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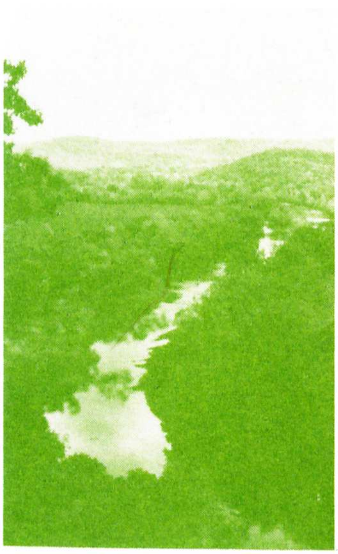

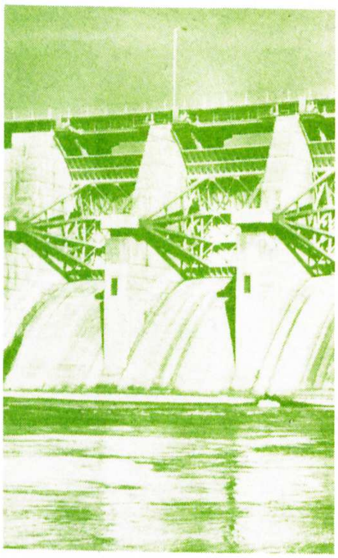

ENVIRONMENTAL IMPACT RESEARCH PROGRAM

TECHNICAL REPORT EL-92-21

# IDENTIFICATION AND EVALUATION OF COASTAL HABITAT EVALUATION METHODOLOGIES

by

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**13. ABSTRACT** *(Maximum 200 words)*
This study was undertaken to review existing methods for evaluating coastal habitats. A total of 15 methods presently in use or in development were examined and evaluated in terms of the type of information needed, the level of expertise and studies required, the amount of time and costs involved in the determination, and form of output. No single method was found that could be used on a nationwide basis for all coastal habitats. Most methods were specific to a single habitat or evaluated a narrow suite of functions. Development of method(s) to evaluate disparate coastal habitat types would provide an essential tool for measuring the success of mitigation efforts and the functioning of coastal ecosystems.

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# Contents

# Preface

This report presents the results of a literature review of methods available for comparison of estuarine and coastal habitat types. The review was performed by Normandeau Associates, Inc., of Bedford, New Hampshire, as a part of the Environmental Impact Research Program (EIRP), sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE). Technical Monitors were Dr. John Bushman, Mr. David Buelow, and Mr. David Mathis, HQUSACE. Dr. Roger T. Saucier, Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), was EIRP program manager.

The report was written by Mses. Marcia Bowen and Mary Small of Normadeau Associates, Inc. Contract monitor was Dr. Gary L. Ray of the Environmental Resources Division (ERD), EL, WES. Work progressed under the general supervision of Mr. Edward J. Pullen, Chief, Coastal Ecology Group, ERD; Dr. Conrad J. Kirby, Chief, ERD; and Dr. John Harrison, Chief, EL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassell, EN.

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# 1 Introduction

## Background

Coastal areas have come under increasing pressure from human uses, resulting in habitat loss and degradation. There is a pressing need to determine the ecological value of these areas, both to evaluate the effects of habitat loss and to develop suitable plans for created/restored replacement habitats. Evaluation of the ecological importance of these areas, especially when they encompass a variety of habitat types, remains a challenge. Habitat evaluation methodologies have been developed in response to the need to accurately determine the functions and values provided by estuarine and coastal areas. An accurate and understandable evaluation of habitat value provides a number of uses such as:

*a.* Regulatory

For permit applications and National Environmental Policy Act documents, it is important to have an accurate description of the existing environment and the likely effects of proposed project alternatives.

*b.* Mitigation Planning and Monitoring

An initial determination of habitat functions and values forms the foundation of a mitigation plan, which strives to replace the functions and values lost as a result of a project. A well-implemented monitoring program can help determine whether the mitigation effort is successful.

*c.* Project Planning

An understanding of an area's value helps in project planning to avoid and minimize detrimental effects. Among the criteria for such a method (after Diaz (1982)) are that it be:

(1) Quantitative, i.e., based on actual data.

(2) Repeatable, i.e., results must be verifiable.

(3) Flexible or applicable to many regions and habitat types.

(4) Understandable, i.e., methodology and results should be easily understood by both technical and nontechnical users.

(5) Accurate i.e., results should faithfully reflect the ecological conditions.

(6) Efficient i.e., the method should be cost-effective.

The purpose of this study was to identify and evaluate existing coastal habitat evaluation methods. The search was restricted to marine and estuarine habitats, with the exception of shrub/scrub and forested wetlands, using the Cowardin et al. (1979) classification scheme. Relying on computerized literature searches, review of in-house literature, and personal communication with scientists in the field, over 200 pertinent citations were identified. Many of the citations pertained to monitoring protocols or impact assessment; however, the focus was placed on true evaluation methodologies. Fifteen methods for coastal habitats, either in the development stage or currently in use, were reviewed. Each method was evaluated in terms of the type of information needed, the level of expertise and studies required, the amount of time and costs involved in the determination, and form of output. This information factored into the assessment of each method's strengths and weaknesses and potential uses.

## Methods

Information about habitat evaluation techniques was obtained through searches of computerized data bases, the literature cited in relevant papers, conversations with experts in the field, and personal knowledge of the literature. A search of the following data bases was conducted:

*a*. AGRICOLA (1984-April 1991)

Keywords used: habitat evaluation, ecological assessment or ecological monitoring, marine habitat, coastal habitat, wetland evaluation.

*b*. AGRICOLA (1970-1978; 1979-1984)

Keywords used: habitat evaluation, ecological assessment or ecological monitoring, wetland evaluation.

*c.* U.S. Government Documents (1978-1991)

Keywords used: habitat evaluation, ecological assessment, ecological monitoring, wetland evaluation.

*d.* Biosis Previews, National Technical Information Service, Oceanic Abstracts, Aquatic Sciences and Fisheries Abstracts, Aquaculture, Water Resources Abstracts, Waternet (1972-present)

Keywords used: habitat evaluation, ecological monitoring, ecological assessment

Subdivisions: marine, estuarine, tidal, intertidal, mudflat, salt marsh, wetland, eelgrass, rocky intertidal, coastal

This search yielded 138 citations.

In addition, the Fish and Wildlife Reference Service in Bethesda, Maryland, conducted a computer search of their holdings using the keyword habitat evaluation with subdivisions coastal, marine, saltwater or estuarine. This search yielded 100 citations.

Results of the literature searches were screened, and pertinent papers were obtained and reviewed. Relevant articles cited in the papers reviewed were also reviewed. Papers that discussed a methodology for assessing marine, estuarine, or tidal riverine systems were then evaluated. Because of time and budget constraints, publications that did not specify a methodology for evaluating habitat or did not pertain to coastal habitats were not included, despite their potential for being adapted into a usable form. Exceptions were those publications that proposed guidelines for choosing and monitoring mitigation sites in estuarine and marine systems.

Many of the authors were contacted and questioned about their methodology, subsequent research, and similar work with which they were familiar. Experts and users recommended by the authors were also contacted.

# 2 Results

## Matrices

Fifteen methods, including evaluation methods and guidelines for establishing and monitoring coastal habitats for mitigation, were evaluated in detail. These are presented in a series of matrices (Tables 1-4). The matrices provide a means to quickly compare the evaluation methods in several key features. These features include:

*a.* Methods available for each habitat class (Table 1).

*b.* Habitat classes that can be evaluated, the data required, and the type of output expected for each method (Table 2).

*c.* Effort, cost, and expertise required along with potential uses (Table 3).

*d.* The use for which the method was developed, its strengths and weaknesses, and the region of the country in which it applies (Table 4).

A more detailed description of each of these methods is presented in the next section. A few additional references that are not true evaluation methods, or have not yet been completed by the author(s), or that were not thoroughly reviewed because of time constraints are also included in the next section.

## Evaluation of Key Methods

### Wetland Evaluation Technique

The Wetland Evaluation Technique (WET) method (WET, Adamus and Stockwell 1983; WET 2.0, Adamus et al. 1987) was developed to assess a wetland's potential to provide 11 different functions.. Three perspectives are used in the evaluation: opportunity or probability that the wetland will provide a function, effectiveness or capability if given the opportunity, and social significance or the importance society places on a wetland function. All three perspectives are not pertinent to every function. The user may choose various assessment levels, which affect the level of detail in the output. A relative value (high, moderate, or low) is given to each of the pertinent perspectives for each function. Additional evaluations may be done for specific fish and wildlife species. The WET method consists of a series of questions or predictors about the wetland and its surrounding watershed. Some of the questions can be answered with a topographic map and other information; a field visit and laboratory analysis may be necessary depending on the assessment level. The WET model can be adapted to coastal habitats by eliminating questions that are inappropriate for tidal conditions. This can eliminate 64 of the 253 predictor questions. Additional questions pertaining only to functions that are present or important in freshwater wetlands (e.g., groundwater recharge, groundwater discharge) may be eliminated, further streamlining the method.

WET results (Figure 1) take the form of low, moderate, or high probability ratings from as many as 3 perspectives for the 11 functions. Model results are usually accompanied by written interpretation to avoid misinterpretation. The method uses a "black box" approach; i.e., input data are not easily related to the results, to decrease the likelihood of biased results.

WET is one of the few evaluation methods that is versatile enough to be used in any type of habitat, including mixed habitats. It fulfills many of the criteria for an assessment method, as it is quantitative, repeatable, flexible, and efficient. However, problems with it have been identified, primarily because it is one of the few methods that have been extensively field tested. Difficulties in using WET stem from the predictor questions and format of the results. The obtuse wording of many of the questions combined with the general nature of the requisite information results in overly general results, particularly for mitigation evaluation. Results depend more on the definition and resulting size of the "assessment area" and adjacent zones than on its pertinent wetland characteristics. The fact that the rating refers to a probability rather than capability lessens the value of the results (Crabtree et al. 1990). Furthermore, utilization of the results, particularly in comparing wetlands, can be difficult and time-consuming. The "black box" approach can also frustrate users that seek to understand the method and validate results.

The WET method also presents some problems unique to its use with marine and estuarine systems. Since the method is geared to the perspective of freshwater wetlands, results do not always faithfully reflect marine and estuarine conditions. For example, tidal wetlands are susceptible to both upstream and downstream (tidal) flows, unlike freshwater wetlands, which are more affected by upstream conditions. The method could be improved by adding predictors that better reflect coastal conditions. Results

**FORM D: EVALUATION SUMMARY SHEET** WET 8/87

**Name of Wetland:** ______________________________

**Wetland Functions and Values**

| | Social Significance | Effectiveness | Opportunity |
|---|---|---|---|
| Ground Water Recharge | | | *** |
| Ground Water Discharge | | | *** |
| Floodflow Alteration | | | |
| Sediment Stabilization | | | *** |
| Sediment/Toxicant Retention | | | |
| Nutrient Removal/Transform. | | | |
| Production Export | *** | | *** |
| General Wildlife Habitat | | *** | *** |
| Wildlife Diversity/Abundance* | | | |
| Breeding | *** | | *** |
| Migration | *** | | *** |
| Wintering | *** | | *** |
| General Fish Habitat | | *** | *** |
| Aquatic Diversity/Abundance | *** | | *** |
| Uniqueness/Heritage | | *** | *** |
| Recreation | | *** | *** |

**Habitat Suitability Evaluation for Species and Species Groups**

**Fish Species Groups:**

__________ Group ___ __________ Group ___ __________ Group ___

**Waterfowl Species Groups:**

| | Breeding | Migration | Wintering |
|---|---|---|---|
| Group __________ | ___ | ___ | ___ |
| Group __________ | ___ | ___ | ___ |
| Group __________ | ___ | ___ | ___ |

**Fish, Invertebrate, and Bird Species:**

| | | | | | |
|---|---|---|---|---|---|
| __________ | ___ | __________ | ___ | __________ | ___ |
| __________ | ___ | __________ | ___ | __________ | ___ |
| __________ | ___ | __________ | ___ | __________ | ___ |
| __________ | ___ | __________ | ___ | __________ | ___ |

Circle levels of evaluation completed: S-1 S-2 E/O-1 E/O-2 E/O-3 HS

Is there any evidence that suggests ratings contrary to the above (explain)?

______________________________

Were alternative sources used for any of the ratings above (explain)? ________

______________________________

The loss rate for ______________________ (identify locality/region) between 19__ and 19__ for ______________________ (identify wetland type) was __________ (acres/year or % loss).

* Wildlife Diversity/Abundance evaluates for wetland-dependent birds. Other wildlife (e.g., game mammals, fur-bearers, etc.) must be evaluated using other methods.

*** WET does not evaluate this function or value in these terms.

Figure 1. Example of evaluation summary sheet for WET 2.0

for coastal wetlands ultimately rely on relatively few attributes.[1] Another shortcoming of the method pertains to WET's habitat suitability model for marine and estuarine fish. WET relies on vegetation, substrate, and salinity criteria to assess an area's value for fish species. The presence of the minimum requirements for a species' presence results in a "moderate" rating. Observation of the species in the wetland, which could require a year-round survey, results in a "high" rating. The model is so general that it provides little definition of habitat value. Similar problems also exist for wildlife habitat suitability models for coastal species that are available only for birds. Furthermore, some of the parameters used in the model do not accurately reflect estuarine conditions and require adaption.

WET has been used in estuarine systems with mixed success. The California Department of Transportation has found that estuarine systems are among those on which WET works best. Results correspond well with professional opinion.[2] Other results suggest WET has limited ability to discriminate among coastal wetlands because relatively few parameters influence the evaluation.[1]

## Habitat Evaluation Procedure

The U.S. Fish and Wildlife Service (USFWS) Habitat Evaluation Procedure (HEP) (USFWS 1980) uses a numeric index to quantitatively describe the value of a habitat to a particular species. A model specific to a species of wildlife, fish, or invertebrate is used to assign a value between 0 and 1 (Habitat Suitability Index or HSI) to each cover type in the area to be evaluated. The HSI and the area of the cover type can be manipulated to reflect future conditions under various scenarios. A rating is assigned to the habitat under each scenario (e.g., existing conditions, the future in 10 years, proposed mitigation sites) based on its HSI value and acreage. These ratings can be compared to assess impacts, determine mitigation required, or to determine management strategies.

HEP is a versatile system because it can be used in a variety of cover types; its level of detail can be adjusted by varying the number of species, combining or separating cover types, changing the number of proposed actions, or changing the sampling system. Although HSI models are available from USFWS, original models can be developed by individuals or committees based on professional experience, expert advice, and literature sources (USFWS 1981). Computer programs are available to speed the calculations.

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[1] Personal Communication, 1991. Dr. Tom Roberts, Department of Biology, Tennessee Technical University, Cookeville, TN.

[2] Personal Communication, 1991. Mark Stauffer, California Department of Transportation.

Nelson (1987) has evaluated HEP's use in estuarine and coastal marine systems. He believes that HEP has been used infrequently in these habitats because few HSI models for marine and estuarine species exist, and users are concerned that the variables measured by existing models do not reflect species' sensitivities. LaSalle and Homziak (1991) conclude that dissolved oxygen, which is often used in HSI models, is of little value in assessing habitat for estuarine and marine species. Nelson (1987) has listed other difficulties involved in using HEP in estuarine and marine systems. One of these is the fact that estuarine habitats are dynamic, so that definition of the habitat boundary is difficult. High natural variability in habitat parameters also makes detection of true changes difficult, at least in the short term. Additionally, estuarine organisms have broad tolerances, so changes in habitat parameters may not result in a detectable effect at the organism level. Furthermore, changes in habitat parameters may cause organisms to move, die, or adapt, thwarting efforts to evaluate habitats at the organism level.

## Environmental Monitoring and Assessment Program

The Environmental Monitoring and Assessment Program (EMAP) is a monitoring program designed by the U.S. Environmental Protection Agency (EPA) to detect long-term trends in natural resources on a national level. The program is described in Hunsaker and Carpenter (1990) and Leibowitz, Squires, and Baker (1991). Hexagons of 40 $km^2$ will be randomly located throughout the United States, and cover types will be identified from aerial photographs, satellite imagery, and National Wetland Inventory data. Representatives of each cover type will be randomly chosen for field sampling. One-fourth of this sample will be visited each year, resulting in complete coverage every four years. Cover types are grouped into six resource categories: near-coastal waters, inland surface waters, wetlands, forests, arid lands, and agroecosystems. Emergent, forested, and shrub/scrub wetlands are included in the wetland resource category; the other estuarine, marine, and tidal river classes are in the near-coastal group. A standard set of characteristics or "indicators" unique to each resource category will be measured for each representative of the resource category. Indicators are divided into a high-priority group, which is ready to be field tested, and a low-priority group, which must be further studied before being field tested. Table 2 describes the high-priority indicators for both resource groups. In addition to field-sampling results, data collected by other programs will be used by EMAP when possible. EMAP's results will be summarized into a report and made available to the public. In addition to annual reports, reports interpreting the data (e.g., identifying the possible cause of a change in the resource) will be prepared every five years.

The EMAP methodology is still in the development stage and is currently being field tested.[1] EMAP is designed to provide an overview of a region's habitats. It is not intended to provide information on specific habitats. Whether data on individual habitats will be made available is currently being debated; one of the major considerations is the landowner's desire for confidentiality versus the Freedom of Information Act. Another consideration is that data will be collected only for representatives of each habitat type in a random sample of the United States, not for all habitats.

It may be possible, however, for an individual to use the EMAP methodology to evaluate a specific habitat, then compare the results to the regional average. This approach has a few drawbacks. The habitat would have to be sampled at the same season and with the same methodology as the EMAP program. Even with this information, a valid statistical comparison could be difficult.[1] Finally, since EMAP looks at some of the characteristics of the wetland, but does not assign functional values, it is not appropriate in its current form for habitat evaluation (Leibowitz, Squires, and Baker 1991).

## Maine Department of Inland Fisheries and Wildlife

The Maine Department of Inland Fisheries and Wildlife (MDIFW) has developed a method to rate coastal habitats in terms of their importance to wildlife. The following description is from Woodward, Hutchinson, and McCollough (1986). Aerial surveys of marine birds and seals in a specific region of the coast are conducted almost every month for a year. Concentration areas are identified from the aerial surveys and are rated according to the proportion of each wildlife species in the region that uses the concentration area each season. Then an accumulative rating for all seasons and species is derived for each concentration area. Concentration areas are placed into classes according to these ratings. Class A areas are of state or national significance; Class B areas are of regional significance; and Class C areas are of local significance. Additional information is derived from ground surveys of nesting marine birds and shorebird feeding areas. These, as well as bald eagle nests, osprey nests, shorebird roosting areas, great blue heron colonies, eider molting sites, and seal haul-outs, are identified as special habitat features.

The entire coastline of Maine has been evaluated with this method, although not all the results have been published.[2] The published information has been released in several reports (including Hutchinson and

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1 Personal Communication, 1991. Nancy Leibowitz, Man Tech Environmental Technology, Inc., Corvallis, OR.

2 Personal Communication, 1991. Alan Hutchinson, Maine Department of Inland Fisheries and Wildfile, Augusta, ME.

Ferrero 1981; Hutchinson and Lovett 1983, 1984; Woodward, Hutchinson, and McCollough 1986), which consist primarily of maps and species lists of the concentration areas. Field testing of this method has been limited.[1] Personal knowledge of the surveyed areas and the results of other studies (e.g., the Midwinter Waterfowl Survey) are consistent with the method's conclusions. The 1979-1980 study of Casco Bay was replicated three years later, but budget concerns prevented rigorous analysis of the data. Initial comparisons were consistent.

## New York State Division of Coastal Resources and Waterfront Revitalization

The New York State Division of Coastal Resources and Waterfront Revitalization (NY DGRWR) has developed a protocol to determine the significance of coastal habitats as part of its Coastal Management Program (Hart and Milliken 1991). The method consists of a rating system for coastal habitats in terms of their support of fish and wildlife species, presence of rare and endangered species, frequency of occurrence, human use, and likelihood of replacement. Areas are designated as significant based on threshold values that have been established for each criterion. Significant areas are reviewed by a professional biologist familiar with the area, which adds to the accuracy of the results. The advantages of the method are that it is relatively straightforward to use and produces accurate results. One drawback is that it has a somewhat narrow focus.

## Puget Sound Estuarine Wetland Restoration Protocol (Puget Sound)

Puget Sound Estuary Program's (1990) Estuarine Wetland Restoration Monitoring Protocol is not strictly a habitat evaluation method, but a system for developing a consistent, scientifically valid protocol for monitoring coastal habitats in the Pacific Northwest. Puget Sound regulators had found it difficult to evaluate proposed and ongoing mitigation projects because of a lack of data that were consistently collected and processed. In response to this need, the Urbanized Estuary Mitigation Working Group, through an exhaustive consensus process involving scientists, users, and regulators, developed a list of representative fish and wildlife species characterizing the eight typical estuarine habitat types and the likely characteristics or attributes important for these species' feeding, reproduction, and refuge. This information provides a framework for developing a monitoring protocol from three perspectives: the type of habitat involved, species or species assemblage critical to the project or area, and key biological and physical characteristics of the habitat. Parameters for monitoring are

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[1] Personal Communication, 1991. Alan Hutchinson, Maine Department of Inland Fisheries and Wildlife, Augusta, ME.

ranked according to their importance (minimum, recommended, preferred). Although the method has been used, it has not been field tested at reference sites using the protocol. Testing of the protocol and development of computer software are in process.

## Benthic Resources Techniques

A number of methods use benthic infauna abundance or biomass as an indicator of habitat value in terms of trophic support for fish and wildlife. A method has been developed specifically for intertidal mud flats by Diaz (1982), although it also has potential for vegetated wetlands and subtidal habitats. The method relies on a graphic comparison of photosynthetically active light and benthic chlorophyll *a*, and the abundance and biomass of major taxonomic groups, to a data base developed from the Chesapeake Bay area. The level of effort required is lower than for other benthic methods because it requires identification of organisms only to a major group. The method has been adapted to New England conditions and successfully utilized, providing results that show agreement with traditional assessment methods (Bowen, Pembroke, and Kinner 1989). The method is an integral part of the WET 2.0 level 2 assessment for aquatic diversity/abundance functional evaluation. Impact assessment may be estimated by computing the reduction in habitat value. This portion of the model, however, may be insensitive to small impacts and overly sensitive to large impacts (Normandeau Associates, Inc. 1987).

Other benthic methods consider infaunal distribution with depth. Models of benthic succession suggest that benthic organisms inhabit shallow depths in disturbed and stressed habitats, and dwell in deepening depths as community "health" increases (Rhoads, McCall, and Yingst 1978). The sediment profile camera (variously called REMOTS and SPI) developed by Rhoads and Cande (1971) provides benthic profile photographs of physical-chemical and biological parameters, such as surface and subsurface characteristics, depth of the redox layer, tube density and type, and presence of infauna. The parameters are used to characterize intertidal and subtidal nonvegetated habitats. Used by themselves or with computerized image processing, the photographs can provide rapid and cost-effective habitat mapping, evaluation, and comparison. Sediment profile imagery has been successfully used in monitoring dredged material disposal activities and as a mapping tool (Rhoads and Germano 1982; 1986; Diaz et al. 1985; Diaz and Schaffner 1988).

Sediment profile imaging has been incorporated into the Luckenback, Diaz and Schaffner (LDS/DE DNR) method (undated), developed for the Chesapeake Bay and currently in use by the Delaware Department of Natural Resources. Phase I of this method determines the presence of large organisms at a 5-cm depth. Phase I may be accomplished through direct sampling to a depth of 26 cm using a box corer or by using a sediment profile camera. Presence of organisms below the 5-cm depth preliminarily indicates a healthy benthic community, whereas absence indicates poor health. Phase I may be sufficient in and of itself, depending on the scope and needs of the assessment. Phases II and III require identification of benthic fauna to family level and determinations of biomass. The results are scored to rank the habitat's benthic community character from poor health/highly disturbed to good health/undisturbed. Results using this method in Delaware and Chesapeake Bay agree well with traditional assessments, yet are produced more rapidly than traditional assessments. Experimentation with the method by the authors of this report indicates that taxonomic indicators would need adaptation to different regions.

The Benthic Resources Assessment Technique (BRAT) (Lunz and Kendall 1982) not only examines benthic resources at various depth strata, categorized according to size, but also the size and depth of benthic fauna consumed by fish and bird species. Fish usage of benthos is determined by examining gut contents of the dominant demersal fish (Lunz and Kendall 1982; Lunz et al. 1988), whereas bird usage is estimated from the bill length and gape of representative shorebirds (Nelson, in preparation). The available benthic resources are compared with the likely fish and bird predators and their favored prey to determine the area's resource value. Although this method more directly estimates resource value and utilization than other methods, data analysis is time-consuming and interpretation of results is difficult. The method has been successfully used in monitoring dredged material disposal (Lunz 1986), and in site selection for open-water disposal (Clarke 1986; Clarke and Kendall 1987). The method can be combined with USFWS's HEP to determine the HSI value for various feeding groups (Nelson, in preparation).

## Guidelines for Mitigation Wetlands

In 1989, EPA published a review of methods for creating mitigation habitats (Kusler and Kentula 1989). Four of the papers included in the review and a similar paper are outlined in Tables 1-4 (Fonseca 1989; Josselyn, Zedler, and Griswold 1989; Broome 1989; Lewis 1989; Thom 1990). Although these papers do not introduce a methodology for assessing habitats, they do provide guidelines for selecting or monitoring a mitigation site. They are included in this review because they discuss created habitats, and the guidelines could form a basis for an evaluation methodology.

The guidelines for monitoring created habitats suggest that characteristics of vegetation growth be compared to those of natural sites or the impacted habitat, to standards agreed upon at the start of the project or to published data (Fonseca 1989, Broome 1989, Lewis 1989). Whether the created habitat functions like a natural system is not evaluated. Lewis (1989) explains that the lack of a consistent data base of habitat characteristics in Florida and natural variability among reference habitats limit the useful characteristics that can be measured. Recommendations for monitoring periods range from two (Fonseca 1989) to five years (Broome

1989). Photographic records are also suggested (Broome 1989, Lewis 1989).

Guidelines for site selection look at a wider range of parameters than do those for monitoring. Waves, elevation, sediment type, and salinity are examples of the type of parameters measured (Table 2). Lewis (1989) and Thom (1990) tend to give fairly specific guidelines for parameter values. Josselyn, Zedler, and Griswold (1989) and Broome (1989) suggest the parameters to measure (Table 2), but do not recommend values for most of them.

## Virginia Institute of Marine Science

This methodology is described by Silberhorn, Daives, and Barnard (1974). The following description is based on that publication.

The Virginia Institute of Marine Science (VIMS) in 1974 proposed a methodology to fulfill its obligations under the Virginia Wetlands Act of 1972 (Code of Virginia 62.1-13.1), which requires the Virginia Marine Resources Commission, with VIMS' help, to produce "guidelines which scientifically evaluate wetlands by type and which set forth the consequences of use of these wetlands types" (Code of Virginia 62.1-13.4, cited by Silberhorn, Daives, and Barnard 1974). The resultant methodology can be used by a lay person. It requires the user to determine the dominant vegetation species and the size of the area to be assessed. The user can then match the area with any of 12 wetland types. The description of each habitat type includes an assessment of the values of five functions: production and detritus availability, waterfowl and wildlife utilization, erosion buffer, water quality control, and flood buffer.

The habitat types are divided into groups based on the values of these functions. These groups are ranked according to the relative importance of preservation. Areas above a certain size—0.1 acre (400 $m^2$) or 2 ft (0.6 m) wide—are automatically considered to have significant values.

This method is sufficiently simple to be used by a lay person. However, this simplicity limits the results to general statements about the habitat type. No information about the specific area is provided. The method is useful only in project planning and selecting sites for preservation.

## Other Methods

The U.S. Department of Agriculture (1978) developed criteria to establish the value of 85 Massachusetts coastal areas as fish and wildlife habitats. Among the factors considered are size and type of area, number of habitat types, and presence of buffer areas. Human use was also taken into consideration by including criteria such as boating and hunting access, visual quality, and habitat uniqueness. This study is useful in that the criteria and rationale could be used in the adaptation or creation of a coastal habitat evaluation method.

Dee et al. (1973) developed an "environmental evaluation system" for riverine systems that has components that could be adapted for coastal use. An evaluation of environmental impact is obtained in four areas: ecology, pollution, aesthetics, and human interest. Each category is divided into more specific components. An area is given a score from 0 (poor quality) to 1 (good quality), based on the measurements for a variety of parameters. A second score is obtained for the area based on the presence of a proposed project. Comparison of the two scores (with and without the project) allows impact assessment.

The Biological Evaluation Standardized Technique (BEST) was developed by MEC Analytical Systems of Carlsbad, California, to determine the ecological value of coastal and wetland habitats. BEST may currently be used for open coast sand bottom, open coast reefs, protected shallow waters and bottom, protected deep waters and bottom, hard bottom, kelp beds, embayments, and natural and restored wetlands. Habitats are evaluated by determining an area's value in terms of productivity, living space, nursery area, feeding area, and spawning area for targeted fish species. Quantitative data are used in the assessment, which are then summarized over habitat types and species. The results may be used in developing mitigation plans for impacted areas. BEST has been used to compare the value of undisturbed reef habitats off the coast of California to artificial reefs and sand bottom habitats in the Port of Los Angeles, and in comparing the value of mitigation wetland sites to similar undisturbed areas in Anaheim Bay, California. The Ports of Los Angeles and Long Beach own the copyright for the BEST program, and MEC Analytical Systems is the sole licensed user.

Several other methods were found but were not thoroughly evaluated because they were not true evaluation methods or were not yet complete.

The U.S. Army Engineer Division, New England is requesting that applicants for a permit under Section 404 do not use an evaluation technique.[1] Instead, they ask for a description of how the area performs each of several functions traditionally associated with wetlands. These functions are groundwater recharge/discharge, flood storage and desynchronization, sediment and shoreline stabilization, sediment/toxicant retention, nutrient retention/transformation, nutrient export, aquatic diversity/abundance, fish and shellfish habitat, wildlife habitat, endangered species, consumptive recreation, nonconsumptive recreation, and uniqueness/heritage (U.S. Army Engineer Division, New England 1991). New

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[1] Personal Communication, 1991. Terry Flieger, USAED, New England, Waltham, MA.

England Division uses these descriptions to decide for itself whether the area is valuable.[1]

A few evaluation methods are still in the development phase. Paul Adamus has written assessment of evaluation methods for freshwater wetlands and coastal habitats for the World Wildlife Fund.[2] It is still in draft form and can be obtained from Mr. Adamus. Candy Bartholdus of Environmental Concern, Inc., (St. Michael's, MD) is developing a procedure to evaluate the functional values of impacted coastal wetlands that may ultimately be used in the design and monitoring of mitigation sites. The procedure uses "elements" (= features or predictors) to determine the relative value of six functions (shoreline bank erosion control, sediment stabilization, wildlife, water quality, fisheries (tidal, nontidal riverine, or nontidal pond/lake), and uniqueness/heritage). The method, designed for nationwide use in emergent coastal wetlands, may also be used to develop critical design features to improve or ensure high functional value.

The Index of Biotic Integrity (IBI) (Miller et al. 1988), first developed for freshwater streams in the Midwest, is currently being adapted for estuarine use. IBI assesses a water body's "ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley 1981 as cited by Miller et al. 1988). It does this by measuring the fish population's characteristics (metrics), which are grouped into three categories: species richness and composition, proportion of fish at different trophic levels, and fish abundance and health. Each category is assigned a score of 5 (undisturbed condition), 3 (somewhat altered), or 1 (high degree of perturbation) based on the result of fish surveys.

Thompson and Fitzhugh (1986) began a preliminary adaptation of IBI for estuaries in Louisiana. They kept the same three categories, but changed the actual characteristics measured to reflect estuarine conditions. The seasonality of estuarine fish and macroinvertebrates, unlike freshwater fish, necessitates quarterly sampling to adequately assess the habitat. A preliminary list of prototype metrics (characteristics) were developed to assess the health of the Calcasieu River (LA) fish population:

*a.* Number and type of estuarine species.

*b.* Presence of large freshwater fish.

*c.* Dominance by bay anchovies or other species.

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1 Personal Communication, 1991. Terry Flieger, USAED, New England, Waltham, MA.

2 Personal Communication, 1991. Man Tech Environmental Technology, Inc., Corvallis, OR.

*d*. Presence of range of specialized feeders.

*e*. Presence of postlarvae and juveniles.

*f*. Presence of disease.

The authors indicated that these characteristics needed additional refinement before a scoring method could be developed. Dr. Linda Deegan of the Marine Biological Laboratory in Woods Hole, Massachusetts, is currently working on the method; the States of Maryland and Florida are interested in using it.[1] Dr. Deegan could not be contacted because she was not available at the time of this review.

A publication that was requested from the Maryland Department of Natural Resources (undated) has not yet been received. Another reference about monitoring mitigation habitats (Horner and Raedeke 1989) could not be obtained in time for review. This sampling and analysis protocol was developed specifically for comparing mitigation areas with natural habitats. Although developed for freshwater habitats, it has been successfully used in coastal habitats. The publication outlines a series of procedures to evaluate a variety of functions such as hydrology, water quality, soil characteristics, and fauna.[2]

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[1] Personal Communication, 1991. B. A. Thompson, Louisiana State University, Baton Rouge, LA.

[2] Personal Communication, 1991. Dr. R. Horner, University of Washington, Seattle, WA.

# 3 Discussion

## Habitat Representation

Habitat evaluation methodologies were available for all types of coastal habitats. Theoretically, all classes of coastal habitats could be evaluated using WET, HEP, EMAP, NY DCRWR's methods, and MDIFW method (Table 1), since these methods are not specific to habitat class. However, only EMAP and MDIFW (marine mammal use only) and a few HEP models explicitly consider hard-bottom habitats (e.g., rock bottom, reef, and rocky shore; or algal bed on rocky shore). Methods that have been specifically developed for these habitats are unknown to the authors.

## Method Validity

One of the most basic questions is whether suitable methodologies can be developed that accurately represent habitat value. Oviatt, Nixon, and Garber (1977) believe that the inherent variability in one habitat, salt marshes, and difficulty in delineating ecological boundaries make it impossible to develop a scientifically valid "ecological rating system." They further question whether rating systems ultimately result in the facilitation of development in lower rated habitats.

Similarly, the New England Division has decided that habitat descriptions and estimations of how well the habitats perform various wetland functions are more accurate than results of habitat evaluation methods such as WET.[1] Other researchers have found that the complexity and

[1] Personal Communication, 1991. Terry Flieger, USAED, New England, Waltham, MA.

variability in estuarine systems complicate the development of such a system (Nelson 1987)[1] or result in counterintuitive results[2].

## Method Evaluation

Selection of an appropriate habitat evaluation method depends on its ultimate purpose and use. The methods evaluated for this report meet a variety of needs. Among the considerations for model selection are:

*a.* Are all habitat values important, or is the focus on fish and wildlife use?

*b.* Do the results need to be understood by those who lack a technical background?

*c.* Is the application for a specific wetland class or region?

*d.* What time and cost constraints are involved?

The results of this evaluation indicate that there is no single method that can be used on a nationwide basis for all coastal habitats. Although WET was designed for this purpose, most users were dissatisfied with the results for a variety of reasons. Other methods focus on key values such as fish or wildlife use (NYDCWR, MDIFW), key fish and wildlife species (HEP), benthic resources (BRAT, Diaz, LDS/DE DNR, REMOTS or SPI) or plant productivity (Fonseca 1989, Thom 1990) Some states (New York and Maine) are designating significant coastal areas, which may preclude the need for evaluating individual habitats.

Other methods are in the development state. EPA's EMAP program and Puget Sound's Estuarine Wetland Restoration Monitoring Protocol both address the need for data that are consistently collected and analyzed, providing a reference for comparison. These studies will ultimately enhance the ability to evaluate coastal habitats. IBI, a successful technique for rapid bioassessment of stream habitats, is currently being adapted for estuarine use. Techniques designed specifically for mitigation areas, such as the technique being developed by Candy Bartholdus (Environmental Concern, Inc.) and Horner and Raedeke (1989) also show promise.

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[1] Personal Communication, 1991. B. A. Thompson, Louisiana State University, Baton Rouge, LA.

[2] Personal Communication, 1991. C. Mason, Vanasse Hangen, Brustlin, Inc., Providence, RI.

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**Table 1**
**Evaluation Methods Available for Each Coastal Habitat Type**

| Habitat System/Subsystem[1] | Habitat Class/Subclass[1] | Methods (see text) |
|---|---|---|
| Marine Subtidal (M1) | All<br>Aquatic bed-rooted vascular (M1AB3)<br>Unconsolidated bottom (M1UB) | WET, HEP, MDIFW, NY DCRWR<br>Thom (1990), Fonseca (1989)<br>LDS/DE DNR, BRAT |
| Marine Tidal (M2) | All<br>Aquatic bed-rooted vascular (2AB3)<br>Unconsolidated shore (M2US) | WET, HEP, MDIFW, NY DCRWR<br>Thom (1990), Fonseca (1989)<br>LDS/DE DNR, Diaz (1985) |
| Estuarine Subtidal (E1) | All<br>Aquatic Bed (E1AB)<br>Aquatic bed-rooted vascular (E1AB3)<br>Unconsolidated bottom (E1UB) | WET, HEP, EMAP (near coastal)<br>Puget Sound, MDIFW, NY DCRWR,<br>Thom (1990), Fonseca (1989)<br>LDS/DE DNR, BRAT |
| Estuarine Intertidal (E2) | All<br>Aquatic bed (E2AB)<br>Aquatic bed-rooted vascular (E2AB3)<br>Unconsolidated shore (E2US)<br>Emergent wetland (E2EM) | WET, HEP, EMAP (near coastal),<br>Puget Sound, MDIFW, NY DCRWR<br>VIMS (1974)<br>Thom (1990, Fonseca (1989)<br>LDS/DE DNR, Diaz (1985)<br>Josselyn, Zedler, and Griswold (1989), Broome (1989), Lewis (1989),<br>VIMS (1974) |
| Riverine Tidal (R1) | All | WET, HEP, EMAP (near coastal), MDIFW |

[1] After Cowardin et al. (1979)

**Table 2**
**Data Input Type, Output Form, and Coastal Habitat Class for Each Evaluaton Method**

| Method | Habitat System Class (Tidal)[1] | Data Required | Form of Output |
|---|---|---|---|
| WET | All | Answers to series of questions. | Relative rating (high, moderate, low) of habitat's potential to provide opportunity, effectiveness, and social significance of 11 functions. |
| HEP | All | Depends on models selected. Generally, requires data on vegetation, sediment, and water column features. | Quantitative ratings in form of habitat units, evaluation forms. |
| EMAP | M, E, R1 | Satellite and aerial infrared photographs. Indicators have not yet been selected, but those being tested include habitat size; surveys of benthos, vegetation, fish, sediments, water column, including toxicity and contaminants. Existing data. | Annual statistical summary reports; periodic interpretative reports, scientific reports, and journal articles. |
| MDIFW | M, E, R1 | Aerial surveys of marine birds, seals, shorebird roosts, nests of bald eagle, osprey, great blue heron; ground surveys of nesting marine birds, shorebird feeding locations. | Maps of important habitats, special features; tables of species at each site. |
| NY DCRWR | M, E | Information on resident fish and wildlife species, threatened and endangered species, ecosystem variety and replaceability. | Designation of significance based on numerical value. |
| Puget Sound | E1UB, AB, E2US, AB, EM | Variety of biological data depending on sampling design. | Sampling protocol for monitoring. |
| LDS/DE DNR | M1UB, M2US, E1UB, E2US | Benthic infauna biomass and taxonomy (to family or class). | Benthic habitat rating from poor/highly disturbed to good/undisturbed. |

*Sheet 1 of 3*

[1] After Cowardin et al. (1979).

| Table 2 (Continued) | | | |
|---|---|---|---|
| **Method** | **Habitat System Class (Tidal)** | **Data Required** | **Form of Output** |
| Diaz (1985) | M2US, E2US | Benthic infauna biomass and abundance of major groups; sediment chlorophyll *a*. | Relative value (low, moderate, high) for primary producers, support populations. |
| BRAT | M1UB, E1UB | Benthic infauna biomass by depth stratum, major group, and size category. Demersal fish stomach contents, by fish species and size class. Biomass as for benthic infauna for bird usage. | Report describing benthic resource potential for fish/bird. |
| Thom (1990) | M1AB3, M2AB3, E1AB3, E2AB3 | Turbidity, sediment, wave action, slope, water at low tide, depth, light, nutrients, salinity, temperature. | Description of site to compare to guidelines in article. |
| Fonseca (1989) | M1AB3, M2AB3, E1AB3, E2AB3 | Survival of planting units, average number of shoots, area covered per planting unit. | Area coverage and number of shoots per planting unit, to be compared to published data or impacted wetland. |
| Josselyn, Zedler, and Griswold (1989) | E2EM | WET 2.0 <u>or</u> HEP <u>or</u> yearlong data on habitat use <u>or</u> site history, topography, water control structures, hydrology, flood events, sediment budget, edaphic characteristics, existing vegetation, existing wildlife, adjacent site conditions. | Could be results from WET 2.0 or HEP; species lists; or maps, photographs, wildlife lists, and reports. |
| Broome (1989) | | | |
| <u>Mitigation site selection</u> | E2EM | Elevation, slope, tidal range, salinity, substrate, sedimentation, sunlight, traffic, herbivory, sediment contamination. | Not specified. |
| <u>Monitoring</u> | E2EM | Photographs, growth measurements of vegetation (e.g., height, number of stems, cover, basal area, aboveground and belowground biomass, percent cover, percent cover by species, number of colonizers, vigor, color. | Quantitative growth measurements to compare to natural sites; photographic record. |

| Table 2 (Concluded) | | | |
|---|---|---|---|
| **Method** | **Habitat System Class (Tidal)** | **Data Required** | **Form of Output** |
| Lewis (1989) | | | |
| Mitigation site selection | E2EM,FO | Exposure to waves, tidal range, elevation of planting, salinity, shading. | Not specified. |
| Monitoring | E2EM,FO | From 1-$m^2$ plots: vegetation height, percent cover in plot, aboveground and belowground biomass. Photographs. | Photographic record; percent survival and percent cover compared to project goals. |
| VIMS (1974) | E2EM, SS, AB | Wetland type based on dominant vegetation and habitat size. | Functional values and relative importance of each general habitat type are provided. No output is specific to the area itself. |
| | | | *Sheet 3 of 3* |

**Table 3**
**Level of Effort, Relative Cost, Expertise Required, and Potential Uses for Each Evaluation Method**

| Method | Field Studies | Lab Studies | Expertise Required | Potential Uses | Time | Relative Cost of Specialized Equip., Lab Tests |
|---|---|---|---|---|---|---|
| WET | Depends on level of assessment. | Depends on level of assessment. | Wetland Scientist | Planning, regulatory, impact assessment, mitigation. | < 1 week. | Low |
| HEP | Depends on models selected, no. of cover types and sample stations. | Depends on models selected, no. of cover types and sample stations. | Scientist | Project planning; impact assessment; management; mitigation site selection, planning, monitoring; preservation needs. | According to USFWS (1980), a detailed water study with 3 proposed actions, 20 evaluation species, 5 cover types, & a 20,000-acre area would require 58-89 work days if a computer were used. | Depends on models selected. |
| EMAP | Annual collection of data on a 4-year rotation. | Many of the indicators require laboratory analysis. | Multidisciplinary teams. | Impact assessment, management preservation/ legislative needs. | Compilation of data collected throughout the United States. | Depends on which indicators are eventually selected. Many require specialized tests. |
| MDIFW | Monthly aerial surveys for a year; ground surveys conducted during 4 months. | NONE | Scientist | Project planning, mitigation site selection, preservation/ legislative needs, impact assessment, management. | Compilation of a year of data for an entire bay. | Airplane rental; boat rental. |
| NY DCRWR | Site visit recommended. | NONE | Biology/Ecology | Regulatory, coastal management plans. | < 1 week. | Low |
| Puget Sound | Depends on protocol. | Depends on protocol. | Fisheries/Wildlife Biologist | Planning, regulatory mitigation. | Depends on protocol. | Depends on protocol. |

## Table 3 (Continued)

| Method | Field Studies | Lab Studies | Expertise Required | Potential Uses | Time | Relative Cost of Specialized Equip., Lab Tests |
|---|---|---|---|---|---|---|
| LDS/ DE DNR | Benthic sampling. | Benthic sample, analysis biomass. | Benthic taxonomy. Possibly SCUBA or sediment photography. | Planning, regulatory, impact assessment. | < 1 week. | Potentially high for field equipment (box corer, benthic camera). |
| Diaz (1985) | Benthic sampling seasonally. | Benthic sample analysis, biomass. | Benthic taxonomy. | Planning, regulatory, impact assessment, management mitigation. | < 1 week per season. | Low (Chlorophyll *a* analysis). |
| BRAT | Benthic infauna and demersal fish sampling. | Benthic sample, fish stomach analysis. | Benthic taxonomy, fisheries biology or ornithology. | Planning, impact potential, regulatory and mitigation. | Weeks - months | High (offshore field sampling). |
| Thom (1990) | Some parameters must be sampled repeatedly for 1 year. | NONE | Scientist | Management, mitigation site selection. | One year | NONE |
| Fonseca (1989) | 8 field visits in a 3-year period. | NONE | Few hours of training; possibly trained in SCUBA. | Impact assessment, management, monitoring mitigation site. | 3 years | SCUBA equipment |
| Josselyn, Zedler, and Griswold (1989) | Depends on method. Ranges from WET 2.0 to yearlong data on species presence. | NONE | Multidisciplinary team or scientist. | Mitigation site selection, project planning, impact assessment, management, preservation needs. | Depends on method. Up to one year. | NONE |

***Sheet 2 of 3***

| Table 3 (Concluded) | | | | | | |
|---|---|---|---|---|---|---|
| **Method** | **Field Studies** | **Lab Studies** | **Expertise Required** | **Potential Uses** | **Time** | **Relative Cost of Specialized Equip., Lab Tests** |
| Broome (1989) | Site selection: Methods not specified. Monitoring: 4-6 weeks after planting, then after growing season for 3-5 years. | Biomass | Scientist | Management; mitigation site selection, monitoring. | 3-5 years for monitoring | Minimal |
| Lewis (1989) | Site selection: Methods not specified. Monitoring: quarterly sampling for 2 years. | Biomass | Scientist | Management; mitigation site selection, monitoring. | 2 years of monitoring | Minimal |
| VIMS (1974) | 1 visit to determine size and dominant vegetation | NONE | Lay | Project planning, management preservation needs. | Minimal | NONE |

## Table 4
## Primary Use, Strength, Weaknesses, and Applicability of Evaluation Methods

| Methods | Primary Use | Strengths | Weaknesses | Applicability |
|---|---|---|---|---|
| WET | Relative value of habitat's potential to provide key functions. | Assesses all wetland functions; relatively rapid; can be used for mixed habitat types; computer program available; "Black Box" approach reduces potential for bias. Based on exhaustive literature review. | Without computer, tabulation is tedious; potential for inaccuracy for coastal habitats; results difficult to interpret; "Black Box" approach reduces model understanding. | Nationwide for all wetland types. |
| EMAP | As an indicator of environmental health throughout the U.S. on a long-term basis. | Can indicate trends over time; consistent across the country; can indicate what is causing change in an ecosystem; can indicate effects of stressors (e.g., pollutants). | Does not evaluate habitat functions. Information presented at regional level; data may not be available for individual wetlands because of confidentiality of data; trend information at any particular site will require 40 to 60 years; still in development stage. Indicators to be surveyed are not finalized. | Information presented at regional level for entire U.S. |
| MDIFW | Determination of important wildlife habitat. | Provides baseline information on selected wildlife use of habitats in a large area which can be used for later project planning, impact assessments. | Does not look at fish or benthos; one year's data may not be representative; needs to be more intensively field tested; too expensive to be produced by individual user. | Developed for State of Maine. |
| HEP | Measure of habitat quality in relation to a certain species or group of species. | Adaptable; can be used in most cover types; quantitative rating; computer program available. | Looks at suitability of habitat to individual species; results dependent on which species chosen; USFWS models available only for some species; some not field tested; or require adaptation to region. | Developed for nationwide use. |

**Table 4 (Continued)**

| Methods | Primary Use | Strengths | Weaknesses | Applicability |
|---|---|---|---|---|
| NYS DCRWR | Determination of significance of habitat based on fish/wildlife use, threatened/endangered species, ecosystem rarity/ replaceability. | Simple, straightforward. No extensive/costly data requirements. | Focus on fish/wildlife. | Developed for NY state but could be expanded. |
| Puget Sound | Development of monitoring protocol for assessing fish/wildlife use of created habitats. | Scientifically accurate; developed by consensus, so likely acceptability high; ensures consistency in monitoring. | Not an evaluation method; restricted to Puget Sound; focus on fish/wildlife. | Limited in scope & region at this point in time, but method development in progress. |
| LDS/DE DNR | Habitat quality based on benthic infauna. | Ground truths well, more rapid than traditional survey. | Lab work potentially time-consuming; subtidal sampling needs box corer or SCUBA diver; focus on benthic resources. | Developed for Chesapeake Bay but adaptable to other regions. Currently in use for Delaware Department of Natural Resources Marina permitting. |
| Diaz (1985) | Determination, relative habitat value based on benthic resources. | Ground truths well; relatively rapid. | Focus on benthic resources; ignores depth distribution of benthos; relies on matrices developed from limited data. | Developed for Chesapeake Bay tidal flats; adapted for New England & other habitat types. |
| BRAT | Benthic resource potential for fish/birds. | Accurate when representative sample obtained. | Results can be difficult to interpret; focus on wildlife potential. | Nationwide, subtidal. Intertidal fish as yet unproven. |
| Thom (1990) | Selection of mitigation sites. | Recommendations are based on results of 17 transplant projects. | Guidelines for evaluation, not a method; discusses what data are needed, but not how to collect it. | Pacific Northwest |
| Fonseca (1989) | Monitoring mitigation sites. | Straightforward. Three years of monitoring. | Guidelines for evaluation, not a method; considers vegetation growth not wetland functions. | Discusses nationwide problems. |

**Table 4 (Concluded)**

| Methods | Primary Use | Strengths | Weaknesses | Applicability |
|---|---|---|---|---|
| Josselyn, Zedler, and Griswold (1989) | Selection of mitigation sites. | Evaluates development and mitigation sites; gives several methods to choose from. | Guidelines for evaluation, not a method; discusses what data are needed but not how to collect it. | Developed for California. |
| Broome (1989) | Selection and monitoring of mitigation sites. | Discusses what parameters would be important for an evaluation method. | Guidelines for evaluation, not a method; looks at physical features, vegetation growth, not functional value; discusses what data are needed for site selection, but not how to collect it. | Florida |
| Lewis (1989) | Selection and monitoring of mitigation sites. | Recommendations are based on success/failure of various mitigation sites. | Vague; guidelines for evaluation, not a method. Looks at physical features vegetation growth, not functional value; discusses what data are needed for site selection, but not how to collect it. | Florida |
| VIMS (1974) | To evaluate habitats by wetland type and to identify the consequences of their use (in accordance with code of Va., 62.1). | Easy for lay person to use; good description of each habitat type and its five functions. | Does not examine values specific to individual habitats; habitat types are limited to those for which a description is provided; groups all freshwater wetlands together. | Coastal Virginia |

*Sheet 3 of 3*