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A Wetland Habitat Assessment Method Using Birds

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Abstract.—A wetland habitat assessment technique (HAT) using birds as indicators of habitat quality was developed from the method of Holmes et al., (1986) and Graber and Graber (1976). The technique is quick, easy, and inexpensive, lending itself to screening large numbers of wetlands. Screening may be required to: (1) select between a large number of alternatives for a development, (2) deal with the volume of site decisions encountered by permitting agencies, and (3) select areas for preservation from a large pool of potential sites. HAT can provide input to more exhaustive techniques such as FHWA or HEP. The technique incorporates both biological value of species diversity and the human value of rarity. Applying the theory of island biogrophy, HAT incorporates the "real world" interplay of ecology and economics. A field test of HAT, and the basis for adapting HAT to any region or habitat type or for using other organisms as indicators, is provided.

Introduction

The extinction or extirpation of species, loss of high quality habitats and unique natural areas, pollution of air and water, and loss of wetlands to development have fostered legislative mandates for environmental protection. In 1646 Rhode Island closed its deer season, establishing one of the earliest environmental laws in North America. In 1916 the Federal Migratory Bird Treaty provided protection for most species of migratory birds. The Wildlife Coordination Act of 1934, and the 1958 Fish and Wildlife Coordination Act authorized assessment of adverse environmental impacts by Federal water projects. The National Environmental Policy Act of 1969 (NEPA) required that Federal agencies consider environmental values for all Federal activities and programs. A variety of federal, state, and local laws address the protection, inventory, and conservation of wetlands resources. Some of these are: the Clean Water Act, Coastal Zone Management Act, Estuary Protection Act, and the Emergency Wetlands Resources Act.

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These laws, and many others, require that the quantity and quality of existing resources be documented as part of the impact assessment of development or management. The United States Fish and Wildlife Services (USFWA, 1980a) identified three basic types of environmental assessments: (1) analysis of energy flow, (2) population estimates, and (3) evaluation of habitat quality. Energy flow assessments are generally used to evaluate small physically well-defined systems, such as inland aquatic systems. Population estimates can be made in a variety of ways, but they are often time consuming, costly, and potentially unreliable because of sampling errors, cyclic population fluctuations, and insufficient statistical time data. Habitat assessment depend upon the detailed, quantitative data concerning the species, habitat requirements, and spatial requirements. Typically habitat assessments involve measurement of habitat variables considered specific to habitat quality.

Habitat quality assessment techniques are developed on the basis of the habitat that can be quantitatively and qualitatively estimated in a defined format, providing repeatability and consistency over time, among sites, and among evaluators. For an assessment, vegetative and other physical characteristics are frequently considered. However, animals are also used as habitat indicators. Sometimes the health of individuals selected randomly from the population is used to evaluate habitat conditions. This type of data is most valuable if compared over years and to a known standard value. Animal diversity indices have also been regarded as indicators of habitat quality. Diversity indices consider the number of species and relative abundance, but do not consider which species are present. Many techniques require an assessment of both vegetative and faunal parameters.

In recent years there has been a proliferation of methodologies to assess impact assessment requirements of environmental legislation. Laidler et al. (1981) critiqued 20 wetlands assessment methods and noted that four additional methods were soon to be implemented. One key finding was that methods should be tailored to an identified use. Methods useful for regulatory actions should generate answers quickly and require moderate levels of technical skills, data, and degrees of accuracy. Similar recommendations were made for methods used in land acquisitions. In their critique, Laidler et al. found that many methods are regional in scope, requiring modifications for use in new areas, and that many methods had not been adequately field tested.

The procedure of Daniels and Lamine (1974) was the primary sequence to the USFWA (1976, 1980b) Habitat Evaluations Procedure (HEP). These procedures rely on species models which allow the assessment of habitat for those species and the guilds they represent. The habitat is the target of assessment, the species themselves are not assessed, and they need not be present. HEP is designed to produce a verifiable, quantified product that is reproducible. It delineates impacts and mitigates in well-defined "Habitat Units". Although HEP can be used to generate quick answers with limited data, it is frequently used where detailed answers are required for extensive or long-term projects. Frequently an interdisciplinary team is employed, and the process can be elaborate, requiring substantial inputs of time and money. HEP generally requires training and certification. Although of unequal value in many situations, it is not applicable under all circumstances.

The U.S. Department of Transportation, Federal Highway Administration (FHWA) is developing a method of wetland assessment (Agency of Transportation, Federal Highway Administration, 1983 Vol. I and II), using the wetlands classification system developed by the USFWA (Cowardin et al., 1977). This procedure yields a high, moderate, or low rating for I wetland functional values, including fish and wildlife. To be completed in full, the procedure requires that individuals proficient in surface and subsurface hydrology, botany, vegetation, wildlife biology, recreation resources, and regional socioeconomics be involved. It also requires detailed field measurements. The procedure was designed to produce an answer, even without a full complement of information. However, Odum (1986) found that a lack of specific values tended to produce low and moderate values. The FHWA technique requires a long series of questions and keys to be used to obtain an assessment. To compare two or more wetlands requires an additional series of data manipulations. Training in the technique is recommended. Like HEP, the FHWA technique is frequently used on long-term or extensive projects, and because of time and cost considerations, it is not applicable to all situations.

Graber and Graber (1976) developed an assessment method that combined birds and their habitats. It unfortunately was applicable in the form developed, only for Illinois. To adapt the technique to other geographical areas requires extensive calculations to produce pro-assessment values for the area of interest. For many areas, the data for these calculations is unavailable. Holmes et al. (1986) developed a technique which used the avifauna as indicators of habitat quality. Their technique was designed to quickly, easily, and inexpensively provide an assessment of wetlands, or other habitats, without detailed measurements and calculations of vegetative or other physical parameters. Their technique also produces a numeric value that allows easy comparison among sampled areas.

The habitat assessment technique (HAT) presented herein is a further refinement of Holmes et al. (1986). Being quick, easy, and inexpensive, the technique is suited for many regulatory actions, for use in acquisition of lands for preservation. HAT can be used to efficiently assess a large number of alternatives, and if a more extensive assessment is required of a reduced number of alternatives, the raw data or output of HAT can frequently be input directly or indirectly into more exhaustive techniques such as HEP or FHWA. A field trial of the technique on two wetland areas, and three mixed forested and emergent, tidally influenced
wetlands in Delaware is presented. The basis for adapting the technique to any region or habitat type is provided. The technique to any region incorporates the interplay of economics with ecology that frequently is inescapable in the modern world.

The Procedure

The HAT procedure is based on the premise that species richness and the value or uniqueness of species can be used to assess the quality of wetlands habitat. The presence of more species and uncommon species makes an area more valuable. There is both ecological and regulatory justification for this premise. In general a habitat of higher quality retains a greater number of species and less common species are frequently found in remaining higher quality habitat, their uncommon status a result of habitat loss or degradation. Habitats that retain larger numbers of species and uncommon species generally are of greater regulatory concern; their loss constitutes a greater impact.

To use HAT, a base value is assigned to each wetland species based on abundance. For each area, the species are enumerated and Species Points totaled. Area totals are averaged (Species Index) for a simple comparison, but more importantly, the totals are adjusted by wetland size. The adjustment is called an Area Factor and adjusted total is the Fauonal Index. This Area Factor (adjustment) is based on the interplay of ecology and economics.

Bird species are assigned base values dependent upon the state's (or other appropriate geographic area) breeding population. Only wetland dependent species are used in the assessment. Wetland dependent species are defined as those which require wetlands for a major life function such as nesting or feeding. Breeding population estimates can be made by qualified ornithologists or "birders". Breeding bird atlases are becoming available in many states and may provide a source for this information.

In Delaware, species base values were assigned as follows: (1) species with a state breeding population of 5,000 or more birds = 10 points; (2) species with 2,500 to 4,999 birds = 20 points; (3) species with 1,000 to 2,499 birds = 40 points; (4) species with 50 to 499 birds = 80 points; and (5) species with less than 50 nesting birds in the state = 160 points. Species with less than 50 individuals are also considered beyond numerical value, as a "red flag" species. Accidents with regard to region or habitat type, migrants and exotics, are excluded from calculations.

The assessment requires that wetland habitat types and acreages be determined. This can be from aerial photographs, maps, or field measurements. Where available, National Wetlands Inventory (NWI) maps may be used. A field survey is required to assess the avifauna composition of each area if the information is not available from amateur or professional ornithologists or organizations, or the literature. Field surveys are best conducted when the likelihood of migrants is low and breeding birds are vocal.

Ideally, a field survey, which is a single window in time, would identify all species in an area, but the full species complement can be identified only if the area is saturated with observers. Therefore, most field surveys are only a subsample of the true species complement. How can surveys of sites that vary by size and other factors be comparable? According to theory, if observations continue at each site until the rate of new species observed is significantly less than during initial observation, the surveys should be comparable among sites. Additional species typically are found at a logarithmically decreasing rate, relative to the number of species observed initially and the total species complement (Preston, 1969; Caughley 1965; Cable and Brock, 1986). After an initial period of observation, each successive observation period must be doubled in length if an equal number of new species is to be found. Mathematically:

$$N_T = N_I + A \log_2 t$$

where:

- $N_T$ = total number of species observed
- $N_I$ = number of species observed during the initial observation period
- $A$ = number of species added during each successive doubling of time
- $t$ = number of time units

For each wetland assessed the Species Points are totaled and the (average) Species Index calculated. This index, by virtue of the species composition, tends to reflect habitat quality. Areas with a greater ratio of rare to common species, or a greater ratio of wetland restricted species to generalist species that use wetlands, generally have a larger Species Index. However, the Species Index, taken independently, fails to incorporate diversity, and a wetland with a single very high value species will rate higher than a wetland with many high value species.

If all wetlands assessed are equal in size, the Species Index would provide a reasonable comparison. However, economics dictate that 50 and 500 acre plots with the same Species Index value are not equal. Economically, if all other factors are held constant, a small area is better than a larger area with the same Species Index. Ecologically, small isolated pieces of habitat, in effect "habitat islands", likely will not retain a high species complement over time. The theory of island biogeography (MacArthur and Wilson, 1967; Simberloff, 1974) explores the direct relationship between island size and species richness, and Janzen (1983) has shown that small habitat islands experience greater species interference from outside. Studies of upland and riparian forests (Calli et al., 1976; Stauffer and Best, 1980), urban parks (Gavareki, 1976), urban cemeteries (Lusshenhoff, 1977), shelterbelts (Martin, 1978), montane habitats (Thompson, 1978;
Picton, 1979), and prairies (Samson, 1980a) have found that for habitat islands, species richness is associated most with tract size. This is a log-linear relationship. The limited data of Holmes et al. (1986) indicates that a similar relationship exists for marshes (N = 8; R² = 0.24; P = 0.22) (Figure 1). Larger tracts have more species, all other factors being equal. According to the equilibrium theory, a small tract with a large species complement is likely to lose species over time.

The proximity of smaller tracts to one another and their configuration can affect their ability to hold a larger number of species (Wilson and Willis, 1975). Small tracts connected by corridors hold species better than separate tracts. Tracts in a small cluster hold species better than tracts in a linear association, and round tracts, with the least exposure to adjacent habitats, hold species better than oval or irregularly shaped tracts. We have not devised a method to take into account the effects small tracts may have upon one another.

Grabler and Grabler (1976) and Holmes et al. (1986) obtained a Faunal Index by dividing the total species points by the common log of the wetland acres, thus adjusting for size. This adjustment is derived from the log-linear increase of species with size. However, such an adjustment consistently favors a smaller size. Samson (1980b), summarizing past work, reported that a minimum area point is reached in a species turnover, a measure of species equilibrium, was reduced on 99 acres or larger tracts of surface coal mine reclamation sites. Some species may have an area requirement larger than this minimum. If species-area curves are known, then species of special interest or those requiring the largest minimum area may be the most appropriate adjustment for habitat size (Robbins, 1979; Samson, 1980b).

A large habitat tract may often be economically disadvantageous; a small tract ecologically inappropriate. Therefore, a change from optimum size should be accounted for in the Faunal Index value. Habitats can vary from infinitely small to infinitely large. We have defined the smallest tract of consideration as 1 acre, the minimum mapping unit for HAT maps. We considered the largest tract as the largest contiguous tract from a continuum of sizes in the area of interest. In Delaware this is approximately 6,000 acres for both estuarine and palustrine wetlands.

The HAT Faunal Index develops the "real world" interplay of conversation and economics. An optimum size is determined from available species-area equilibrium data. Both larger and smaller tracts require a higher Species Point value than the optimum sized tract to obtain an equivalent Faunal Index. For a wetland, the Faunal

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**Fig. 1. Wetland Bird Species versus Marsh Size in Indiana**

**Fig. 2. Observed versus potential wetland Breeding Birds in Delaware.**
Index equals the total Species Points divided by the Area Factor. The Area Factor maximum is defined as the common log of the largest wetland tract, and the Area Factor for the smallest tract equals that of the largest. Therefore, adjustment for minimum and maximum sizes is equal, in the case of Delaware 3.78. The Area Factor for optimum wetland size is defined as 1.0. The Area Factor for wetlands between optimum and largest or smallest equals the percentage change in size from optimum, multiplied by the difference between optimum and maximum (minimum) Area Factors (AF). For wetlands larger than optimum:

$$AF_L = \frac{A - O}{N_x \log N_x - 1} + 1$$

For wetlands smaller than optimum:

$$AF_S = \frac{(O - A)}{O - Mn}$$

Where A is size of the wetland of interest, and N, Mn, and O are the maximum, minimum, and optimum wetland sizes.

In Delaware, both tidally influenced emergent estuarine and forested palustrine wetlands were sampled. When a single contiguous wetland contained both wetland types, an Area Factor was determined for both types. From past studies, a 100 acre optimum size was used for forested palustrine wetlands and an 150 acre for emergent estuarine wetland.

A Field Application of HAT

A total of eleven wetlands in Delaware were assessed using HAT (Table 1). Two of these were predominantly forested palustrine, six were predominantly emergent estuarine, and three had significant proportions of both types. All were tidally influenced. Overall, 32 wetland dependent bird species were observed (Table 2); up to 14 species were found in a single wetland. Fifty-four species of wetland birds breed in Delaware. All of the most common species were found in at least one wetland, while only two of the 12 least common species were found (Figure 2). In other words, there was an inverse relationship between rarity and occurrence, substantiating the need for weighting rarer species more heavily. Faunal Index values ranged from 25.8 for a small suboptimal wetland with a few relatively common species, to 356.4 for a wetland of near optimum size, with both common and rarer species. The largest wetland, although surpassing optimum size, had the second highest Faunal Index because a large number of species with high containing a moderate number of species with moderate species base values received a moderate Faunal Index of 237.6.

It was apparent from field testing that HAT could be used on both forested palustrine and emergent estuarine wetlands. We noted no problem incorporating several wetland subtypes (Cowardin et al., 1977) within a wetland. For example, contiguous temporarily and seasonally

<table>
<thead>
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<th>Type</th>
<th>Wetland</th>
<th>Species</th>
<th>Species Points</th>
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<td>E</td>
<td>105.5</td>
<td>14</td>
<td>450</td>
</tr>
<tr>
<td>E</td>
<td>298.4</td>
<td>9</td>
<td>220</td>
</tr>
<tr>
<td>E</td>
<td>462.2</td>
<td>6</td>
<td>70</td>
</tr>
<tr>
<td>E</td>
<td>174.5</td>
<td>14</td>
<td>70</td>
</tr>
<tr>
<td>M</td>
<td>156.1</td>
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</tr>
<tr>
<td>M</td>
<td>188.2</td>
<td>9</td>
<td>20.0</td>
</tr>
<tr>
<td>M</td>
<td>38.6</td>
<td>25</td>
<td>25.0</td>
</tr>
<tr>
<td>M</td>
<td>144.2</td>
<td>10</td>
<td>31.0</td>
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<td>M</td>
<td>126.7</td>
<td>11</td>
<td>30.0</td>
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<tr>
<td>M</td>
<td>296.6</td>
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<tr>
<td>E</td>
<td>248.6</td>
<td>1.81</td>
<td>248.6</td>
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Table 2. The base values of wetland birds found in eleven estuarine and palustrine tidal wetlands in Delaware.

<table>
<thead>
<tr>
<th>Species</th>
<th>Base Value</th>
<th>Palustrine 1 2</th>
<th>Mixed 3 4 5</th>
<th>Estuarine 6 7 8 9 10 11</th>
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<tbody>
<tr>
<td>Red-winged blackbird</td>
<td>10</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Common yellowthroat</td>
<td>10</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Marsh wren</td>
<td>10</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Wood duck</td>
<td>10</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Boat-tailed grackle</td>
<td>10</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Clapper rail</td>
<td>10</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Seaside sparrow</td>
<td>10</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Yellow-breasted chat</td>
<td>10</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Mallard</td>
<td>20</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Tree swallow</td>
<td>20</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
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<tr>
<td>Swamp sparrow</td>
<td>20</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
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<tr>
<td>Snowy egret</td>
<td>20</td>
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<td>X X X</td>
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<tr>
<td>Cattle egret</td>
<td>20</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Willet</td>
<td>20</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
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<tr>
<td>Kildeer</td>
<td>20</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Fish crow</td>
<td>20</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Prothonotary warbler</td>
<td>20</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Laughing gull</td>
<td>20</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Yellow warbler</td>
<td>40</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Great blue heron</td>
<td>40</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Green-backed heron</td>
<td>40</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Great egret</td>
<td>40</td>
<td>X X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Belted kingfisher</td>
<td>40</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>Glossy ibis</td>
<td>40</td>
<td>X</td>
<td>X X X</td>
<td>X X X X X X</td>
</tr>
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Table 2. Continued.

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<thead>
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<th>Species</th>
<th>Base Value</th>
<th>Palustrine 1 2</th>
<th>Mixed 3 4 5</th>
<th>Estuarine 6 7 8 9 10 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black-crowned night heron</td>
<td>40</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Herring gull</td>
<td>40</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Forster's gull</td>
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<tr>
<td>Yellow flycatcher</td>
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<td>Northern harrier</td>
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<td>X</td>
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<tr>
<td>Sharp-tailed sparrow</td>
<td>160</td>
<td>X X</td>
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flooded palustrine woodlands are similar with the same dominant vegetation type, and we were unable to set distinctly different optimum sizes proportionately small area of streams or other wetland type within a larger wetland was not sufficient to subdivide a contiguous wetland. Streams are an integral part of many palustrine or estuarine wetlands, as is the interspersion of open water pockets within many marshes. Thus, despite their classification as a different wetland type or subtypes, they need not be assessed independently. In contrast, two or more distinctly different types of wetlands, each a sizeable portion of the contiguous whole, will require a modification to the assessment if optimum sizes are different. For the Delaware assessment we simply completed the assessment for both types, based on the arescues of each, and considered the higher Faunal Index value most indicative of the true wetland value.

HAT in Nonwetland Habitats

HAT is applicable to any habitat or geographical area, and indeed can be easily redesigned to examine any specified subset of the environment. If for example prairies in Kansas are of interest, HAT simply requires: (1) estimates of breeding populations of prairie species in Kansas found during field surveys and assignment of appropriate species base values, (2) a determination of maximum and minimum prairie sizes, and (3) optimum prairie size based on species-area curves, habitat area-species complement curves, or habitat area-turnover rates. As ecological and environmental sciences progress it is likely that these types of information will become increasingly available and these requirements will become easier to fulfill. The same three requirements must be met for any assessment using HAT. HAT can be easily adapted to use taxa other than birds. We use birds because many species are easily identified visually or by call, and this we feel minimizes field time. Potentially, plant species could be used. HAT could be adapted to examine hunted species in an area or habitat.

Discussion

HAT has a variety of uses which supplement existing habitat assessment techniques. The technique is fast, inexpensive, and provides a comparison of sites as part of the output. Therefore it will be most useful where a large number of areas must be assessed such as when: (1) selecting between or reducing a large number of alternatives for a project, (2) dealing continuously with a large number of site decisions as is frequently required by resource agencies, or (3) selecting a limited number of sites for preservation from a larger number of potential sites.

The raw data or output of HAT can frequently be used directly or indirectly as input to some of the more expensive evaluation techniques. For example, if HAT were employed to examine the wetlands in several alternatives of a proposed roadway, the avifauna data could be used directly in the wildlife portion of detailed FHWA assessments of wetlands on a reduced number of alternatives. HAT avifauna data should be helpful in selecting appropriate birds for a HEP analysis.

The wetland values derived from HAT are directly related to species diversity, an important component of habitat value. However, by incorporating abundance through species base values, the rarity (importance) of species is also taken into account. Similarly, the importance of habitat patch size is incorporated into the assessment. Ecologically, larger is better; economically smaller may often be of importance. HAT provides the first known attempt to directly incorporate both.

Setting the optimum habitat patch size, the point that provides the most appropriate interplay between economics and ecology is the least precise component of the HAT assessment. Optimum is based upon the area required to maintain species diversity, especially diversity of rarer species. There are a limited number of studies completed, in a variety of habitats, to address the topic. Additionally, these studies have approached the topic from three view points: (1) the number of species an area can hold, (2) the stability of the species complement in an area, and (3) the area requirements of individual species. If there is one or more species of special interest to the study, or if the areal requirement of the most restrictive species is known, the third approach may be preferable. The area requirement is the minimum habitat area required before a species will nest there. This is not the species' territory size. For example, the territory of an ovenbird is less than an acre but they do not nest in habitat patches less than 27 acres and are only dependably found in patches 6550 acres or larger (Robbins, 1979). Regardless of the method used to select optimum size, the selection may be based on background information of less than 100 percent applicability. As ecological and environmental studies progress, more accurate site specific data will become available.

HAT is easily adapted to any geographic area or habitat type. Minimally, preparation to use HAT requires only that the areas to be assessed are delineated. For the first application of HAT to a specific habitat in a specific geographic area, the breeding bird populations of species found must be estimated and species values assigned. Maximum, minimum, and optimum habitat sizes must be defined. With forethought and use of local or regional expertise, all of these requirements can be met without additional time inputs. Field time in minimal since only one environmental variable, bird species, is of interest. The field observer should be a proficient birder in the cohabitation (in the geographic area) of interest, or if other taxa are used, proficient in taxonomy of those species. Field observations continue until new species are added only infrequently. The length of time required for a field assessment depend upon the number of species to be found and therefore, in part, upon the size of the area assessed. A field visit is not required if the birding records of others can be obtained. Field equipment is a pair of binoculars. Mathematical calculations take only a few minutes and require only
simple math that can be computed by hand, with the exception of the single log value.

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