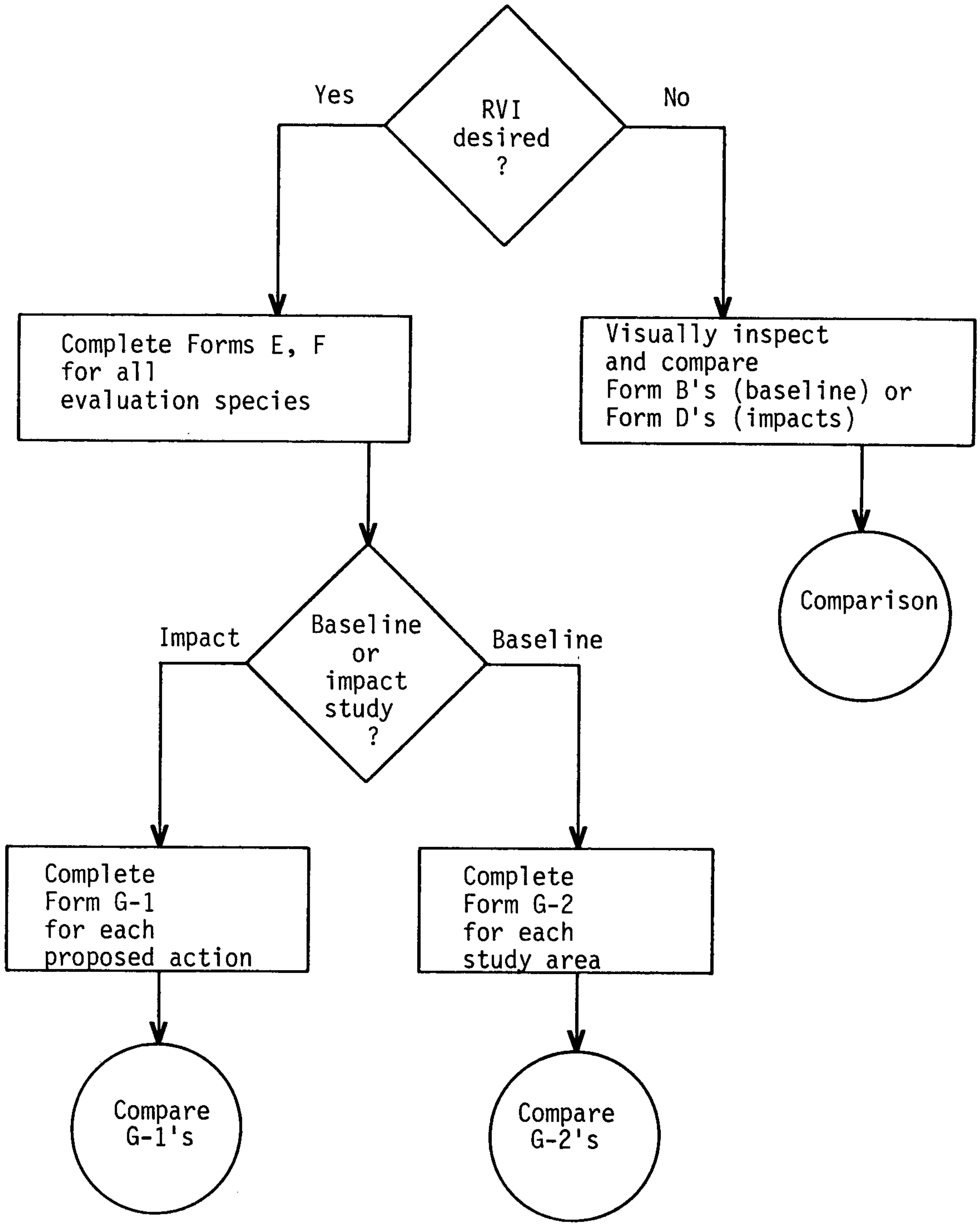

Figure A-2. Comparison of HU's for different study areas and proposed actions (Forms E, F, G-1, and G-2).

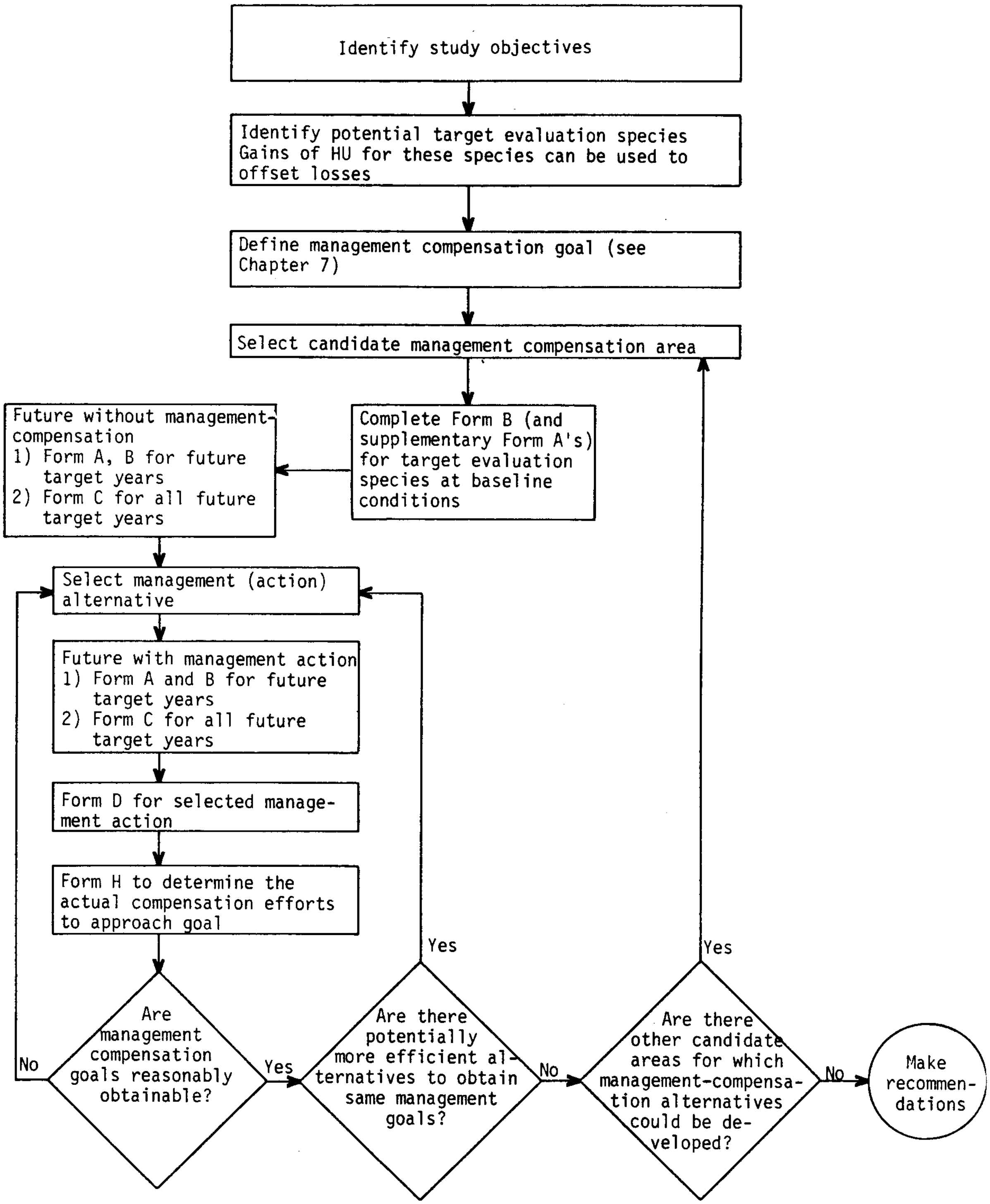

Figure A-3. The compensation process

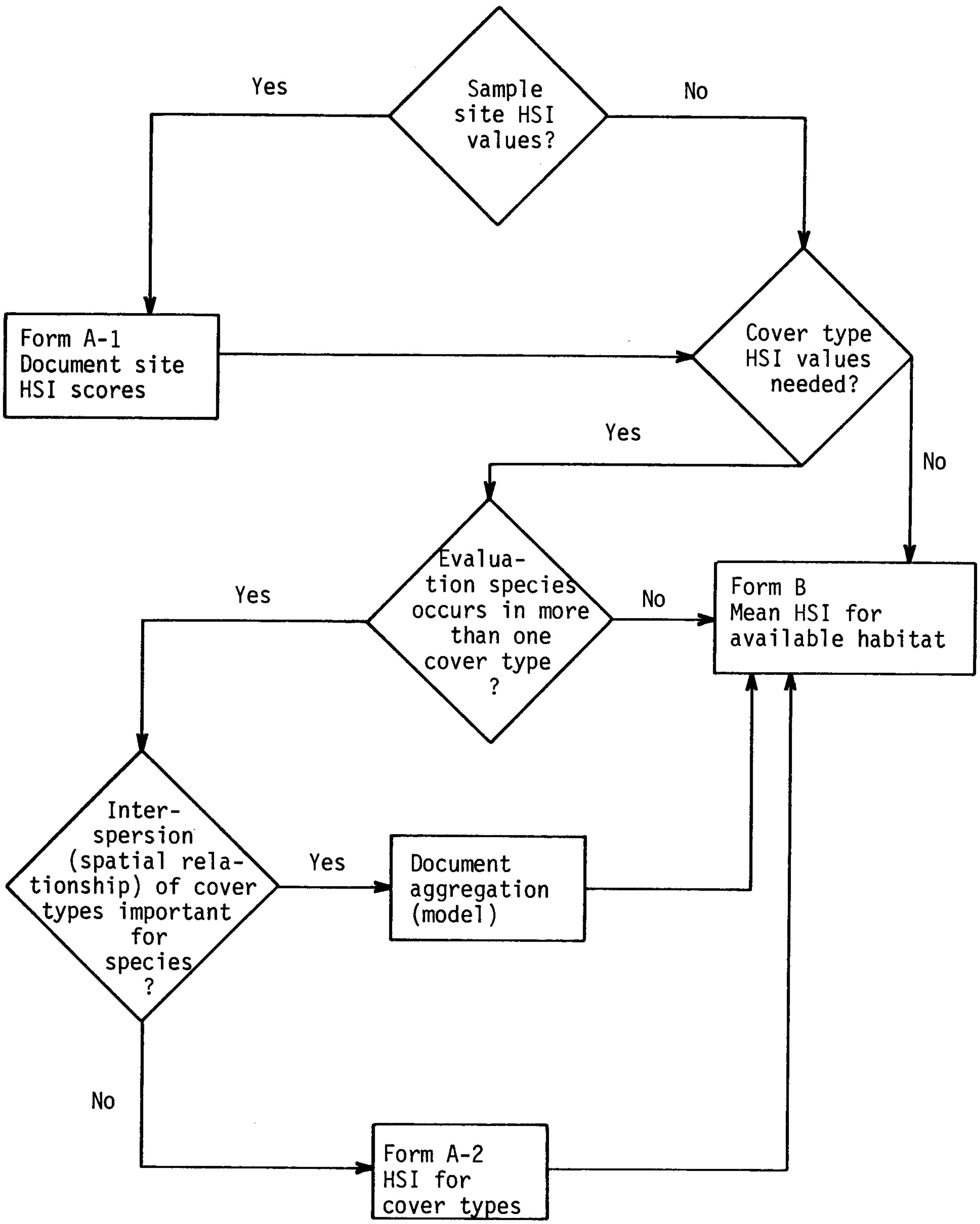

Figure A-4. Determination of when to use Forms A-1 and A-2.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.2 Form A-1. Display of HSI's for individual sample sites by cover type.

A. Purpose. Form A-1 displays evaluation species HSI's at individual sample sites in a cover type or subarea so that a mean HSI for all sample sites in the cover type can be calculated. The form also serves as a permanent record of sample site HSI values for statistical analysis of data. A complete HSI model must be developed to aggregate the mean cover type HSI's (displayed on this form) into an evaluation species HSI before entry into Form B, Column 6.

B. Instructions.

(1) Block 1. Enter the study name and the specific study area to which the form applies. For a large study, there may be several specific study areas that are evaluated.

(2) Block 2. Enter the name of the proposed action to be evaluated.

(3) Block 3. Enter the target year for which the form will apply. If the study area does not vary with the proposed action, it may be possible to evaluate the baseline for all proposed actions on the same form.

(4) Block 4. Enter the name of the cover type. If the cover type has been divided into more than one subarea for sampling purposes, enter the subarea number. A different form must be completed for each subarea within a cover type.

(5) Block 5. Enter the area for the cover type or subarea listed in Block 4.

(6) Block 6. Enter the date the sampling was performed. If the form is being used to describe future conditions, enter the date the form was completed.

(7) Column 7. Enter the name of each evaluation species for which sample site HSI's were calculated for the cover type listed.

(8) Column 8. List sample site HSI's for each Column 7 entry. Additional forms may be required if more than 10 sample sites are used.

(9) Column 9. Enter the arithmetic mean of the individual sample site HSI's for each evaluation species.

(10) Block 10. Sum vertically all the HSI figures in each sample site to obtain the site score. The purpose of this step is to recognize the HSI of the sample site. The calculation is optional and is not used as the basis of other calculations.

(11) Block 11. Enter the arithmetic mean of the numbers listed in Column 9. The purpose of this step is to recognize the average HSI for the cover type in question at the given target year. This calculation is optional and is not used as the basis for other calculations.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

1. Study	2. Proposed action
3. Target year	4. Cover type or subarea
5. Area	6. Date

7. Evaluation species	8. HSI of sample sites										9. Mean HSI in cover type or subarea
	01	02	03	04	05	06	07	08	09	10	
10. Site scores											11. Mean

Form A-1. Display of HSI's for individual sample sites by cover type.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.3 Form A-2. Determination of evaluation species mean HSI in available habitat.

A. Purpose. This form is used to calculate the evaluation species mean HSI in available habitat from evaluation species HSI's for cover types or subareas. The form cannot be completed unless the HSI models used in all cover types or subareas listed on Form A-2 (Column 6) had the same denominator (i.e., definition of optimum habitat) in the HSI equation.

B. Instructions.

(1) Block 1. Enter the name of the study and the specific study area being evaluated.

(2) Block 2. Enter the name of the proposed action being evaluated.

(3) Block 3. Enter the name of the evaluation species.

(4) Block 4. Enter the date the sampling was performed. If future conditions are being evaluated, enter the date of form completion.

(5) Block 5. Enter the target year.

(6) Column 6. List the different cover types or subareas into which available habitat was divided.

(7) Column 7. Enter the area of each Column 6 entry.

(8) Column 8. Enter the evaluation species mean HSI for each cover type or subarea listed in Column 6. This value is derived by entering habitat variable measurements from each cover type into an HSI model.

(9) Column 9. For each cover type or subarea, multiply the number in Column 7 by the number in Column 8 and enter the product.

(10) Block 10. Enter the sum of the numbers in Column 7. This is the area of available habitat (for entry in Form B, Column 5).

(11) Block 11. Enter the sum of the numbers (HU's) listed in Column 9 and enter the result. This is the total number of HU's in the study area available to the evaluation species.

(12) Block 12. Divide the total number of HU's in Block 11 by the area of available habitat in Block 10 and enter the quotient. This is the evaluation species mean HSI in available habitat in the study area (for entry in Form B, Column 6).

Appendix A. Forms for Use in the Habitat Evaluation Procedures

1. Study		2. Proposed action	
3. Evaluation species		4. Sample dates	5. Target year

6. Cover type or subarea	7. Area	8. Mean HSI of area	9. Available Habitat Units (Block 7 x Block 8)
	10.		11.

12. Mean HSI for available habitat = $\frac{\text{Block 11}}{\text{Block 10}}$ = ________

Form A-2. Determination of Evaluation Species mean HSI in available habitat.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.4 Form B. Habitat Units in the study area for selected target year and proposed action.

A. Purpose. This form is used to calculate the total number of HU's in a specific study area for a specific proposed action and a specific target year. A target year may be baseline or any future year. Form B is not a field form; it is used after the data necessary to utilize an HSI model have been collected. Field data must be documented and may be displayed on Forms A-1, A-2, or a user developed data sheet. Figure A-4 provides guidance on when Forms A-1 and A-2 must be completed in addition to Form B.

B. Instructions.

(1) Block 1. Enter the study name, specific study area, and size of the specific study area to which the form applies. For a large study, there may be several specific study areas that are evaluated.

(2) Block 2. Enter the name of the proposed action to be analyzed. If evaluating conditions without a specific proposed action, enter the word "none".

(3) Block 3. Enter the target year.

(4) Column 4. List the evaluation species chosen.

(5) Column 5. Enter the area of available habitat for each evaluation species in the study area.

(6) Column 6. Enter the evaluation species mean HSI in the available habitat. This number is determined by applying an HSI model (HSI model development is described in Sections 4.1 and 4.2) to the areas of available habitat listed in Column 5. The data used to derive this value must be documented. Figure A-4 is used to determine if Form A-1 or Form A-2, or both, must be completed before completing this column.

(7) Column 7. For each evaluation species listed, multiply the number in Column 5 by the number in Column 6 and enter the product. This is the number of HU's in the study area for the listed evaluation species at the specific target year.

(8) Block 8. Enter the sum of all Column 7 entries. This represents the total number of HU's available on the study area at the specific target year for all evaluation species listed.

1. Study

2. Proposed action

3. Target year

4. Evaluation species	5. Area of available habitat	6. Evaluation species mean Habitat Suitability Index in available habitat	7. Habitat Units in study area
		Total	8.

Form B. Habitat Units in the study area for selected target year and proposed action.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.5 Form C. Calculation of Average Annual Habitat Units available for an evaluation species under a proposed action.

A. Purpose. This form is used to calculate the AAHU's for an evaluation species over a specified time period (see Chapters 4 and 5 for discussion). In general, annualization uses HSI and area figures predicted for specific points in time to estimate the average number of HU's available over the specified time frame. Some types of analyses do not require annualized data; for those projects point-in-time analyses for the target years are used instead of annualized data (see Chapters 4 and 5).

B. Instructions. Prepare one Form C for each evaluation species being considered under each proposed action.

(1) Block 1. Enter the study name.

(2) Block 2. Enter the name and size of the geographic area of the study.

(3) Block 3. Enter the name of the proposed action to which this form will apply. If evaluating the future without a specific proposed action, enter the word "none".

(4) Block 4. Enter the name of the evaluation species.

(5) Block 5. For the evaluation species listed in Block 4, enter the HSI in available habitat (from Form B, Column 6) and area of available habitat (from Form B, Column 5) for the baseline and each target year (TY). Target years should be identified relative to the baseline year (TY-0).

(6) Block 6. Calculate the HU's that will be present between successive target years by using the formula in Block 6.

(7) Blocks 6A-6E. Calculate the number of HU's in the interval between the baseline year (TY-0) and target year one (TY-1) using the formula provided and enter the answer in Column 7. The first calculation will *always* involve a 1-year time interval. For example, if baseline conditions are determined in 1980, and will remain stable until 1985 when changes due to a proposed action will start to occur, TY-0 would be 1985, and TY-1 would correspond to 1986. Conditions from 1980 to 1985 are not included in the annualization calculation. Continue by calculating the HU's between each successive pair of target years and enter the results of the calculation in Column 7. For example, if the target years TY-0, TY-1, TY-20, and TY-100 are used, calculations are performed between TY-0 and

TY-1, TY-1 and TY-20, and TY-20 and TY-100. If additional space is required because of a larger number of target years, perform the calculations on an additional page and enter the total of all additional calculations on Line 6E.

(8) Column 7. Enter the results of the calculations from Block 6.

(9) Block 8. Sum the numbers in Column 7.

(10) Block 9. Enter the number of years of the life of the project (see Chapters 4 and 5). This number does not always equal the number of target years. This number must be entered even when evaluating the proposed action "no project".

(11) Block 10. Divide the number in Block 8 by the number of years in Block 9 and enter the quotient.

1. Study name	2. Study area	3. Proposed action

4. Evaluation species	5. HSI and area by target year (TY)													
	Baseline(TYO)		TY1		TY		TY		TY		TY		TY	
	HSI	Area	HSI	Area	HSI	Area	HSI	Area	HSI	Area	HSI	Area	HSI	Area

6.

$$\text{Total number of HU years} = (T_2 - T_1)\left[\left(\frac{A_1H_1 + A_2H_2}{3}\right) + \left(\frac{A_2H_1 + A_1H_2}{6}\right)\right]$$

where: T_1 = First year of time interval
T_2 = Last year of time interval
A_1 = Habitat area at first target year
A_2 = Habitat area at second target year
H_1 = HSI at the first target year
H_2 = HSI at the second target year

Calculations	7. Habitat Units between target years
6A.	
6B.	
6C.	
6D.	
6E. Total from additional target years	
Sum of Habitat Units	8.

9. Life of project	10. Average Annual HU's Block 8 ÷ Block 9

Form C. Calculation of Average Annual Habitat Units available for an Evaluation Species under a proposed action.

A.6 Form D. Determination of net change in Average Annual Habitat Units of future condition with an action vs. future without the action.

A. Purpose. This form is used to determine the change in AAHU's attributable to a proposed action. The same length of time must be used for both the with and without proposed action calculations.

B. Instructions. Complete a Form D for each proposed action being considered.

(1) Block 1. Enter the study name and the name of the specific study area being evaluated.

(2) Block 2. Enter the name of the proposed action being evaluated.

(3) Column 3. List vertically the evaluation species being considered. (Collectively these will be the same evaluation species entered in each Form C, Block 4 for the proposed action).

(4) Column 4A. For each evaluation species, list AAHU's available with this proposed action. These figures are from the Form C's (Block 10) completed for each evaluation species and the proposed action listed in Block 2.

(5) Column 4B. For each evaluation species, list AAHU's available without the proposed action listed in Block 2. For each evaluation species, the number is entered from the Form C (Block 10) with "none" entered in Block 3.

(6) Column 5. For each evaluation species, subtract the number in Column 4B from the number in Column 4A and enter the result. This number represents the change in AAHU's, for an evaluation species, attributable to the proposed action.

(7) Block 6. Sum the values in Column 5 for each evaluation species. This represents the total change in AAHU's, for all evaluation species, attributable to the proposed action.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

1. Study		2. Proposed action	
3. Evaluation species	4. Average Annual Habitat Units		5. Change in Average Annual Habitat Units
	a. Future with action	b. Future without action	
		Total	6.

Form D. Determination of net change in Average Annual Habitat Units of future condition with an action vs. future without the action.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.7 General instructions for Forms E, F, G-1, G-2. Calculation of Relative Value Indices (RVI) and their application to the Habitat Unit changes attributable to a proposed action.

A. Purpose. The purpose of these forms is to facilitate the consideration of factors not considered in determining HU's for the evaluation species in a HEP analysis. These factors can include various environmental, social, and economic criteria believed to be important to a future land or water use decision. Identified criteria are weighted according to their importance when compared to the other criteria. Each evaluation species is then ranked according to each criterion. The result of this process is a Relative Value Index (RVI) which is simply an index for quantifying importance of each evaluation species relative to the other evaluation species. This index is applied as a weighting factor to the Habitat Units of the evaluation species to yield a "relative Habitat Unit" figure. The relative HU figures are used to compare alternative study areas and proposed actions.

B. Instructions. Specific instructions are available with each of the forms in this package. One Form E and one Form F generally will be required for each HEP application when RVI computations are desired, a Form G-1 will be required for each proposed action, and a Form G-2 will be required for each study area. Forms E, F, G-1, and G-2 should not be completed if the evaluation team decides that all evaluation species should be considered equally important in the HEP analysis. In that case, the numbers from Form D, Column 5, are used without modification.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.8 Form E. Pairwise comparison matrix for determining relative weights for each ranking criterion.

A. Purpose. The form is used to determine the relative weights of the criteria that will be used to modify HU's for different evaluation species. Weights are established through a pairwise comparison which compares each criterion to every other criterion. In each comparison, a decision is made about which criterion of any pair is the more important. The more important of the pair is assigned a value between 0.5 and 1.0. The values for both criteria in a comparison must total 1.0 (Chapter 6). A dummy criterion is included in the pairwise comparison analysis to ensure that all real criteria will have some weighting value. The dummy criterion is always assigned a zero relative weight in Column 6.

B. Instructions. Only one Form E is required for a study. Each ranking criterion must be compared to every other criterion. If more than six criteria are used, an expanded form must be prepared with additional rows and columns for the additional criteria.

(1) Block 1. Enter the study name.

(2) Column 2. List the ranking criteria to be used. These criteria are selected according to the guidelines presented in Chapter 6. A dummy criterion has already been included in the form to assure that each real criterion will receive some value.

(3) Block 3. The matrix formed by Column 2 and Block 3 has rows and columns corresponding to each criterion. There is one row and one column for each criterion. Each matrix cell can be identified by a row and column descriptor. For example, matrix cell (2,3) is in Row 2 and Column 3, and corresponds to ranking criteria (2) and (3). There are two cells common to each pair of criteria. For example, the cell formed by (3) and (2) also corresponds to the cell formed by criteria (2) and (3); the sum of the entries in these common cells must total 1.0.

Compare the criterion in each row to all columns to the right of the cells with the X's.

Assign the criterion in the row a value of 0.5 if it is equally important to the criterion in the column, a 0.0 to 0.5 if it is less important, and a 0.5 to 1.0 if it is more important. For example, if criterion (1) is of equal importance to criterion (2), then enter 0.5 in matrix cell (1,2).

Then locate the other common cell (this cell will always be to the left of the cells with X's) and enter the difference between the first value and 1.0. For the example, 1.0-0.5 or 0.5 would be entered in cell (2,1).

(4) Column 4. Horizontally sum the row values of Block 3, including the dummy value, and enter in the appropriate space.

(5) Block 5. Total all Column 4 entries and enter the result in Block 5.

(6) Column 6. Divide each number in Column 4 by the total in Block 5 and enter the result in Column 6. This number represents the relative weight of a specific criterion to the other criteria.

(7) Block 7. Total the relative weights vertically and enter in Block 7. The total should equal 1, but may be slightly less than or greater than 1 due to rounding error. This step is provided as a check to ensure that the relative weights are calculated correctly (See Chapter 6 for discussion).

1. Study

2. Ranking criteria	3. Ranking criteria (1)	(2)	(3)	(4)	(5)	(6)	Dummy	4. Sum	6. Relative weight
(1)	XXXXX						1.0		
(2)		XXXXX					1.0		
(3)			XXXXX				1.0		
(4)				XXXXX			1.0		
(5)					XXXXX		1.0		
(6)						XXXXX	1.0		
Dummy criterion	0	0	0	0	0	0	XXXXX	0.0	0.00
								5. Total	7. Total weight

Form E. Pairwise comparison matrix for determining relative weights for each ranking criterion.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.9 Form F. Determination of Relative Value Indices for each evaluation species.

A. Purpose. The purpose of this form is to develop a Relative Value Index (RVI) for each evaluation species. The RVI values are determined by combining the relative weights for ranking criteria (Form E, Column 6) with relative importance of each ranking criterion to each evaluation species.

B. Instructions. Enough Form F's must be completed so that an RVI is calculated for each evaluation species. If there are more than six ranking criteria (Form E), a new Form F must be developed with enough additional columns for each ranking criteria.

(1) Block 1. Enter the study name.

(2) Column 2. List vertically the evaluation species being ranked above each dashed line.

(3) Block 3. List horizontally, under the appropriate number, the relative weight (Form E, Column 6) of the ranking criteria listed on Form E, Column 2.

(4) Column 4. On a scale of 0.1 to 1, rank each evaluation species on how well it meets each ranking criterion and enter that rank in the appropriate column above the dashed line. For information on what to consider in this ranking, and how a number is applied, see Chapter 6. For each evaluation species and each ranking criterion, multiply the relative weight of the ranking criterion (Block 3) by the number above the dashed line in Column 4 and enter the product below the dashed line.

(5) Column 5. Sum horizontally the products for each evaluation species and enter the total in the appropriate space in Column 5.

(6) Column 6. For each evaluation species, divide the number in Column 5 by the highest number that appears in Column 5 for any evaluation species and enter the quotient in the space provided.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

1. Study

2. Evaluation species	**3. Relative weight of ranking criteria**						**5. Relative value**	**6. Relative Value Index**
	1	2	3	4	5	6		
	4. Relative importance of each ranking criterion to each evaluation species.							
Product								
Product								
Product								
Product								
Product								
Product								
Product								
Product								
Product								
Product								

Form F. Determination of Relative Value Indices for each Evaluation Species.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.10 Form G-1. Calculation of total change in relative Average Annual Habitat Units due to a proposed action.

A. Purpose. This form provides a format for using the change in AAHU's (Form D, Column 5) and RVI's (Form F, Column 6) to calculate a single measure of impact for a proposed action (change in relative AAHU's).

B. Instructions.

(1) Block 1. Enter the study name and the study area being evaluated.

(2) Block 2. Enter the name of the proposed action being evaluated, corresponding to that entered in Block 2, Form D.

(3) Column 3. List vertically the evaluation species utilized in the analysis. Use additional forms if necessary.

(4) Column 4. Enter the change in AAHU's from Form D, Column 5, in the appropriate space for each evaluation species.

(5) Column 5. List the RVI from Form F, Column 6, for each evaluation species.

(6) Column 6. Multiply the change in AAHU's (Column 4) by the RVI (Column 5) for each evaluation species and enter the product in the appropriate space in Column 6.

(7) Block 7. Sum the change in relative AAHU's (Column 6) and enter the total in Block 7. If more than one Form G-1 was used, complete Block 7 for the last Form G-1 only, summing Column 6 data from all Form G-1's. This single figure is a measure of how the total impacts of the proposed action listed in Block 2 are believed to be perceived by the public or decisionmakers.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

1. Study		**2. Proposed action**	
3. Evaluation species	**4. Change in** Average Annual Habitat Units	**5. Relative** Value Indices	**6. Change in relative** Average Annual Habitat Units
		Total change in relative Average Annual Habitat Units.	7.

Form G-1. Calculation of total change in relative Average Annual Habitat Units due to a proposed action.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.11 Form G-2. Calculation of total relative Habitat Units.

A. Purpose. This form combines estimates of HU's in a study area (Form B, Column 7), for different evaluation species at baseline conditions, with a subjective estimate of the importance of individual evaluation species to the decisionmaking process. The result is a single number (total relative Habitat Units) which describes how "valuable" the study area is perceived to be. If all evaluation species are believed to be equally important in the decisionmaking process, Form G-2 is not used. A different Form G-2 must be completed for each study area.

B. Instructions.

(1) Block 1. Enter the name of the study and study area being evaluated.

(2) Column 2. List the evaluation species for which Form B's were completed for each study area. Use additional forms if necessary.

(3) Column 3. Enter the number of HU's in the study area (Form B, Column 7) for each evaluation species. The only target year used is baseline.

(4) Column 4. Enter the RVI calculated for each evaluation species (from Form F, Column 6).

(5) Column 5. For each evaluation species, multiply the number in Column 3 by the number in Column 4 and enter the product.

(6) Block 6. Total all Column 5 entries from all Form G-2's used for this proposed action and enter the result in Block 6 of the last form used.

1. Study			
2. Evaluation species	3. Habitat Units	4. Relative Value Indices	5. Total Relative Habitat Units (Column 3 x Column 4)
		Total relative Habitat Units	6.

Form G-2. Calculation of total relative Habitat Units.

Appendix A. Forms for Use in the Habitat Evaluation Procedures

A.12 Form H. Calculation of compensation area requirements for a proposed action with a proposed management plan.

A. Purpose. This form is used to calculate the compensation requirements for a proposed action using a selected management plan. An analysis of future without management conditions on the study area is required. The result of treating the management plan as a proposed action is that one can determine, for each evaluation species, the change in AAHU's (Form D, Column 5) or the change in relative AAHU's (Form G-1, Block 6), attributable to the management of the area. The size of a management area needed to compensate for impacts due to a proposed action is then calculated by use of the formula appropriate to the selected compensation goal (Chapter 7).

B. Instructions. Complete a Form H for each combination of proposed actions and management plans that need to be evaluated.

(1) Block 1. Enter the study name and the name of the study area being evaluated.

(2) Block 2. Enter the name of the proposed action for which compensation is desired.

(3) Block 3. Enter the name of the proposed management plan.

(4) Block 4. Enter the size of the area covered by the proposed management plan listed in Block 3.

(5) Column 5. List the evaluation species which will be used to determine compensation requirement. Use additional forms as needed. If Goal 1 (Chapter 7) is the compensation goal, only list those evaluation species with a loss in total or relative AAHU's due to the proposed action.

(6) Column 6. Enter the appropriate change in relative AAHU's for each evaluation species (from Form G-1, Block 6) if Form G-1 was used to evaluate the proposed action; or

Enter the appropriate change in AAHU's for each evaluation species (from Form D, Column 5) if Form G-1 was not used to evaluate the proposed action.

(7) Column 7. Enter the corresponding information for the management scheme that was entered in Column 6 for the proposed action.

(8) Column 8. Enter the square of the number entered in Column 7.

(9) Column 9. For each evaluation species, divide the number in Column 6 (which may be a negative number) by the number in Column 7 and enter the absolute value (i.e., ignore the minus sign) of the result.

(10) Column 10. For each evaluation species, multiply the number in Column 6 by the number in Column 7 and enter the result.

(11) Column 11. For each evaluation species with a negative number in Column 6, multiply the number in Column 9 by the number in Block 4 and enter the result. This number (compensation need) is the size of an area, with the same habitat characteristics as the management area evaluated, that would have to be managed to compensate for losses of the evaluation species' habitat due to the proposed action. For each evaluation species with a positive number in Column 6, enter a 0.

Blocks 12 through 17 are completed using data for all evaluation species. If more than one form is needed to list all evaluation species, Blocks 12 through 17 are only completed on the last form, using data from all appropriate forms.

(12) Block 12. Enter the sum of all Column 6 entries.

(13) Block 13. Enter the sum of all Column 7 entries.

(14) Block 14. Divide the number in Block 12 by the number in Block 13 and enter the result.

(15) Block 15. Enter the sum of all Column 8 entries.

(16) Block 16. Enter the sum of all Column 10 entries.

(17) Block 17. The method used to complete this block depends on the compensation goal. These goals are explained in detail in Chapter 7:

Goal 1. In-kind (no trade-off). The number in Block 17 is determined by the following formula: Compensation requirement equals

$$(\text{Number in Block 4}) \times \frac{-\text{Number in Block 16}}{\text{Number in Block 15}} .$$

Goals 2 & 3. Equal replacement (equal trade-off) and relative replacement (relative trade-off). The number in Block 17 is determined by the following formula: Compensation requirement equals (Number in Block 4) x (-Number in Block 14).

Appendix A. Forms for Use in the Habitat Evaluation Procedures

1. Study	2. Proposed action to be compensated
3. Proposed management plan	4. Size of management area

5. Evaluation species	6. Change in (total or relative) Average Annual Habitat Units due to proposed action	7. Change in (total or relative) Average Annual Habitat Units due to management plan	8. Column 7 squared	9. Ratio of Column 6 to Column 7	10. Column 6 times Column 7	11. Evaluation species compensation need (Block 4 x Column 9)
	12. Total	13. Total	15 Total		16 Total	17. Compensation requirement
	14. Ratio of 12 to 13					

Form H. Calculation of compensation area requirements for a proposed action with a proposed management plan.

Appendix B. Guidelines for Development of Sampling

B.1 Introduction. Two commonly stated objectives of parametric statistics are to: 1) estimate population parameters; and 2) test hypotheses concerning these parameters (Freese 1974). In HEP, the primary concern is to estimate habitat parameters. How well the estimate approximates the true value depends on the accuracy of the sample data, the sample size, and the natural variability of the sampled parameter. Clearly then, a statistically valid sampling design can increase both accuracy and efficiency in estimating HSI model variables. Carefully designed sampling also permits inferences to be drawn from specific ecological measurements with a specified degree of confidence.

The purposes of this Appendix are to emphasize the need for sound statistical considerations and to discuss basic statistical concepts that apply to sampling design and to estimating HSI model variables. It is beyond the scope of this discussion to present detailed explanations of experimental design or sophisticated statistical procedures. A professional statistician should be consulted early and frequently during a HEP study to obtain assistance with site specific problems associated with sampling HSI model variables.

B.2 Basic statistical concepts. The term population is used in statistics to denote the aggregate from which a sample is chosen. It is the collection, or set, of individuals, objects, or measurements whose properties are to be analyzed. The concept of population is the most fundamental in statistics. The population of interest, or target population, is considered well defined only when its membership is specified. Biologists typically think of a population as a collection of individuals of a particular species. However, a statistical population can be a collection of measurements, such as a set of tree heights or estimates of canopy closure. The population usually referred to in a HEP analysis is the set of all available habitat for each evaluation species in the study area.

Sample refers to a subset of the target population and consists of individuals, objects, or measurements selected from the population by some specified procedure. The purpose of a sample is to accurately estimate population parameters without having to measure the entire population. A parameter is a measurable characteristic that describes the entire population while a statistic is a measurable characteristic of a sample. A statistic is used to estimate the population parameter of interest. Two statistics, the mean and the standard deviation, play an important role in procedures for parameter estimation in HEP. In ecological studies, there are no "typical" objects. Assume, for example, that some characteristic is measured n times from a population. The n measures can be denoted by: $x_1, x_2, x_3, \ldots, x_n$. An average describes the condition about which these measurements fluctuate. The sample mean ($\bar{x}$) is used to mark that central location. The mean is computed by:

$$\bar{x} = \frac{\Sigma x}{n} = \frac{x_1 + x_2 + x_3 + \ldots + x_n}{n} \quad (B1)$$

where x = the observed value of each unit in the sample

n = the number of units in the sample

Variation around, or dispersion of sample units about the mean is characterized by the standard deviation. The standard deviation (s) is calculated by the following formula:

$$s = \sqrt{\frac{\Sigma (x-\bar{x})^2}{n-1}}$$

where $(x-\bar{x})$ = the deviation of each observed unit value from the sample mean.

The standard deviation is more easily computed by:

$$s = \sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n-1}} \quad (B2)$$

There are three types of variability pertinent to sampling problems in a HEP analysis:

A. Temporal variability. Ecological units are often time-related. Parameters assume different values according to diurnal, seasonal, or annual fluctuations and, thus, vary cyclically over time. Sampling must coincide with the time periods identified in the HSI models. Literature reviews or pilot studies may be required to determine the status of temporal variability and its effects in the study area.

B. Spatial variability. Ecological units can also vary spatially. Parameters assume different values according to changes over area. Cover types are used to reduce spatial variability by identifying areas of land and water which exhibit some degree of homogeneity of physical, chemical, and biological characteristics.

C. Measurement variability. The possibility of error is present whenever measurement occurs. It is useful to distinguish between two different types of errors that may be present in statistical measurements: 1) random errors; and 2) systematic errors. These are strongly related to the concepts of precision and accuracy, respectively.

(1) Random errors. Random errors arise from a large number of uncontrollable factors and can be conveniently described by the term "chance." For example, if repeated samples are drawn from a statistical population, the mean will differ somewhat from sample to sample. These sample means tend to distribute themselves around the "true" population mean. The difference between the sample mean and the "true" parameter mean is referred to as a random error because the complete collection of factors that could explain the difference is unknown. The size of the differences between the sample value and the corresponding population value are indications of reliability or precision. The magnitude of a random error usually decreases as sample size is increased. Larger samples are preferred over smaller ones because the results are generally more reliable (i.e., more precise).

(2) Systematic error or bias. Systematic error is due to problems in the measurement process. These errors may also occur in the planning stage or before or after the collection of data. Causes of systematic errors include faulty sampling design, incorrect use of measurement instruments, and deficiencies in the measurement techniques being employed. The potential presence of systematic error or bias in HEP applications may be illustrated by a simple example. Suppose several stream velocity measurements were made at the same spot in a stream with a current meter. If the meter was not calibrated correctly, there would be a systematic error present in each of the measurements. Note that the observations may have been very precise in the sense that all measurements were very close to that of every other measurement. However, no measurement would have been accurate; accuracy refers to how closely the sample statistic estimates the true parameter value.

(3) Summary. Each individual measurement may be viewed as the sum of three components: 1) the true parameter value; 2) systematic error; and 3) random error. This relationship is stated in equation form below:

$$\text{Individual measurement} = \text{True parameter value} + \text{Systematic error} + \text{Random error} \qquad \text{(B3)}$$

Accuracy of individual measurements is increased when systematic and random errors are minimized. Systematic error is avoided by proper instrument calibration, proper statistical sampling design, and use of proper measurement techniques. Random error can be minimized by increasing the sample size. The remaining sections in this Appendix discuss how statistical sampling procedures aid in increasing accuracy for parameter estimation.

B.3 Considerations in population sampling. The field sampling plan in a HEP analysis should be designed to describe the condition of the habitat for each evaluation species. The objective of sampling is to estimate the important ecological parameters as defined by each HSI model. The following discussion is pertinent to HSI models that require the measurement of parameters from several sample sites within each cover type. Other types of HSI models may require other sampling designs (Chapter 4).

Sampling design commonly has two objectives: 1) definition of the rules or operations used to sample members of the population; and 2) estimation of sample statistics (Kish 1965). The following discussion is limited to the first objective. The second objective is dictated by the specific HSI model used and the assorted parameter estimation techniques and statistics to be used.

Statistical sampling theory plays a minor role in some of the steps in accomplishing this first objective. These steps include the following: 1) the determination of the population of available habitat for each evaluation species; 2) the selection of the types of variables to be measured for each HSI model; 3) the selection of the measurement methods and techniques, including size and type of sample site needed to collect the data; and 4) the planning and organization of field work. Although these topics are not discussed in detail here, their importance should not be ignored. Sampling demands attention to all phases and poor work in one phase may ruin a sample in which everything else is done well.

Application of sampling theory increases efficiency in estimating target population statistics. Sampling theory aids in the development of sample selection and of estimation methods that provide, at the lowest possible cost, estimates that are precise enough for the given purpose.

A. Defining the population of interest. The population of all available habitat should be defined for each evaluation species in the study area. Habitat use can vary greatly between evaluation species. Ideally, a separate sampling strategy should be designed and applied for each evaluation species. Realistically, however, this usually is not feasible. Therefore, the sampling design should be based on the evaluation species identified as most important to the study.

The sample population should be the same as the population of interest. Sometimes, however, the sample population is more restricted than the population of interest. Restricted sampling occurs when all of an area is not available for sampling, and sample sites are selected only from the areas that are available for sampling. Restricted sampling is used, for example, when difficulty of access or ownership excludes the sampling of some portion of the study area. Inferences drawn from a restricted sample only apply to the sampled population and cannot be readily applied to the population of interest.

B. Distribution of sample sites. The variability of ecological phenomena makes it necessary for sampling to be conducted in such a way that each sample statistic approximates its true parameter value. Three sampling designs often employed in HEP applications are: 1) simple random sampling; 2) stratified random sampling; and 3) systematic sampling. Restricted sampling, described earlier, may be applied to any of these three sampling designs.

(1) Simple random sampling. Simple random sampling occurs when all potential sample sites have an equal chance of being sampled. This technique is best employed in homogeneous habitats. The random location of a sample site in an area can be accomplished by several methods, including: 1) randomly selecting points defined by latitude and longitude and designating each point as either a fixed location or the starting location of a transect or plot; 2) superimposing a grid structure over the area and randomly selecting grid cells as sampling locations; or 3) randomly selecting an access point and using a predetermined direction and distance from the access point to locate a plot or transect. A table of random numbers, available in most statistical textbooks, should be used to locate random sites.

(2) Stratified random sampling. Stratified random sampling can be used to divide heterogeneous habitats into subareas, each of which is internally homogeneous. Sample sites are then selected randomly in each subarea. Stratification usually occurs by cover types although further stratification within cover types is often useful.

The principal reasons for stratification are:

(a) Different sets of parameters may need to be sampled in different strata;

(b) Data of a different precision may be desired for certain subdivisions; and

(c) Stratification may produce an increased precision using fewer sample points for certain parameters.

(3) Systematic sampling. Systematic sampling involves the selection of sample sites at fixed intervals throughout an area. This technique is often easier to use without error than the other sample designs, and ensures that samples are more evenly spread across the study area. Systematic sampling is also effectively utilized in multiple sampling of periodic parameters (e.g., stream flow and temperature over time) when using line transects for measurements or when collecting spatial measurements from aerial photographs or cover type maps.

Systematic samples are located so that a sample site occurs at every kth unit, where k represents some interval. For example, transects could be located every fifth mile along a river or a seasonal variable could be sampled weekly.

Systematic sampling can also be employed to distribute sample sites within each subdivision after stratification has occurred.

C. Determination of sample size. The determination of sample size involves three tasks: 1) establishing reliability standards; 2) estimating the mean and standard deviation of habitat parameters important in an HSI determination; and 3) applying the appropriate formula dictated by the selected sampling design.

(1) Reliability standards. When only portions of the population are sampled, reliability standards provide a means of describing the degree to which the sample mean represents the true mean. Two parameters, relative precision (D) and confidence level (C), are used to define the reliability standards. The relative precision determines the magnitude of the difference that can be tolerated between the sample parameter mean and the true parameter mean. A relative precision of 10%, for example, indicates that enough sites must be sampled so that the sample site mean $\bar{x}$ ± 10% of $\bar{x}$ will include the true mean within a specified confidence level. The confidence level determines the probability (expressed as a percent) that the interval determined by D will include the true parameter mean. For example, if just enough sample sites are selected to meet a relative precision of 10% with a confidence level of 80% (0.80), then 8 times out of 10 the sample site mean $\bar{x}$ ± 10% of $\bar{x}$ will bound the true mean. Reasonable reliability standards for most HEP analyses are 25% relative precision and 90% confidence level.

Reliability standards can be set for a parameter, a set of parameters functioning as model inputs, or for the HSI value of individual evaluation species. It is usually more appropriate to base reliability standards on a set of model parameters. However, increasing the accuracy of estimation of various model inputs does not necessarily increase the accuracy of the HSI value derived from the model. Close inspection of the model should alert the user to important parameters whose accurate estimation will significantly increase HSI accuracy. The user then can make decisions about basing reliability standards on the HSI, or on certain parameters.

(2) Estimating the mean and standard deviation. There are three ways of estimating population means and standard deviations for sample size determinations;

(a) Analyze the results of a pilot survey (or presample);

(b) Analyze the results of previous sampling of the same or similar habitat types (usually within close proximity); and

(c) Assume certain facts about the structure of the population, assisted by some mathematical results. For example, sample size for parameters measured in percentages or proportions (such as HSI) can be determined by use of the binomial distribution, which requires only that the mean (x) be estimated.

(3) Application of the appropriate formula. The final task in sample size determination is the application of a formula suitable to the chosen sample design. These formulas are presented below:

(a) Simple random sampling. The formula for determining sample size (n) in sampling for percentages of units in the population which posses some characteristic (e.g., % dbh greater than 12 in) or proportions (e.g., HSI) is:

$$n = \frac{Z_c^2 \cdot p \cdot q}{D^2} \qquad \text{(B4)}$$

where n = the recommended sample size

Z_c = the value obtained from a standardized normal table (Table B-1). C is the specified confidence level. Use the corresponding Z-value of C found in the left column of Table B-1

p = the estimate of the parameter mean expressed in decimal form

q = 1 - p

D = the relative precision

Table B-1. Standard normal table (two-tailed).

Z_c value	Confidence level C
2.576	0.99
1.960	0.95
1.645	0.90
1.440	0.85
1.282	0.80
1.150	0.75
1.036	0.70

The formula for determining sample size (n) in sampling parameters which are not proportions or percentages (e.g., tree height, stream width) is:

$$n = \left(\frac{Z_c \cdot s}{D \cdot \bar{x}}\right)^2 \qquad (B5)$$

where s = the estimated standard deviation

$\bar{x}$ = the estimated mean

(b) Stratified random sampling. Determination of sample size for stratified random sampling designs can be complex. The total sample size n is equal to the sum of all samples in each stratum or

$$n = \sum_{i=1}^{m} n_i \qquad \text{(B6)}$$

where m = number of strata

n_i = sample size for each stratum

Initially, the sample size for each stratum can be determined by the rules and formulas presented for simple random sampling. However, the total sample size (sum of stratum sample sizes) may not fall within budget constraints. In that case, a decision will need to be made about which stratum sample sizes are to be reduced. Some suggested considerations for the final determination of the sample size for each stratum include:

(1) Stratum importance. An attempt should be made to meet the reliability standards in the most important stratum. Importance may be determined by the number or value, or both, of the evaluation species to be sampled in the stratum.

(2) Area size. Sample sites are often allocated in proportion to area size; i.e., larger strata are allocated more sample sites.

(3) Equity. Reductions in sample sites can be shared equally by every stratum. For example, if a particular stratum was originally allocated 10 of 100 total sample sites, but only 80 sites can be used, then the sample sites in that stratum would be reduced to 8, or one-tenth of the adjusted total sample size.

(c) Systematic sampling. The rules for determining sample size using systematic sampling techniques can be very complex. However, a good general rule to follow is to use the simple random sample formula and then distribute the sample sites systematically.

(4) Finite population correction factor. Sampling theory assumes that the population from which the sample is taken is infinitely large; this may not always be the case. In a situation where area plots are used for sample sites (instead of line transects or points), the target population may be finite. Each sample plot should be distinct and nonoverlapping. For example, in a study area of 10 acres, only 100 sample sites with a size equal to 0.1 acre could possibly be sampled. When the population size is finite, the factor $\sqrt{1 - n/N}$ should be used to adjust the estimate of the standard deviation. Here N refers to total population size and n to sample size. The factor $\sqrt{1 - n/N}$ for the standard deviation is called the finite population correction (fpc). This factor remains close to one when the sampling fraction n/N remains low. In practice, the fpc can be ignored whenever the sampling fraction n/N does not exceed 10%. The effect of ignoring the correction is to overestimate the standard deviation. The fpc can be used to reduce the overestimated standard deviation by use of the following formula:

$$s_f = s_o \sqrt{1 - n/N} \qquad \text{(B7)}$$

where s_f = corrected standard deviation

s_o = standard deviation as estimated from the sample

n = sample size used

N = total population size

For example, data on stream width might have been collected from 52 out of 110 possible sites. Suppose the mean width was found to be 20 feet with a standard deviation of 1.0. The estimate of the standard deviation could be adjusted downward by:

$$s_f = 1.0 \sqrt{1 - 52/110}$$

$$s_f = 0.726$$

Thus, the dispersion around the mean, as measured by the standard deviation, can be significantly reduced by the fpc.

The fpc for the standard deviation is primarily used in HEP to estimate the sample size needed in a planned application. In determining sample size, the correction is used to adjust downward the suggested sample size (n); n is first computed by one of the sample size formulas presented in Section C above. Then, the correction is made with the following formula:

$$n_f = \frac{n}{1 + n/N} \qquad \text{(B8)}$$

where n_f = corrected sample size

n = original estimate of sample size

N = total population size

For example, if the calculation of sample size indicated that 100 sites (1 acre plots) were necessary to meet the reliability standards and there were only 110 possible sites (total area = 110 acres), the revised number of sites would be:

$$n_f = \frac{100}{1 + \frac{100}{110}}$$

$$= 52 .$$

Appendix C. Glossary

Assessment - An activity designed to identify, predict, and quantify information about the impact of an action initiated by man (Munn 1975). Such assessments should address all physical, chemical, biological, economic, and social parameters relevant to the change expected to result from man's proposed action.

Available habitat - An area of land or water, or both, composed of one or more cover types, capable of providing direct support for an evaluation species. For example, upland hardwoods could be available habitat for squirrels, but not for bass.

Average Annual Habitat Unit (AAHU) - The total number of Habitat Units gained or lost as a result of a proposed action, divided by the life of the action.

Baseline conditions - Habitat conditions that occur in a given area prior to any proposed change in land or water use.

Baseline year - The point in time when habitat conditions were described before proposed action-induced changes occurred.

Compensation - Taking mitigation measures which, in the judgment of the relevant decisionmaker, make wildlife resources whole from unavoidable losses due to a project.

Cover type - An area of land or water with similar physical, chemical, and biological characteristics that meets a specified standard of homogeneity.

Environmental variable - A variable used in the determination of a Habitat Suitability Index.

Evaluation - Value judgments that man must make following examination of information from an assessment (Holling 1978).

Evaluation species - Individual animal species, groups of species, life stages of a species, or life requisites of a species selected for purposes of analysis.

Future with action - A description of the most probable, estimated future habitat conditions expected to reasonably occur as a result of implementation of a specific action and its reasonable alternatives.

Future without action - A description of the most probable, estimated future habitat conditions expected to reasonably occur in the absence of any proposed action plan.

Guild - A group of species that share common ecological characteristics. Guilds are defined by guild descriptors that may be general or specific, and the guilds may contain many or few species in response to the number of guild descriptors.

Appendix C. Glossary

Habitat Suitability Index (HSI) - unitless number bounded by 0 and 1 where 0 represents no habitat and 1 represents optimum habitat.

Habitat Suitability Index model - The rules, in either narrative or mathematical form, by which a Habitat Suitability Index is determined for a particular evaluation species at a particular location. The HSI model consists of two parts: a value of interest (numerator) and a standard of comparison (denominator). The denominator is a description of optimum habitat; the numerator is a description of habitat in the area of interest. The descriptions may be either narrative or mathematical.

Habitat Unit (HU) - A value derived from multiplying the Habitat Suitability Index for an evaluation species by the size of the area for which the HSI was calculated. The HU provides a standardized basis for comparing habitat changes over time and space.

Impact segment - An area within the study area that will change uniformly as a result of implementation of a proposed action.

Impacted species - In a HEP evaluation, species for which there is a predicted increase or decrease in Habitat Units is known as an impacted species.

In-kind compensation - Complete replacement of losses with the same species or habitats that were lost as a result of some action.

Instream habitat type - That portion of a stream (study area) which provides the life requisites for a life stage of an organism. This is typically referred to as micro-habitat by the fishery biologist.

Interspersion - The spatial relationship of cover types to one another. Interspersion is considered for species that must have more than one cover type to meet life requisites.

Life requisite - Food, water, cover, reproductive, or special requirements of an evaluation species supplied by its habitat.

Life Stage - Egg, larval, fry, juvenile, or adult stage of a species.

Negatively impacted species - In a HEP evaluation, a species for which there is a predicted decrease in Habitat Units is known as a negatively impacted species.

Net impact - The overall change after both gains and losses have been considered in comparing two future conditions.

Out-of-kind compensation - Complete replacement of losses with difference species or habitats than were lost as the result of some action.

Appendix C. Glossary

Pairwise comparison - A technique to determine the relative importance between any two considerations.

Proposed action - A change in land or water use by man which results in an alteration of the environment.

Relative Value Index (RVI) - A value between 0.0 and 1.0 that is used to adjust Habitat Unit data to accommodate socioeconomic and environmental considerations.

Representative stream reach - A subunit of a stratified stream segment which is selected as the sample site from among a population of candidate reaches.

Stratified stream segment - A subunit of a stream (study area) which is relatively homogeneous with respect to morphology and physical, chemical, and biological characteristics.

Stratum descriptor - A term used to define a physical location within a cover type.

Study area - A specified area of land or water for which habitat conditions are evaluated. There may be more than one study area evaluated as components of a single study name.

Study name - A general term describing the overall scope of a Habitat Evaluation Procedures application. The study name may consist of multiple study areas.

Target species - A species for which gains in Habitat Units, obtained through compensation measures, can be used to offset projected habitat loss resulting from a proposed action.

Target year (TY) - A specific year for which habitat conditions are measured or estimated.

Trade-off analysis - A consideration of unlike habitats by evaluating the relative values of their wildlife species.

Weighted useable area - The product of the total surface area of the sampled unit of a stream (i.e., representative reach) and a composite weighting factor which represents the combination of hydraulic conditions present.

Wildlife - Includes birds, fishes, mammals, and all other classes of wild animals.

Word model - A narrative description of habitat requirements that can be used to determine the Habitat Suitability Index for an evaluation species.

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