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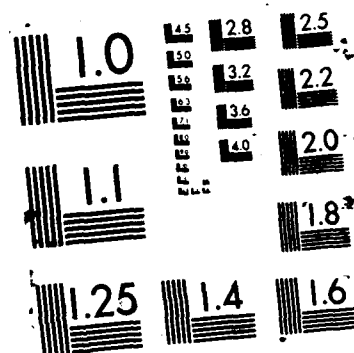
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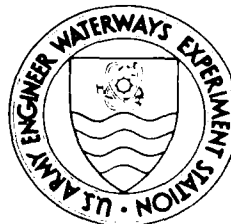
USE OF HABITAT EVALUATION  
PROCEDURES IN ESTUARINE AND  
COASTAL MARINE HABITATS

by

David A. Nelson

Environmental Laboratory

DEPARTMENT OF THE ARMY  
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July 1987

Final Report

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Prepared for DEPARTMENT OF THE ARMY  
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| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       |                                          |                                                                                                  | Form Approved<br>OMB No. 0704-0188                 |                    |
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| 1a. REPORT SECURITY CLASSIFICATION<br>Unclassified                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |       |                                          | 1b. RESTRICTIVE MARKINGS                                                                         |                                                    |                    |
| 2a. SECURITY CLASSIFICATION AUTHORITY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |       |                                          | 3. DISTRIBUTION / AVAILABILITY OF REPORT<br>Approved for public release; distribution unlimited. |                                                    |                    |
| 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |                                          |                                                                                                  |                                                    |                    |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S)<br>Miscellaneous Paper EL-87-7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |                                          | 5. MONITORING ORGANIZATION REPORT NUMBER(S)                                                      |                                                    |                    |
| 6a. NAME OF PERFORMING ORGANIZATION<br>USAEWES<br>Environmental Laboratory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       | 6b. OFFICE SYMBOL<br>(If applicable)     | 7a. NAME OF MONITORING ORGANIZATION                                                              |                                                    |                    |
| 6c. ADDRESS (City, State, and ZIP Code)<br>PO Box 631<br>Vicksburg, MS 39180-0631                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |       |                                          | 7b. ADDRESS (City, State, and ZIP Code)                                                          |                                                    |                    |
| 8a. NAME OF FUNDING / SPONSORING ORGANIZATION<br>US Army Corps of Engineers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       | 8b. OFFICE SYMBOL<br>(If applicable)     | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER                                                  |                                                    |                    |
| 8c. ADDRESS (City, State, and ZIP Code)<br>Washington, DC 20460-1000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |       |                                          | 10. SOURCE OF FUNDING NUMBERS                                                                    |                                                    |                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |       |                                          | PROGRAM<br>ELEMENT NO.                                                                           | PROJECT<br>NO.                                     | TASK<br>NO.        |
| 11. TITLE (Include Security Classification)<br>Use of Habitat Evaluation Procedures in Estuarine and Coastal Marine Habitats                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |       |                                          |                                                                                                  |                                                    |                    |
| 12. PERSONAL AUTHOR(S)<br>Nelson, David A.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |                                          |                                                                                                  |                                                    |                    |
| 13a. TYPE OF REPORT<br>Final report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |       | 13b. TIME COVERED<br>FROM _____ TO _____ |                                                                                                  | 14. DATE OF REPORT (Year, Month, Day)<br>July 1987 |                    |
| 15. PAGE COUNT<br>18                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |       |                                          |                                                                                                  |                                                    |                    |
| 16. SUPPLEMENTARY NOTATION<br>Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |       |                                          |                                                                                                  |                                                    |                    |
| 17. COSATI CODES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |                                          | 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)                |                                                    |                    |
| FIELD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | GROUP | SUB-GROUP                                | Habitat Assessment HEP                                                                           |                                                    |                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |       |                                          | Habitat Evaluation Procedures HSI                                                                |                                                    |                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |       |                                          | Habitat Suitability Index                                                                        |                                                    |                    |
| 19. ABSTRACT (Continue on reverse if necessary and identify by block number)<br>The Habitat Evaluation Procedures (HEP) accounting system is suitable for application in estuaries. However, application of the Habitat Suitability Index (HSI) component of HEP can be problematic because of the complex, dynamic nature of estuaries. HEP has not been applied frequently in estuarine settings. It is best known for its application in upland environments and secondly for its application in freshwater environments. The limited application of HEP in estuarine/coastal environments is probably due to two factors: the small number of models available for estuarine or coastal marine species and the concern that species indigenous to estuarine and coastal marine habitats are inherently insensitive to changes in physical and chemical conditions used as variables in HSI models for these species.<br><br>The difficulties in estuarine/coastal marine applications of HEP/HSI are that (a) the habitat may not be the issue, (b) the habitats may not be definable, (c) a chemical or physical change may not be detectable, and (d) a biotic response may not be detectable. |       |                                          |                                                                                                  |                                                    |                    |
| 20. DISTRIBUTION / AVAILABILITY OF ABSTRACT<br><input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |       |                                          | 21. ABSTRACT SECURITY CLASSIFICATION (Continued)<br>Unclassified                                 |                                                    |                    |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |       |                                          | 22b. TELEPHONE (Include Area Code)                                                               |                                                    | 22c. OFFICE SYMBOL |

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19. ABSTRACT (Continued).

Key assumptions associated with HSI model technology should be understood before undertaking an application. HSI models have generally been developed for species that are economically, esthetically, scientifically, legally, and/or politically important. Species with low mobility, specific habitat requirements, and high detectability are best suited for habitat quality measurements. In addition, a species should exhibit a preference for a range of habitat conditions. Fishes are less suitable for HEP assessments in estuarine habitats because of their transient nature and difficulties in sampling them quantitatively. Macrobenthos and submergent vegetation are regarded as good environmental indicators because of their sedentary nature. Also, they can be quantitatively and efficiently sampled. Macrobenthos and submergent vegetation may not be as socially relevant as fishes. A link to socially relevant species should be made before a change is considered adverse or beneficial. Species selection may be improved with the use of a habitat classification scheme and/or guilds.

The US Fish and Wildlife Service has published models that must be modified for them to be more accurate predictors of a selected measurable response. Salinity, substrate, water temperature, vegetation, and dissolved oxygen are variables most commonly used in the published models. Variables in project-specific models should be limited to those to which a species responds, that can be easily measured and predicted, that will likely be changed by a project, and that may be influenced by planning and management decisions. Because of the natural variability of water quality measurements in estuaries, they are difficult to measure and predict. Substrate, vegetation, current velocity, and depth (bathymetry) may be the most useful variables in project-specific models.

HEP is being used more frequently in coastal marine and estuarine habitats. As the use of HEP increases, new models are needed to focus on species that are the best indicators of a habitat and habitat changes. A more thorough understanding of the attributes and limitations of alternative species, variables, and modifications for HSI models is needed for estuarine and coastal marine systems because of their physicochemical complexity and variability. Monitoring and evaluation of predictions as part of the HEP/HSI process are needed and are critical to improving and refining the use of habitat information for fish and wildlife planning. The HEP framework allows for almost any input that gives quantity and quality (converted to a 0.0 to 1.0 scale) of a habitat. The HSI models are only one type of input. To improve the flexibility of HEP in estuarine and coastal marine systems, alternative inputs into the HEP accounting system are needed.

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## Preface

This report was sponsored by the Office, Chief of Engineers (OCE), US Army, as part of the Environmental Impact Research Program (EIRP), Work Unit 32390, entitled Application of Habitat-Based Evaluation Methods. The Technical Monitors for the study were Dr. John Bushman and Mr. Earl Eiker of OCE and Mr. David B. Mathis, Water Resources Support Center. The draft final report was prepared during the period October 1985 to September 1986.

This report was prepared by Mr. David A. Nelson, Coastal Ecology Group (CEG), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). Mr. Nelson was principal investigator for this report, under the general supervision of Mr. Edward J. Pullen, Chief, CEG; Dr. Conrad J. Kirby, Jr., Chief, Environmental Resources Division; and Dr. John Harrison, Chief, EL. Dr. Roger Saucier, WES, was Program Manager of EIRP. The following are gratefully acknowledged for their reviews of this report: Ms. Jean O'Neil, Wetlands and Terrestrial Habitat Group, EL, and Mr. John D. Lunz, Dr. Douglas G. Clarke, and Dr. Jurij Homziak, CEG. The report was edited by Ms. Lee T. Byrne of the WES Information Products Division, Information Technology Laboratory.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

Cover photograph of pumpkinseed fish is used courtesy of Carolina Biological Supply Company.

This report should be cited as follows:

Nelson, David A. 1987. "Use of Habitat Evaluation Procedures in Estuarine and Coastal Marine Habitats," Miscellaneous Paper EL-87-7, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.



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## USE OF HABITAT EVALUATION PROCEDURES IN ESTUARINE AND COASTAL MARINE HABITATS

### Introduction

1. The Habitat Evaluation Procedures (HEP) accounting system is suitable for application in estuarine and coastal marine habitats. However, application of the Habitat Suitability Index (HSI) component of HEP can be problematic because of the complex, dynamic nature of these systems. To effectively apply HEP in these systems, a better understanding of HEP and associated models is needed. This paper identifies the attributes and limitations of using HEP/HSI and the future needs for applications of HEP/HSI in estuaries.

### Background

#### Habitat Evaluation Procedures

2. Simply defined, HEP is a method of assigning a number to an area to represent its value to a plant or animal in terms of both quantity and quality. This accounting procedure was developed by the US Fish and Wildlife Service (USFWS) (1980) as a standardized, structured evaluation framework that can be used to quantify, display, and document a habitat assessment process. The HEP accounting framework combines habitat area (acres/hectares) and habitat quality to determine its basic accounting unit, the habitat unit (HU). Estimates of habitat quality have been derived most often from Habitat Suitability Index (HSI) models.

#### Habitat Suitability Index models

3. An HSI model assigns a number to an area to represent its value to a specific plant or animal. These operational planning models are based on the best available information at the time of their preparation.\* HSI values are determined by comparing optimum habitat conditions with study or project area habitat conditions. These conditions are displayed graphically as Suitability Index (SI) curves. The curves allow conversion of chemical and physical

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\* L. J. O'Neil et al. In preparation. "A Procedure to Modify Habitat Suitability Index Models," submitted to the Journal of Wildlife Management.

variable measurements or estimates into standard 0.0 to 1.0 Suitability Index values, which are combined into an HSI. The HSI is then multiplied by the number of acres of the habitat to obtain an HU.

### Application of HEP and HSI Models in Estuaries and Marine Coasts

#### Historical applications

4. HEP has not been applied frequently in estuarine and coastal marine settings (Cordes, Thornhill, and Howard 1985). HEP is known for its application primarily in upland environments and secondarily in freshwater environments. The limited application of HEP in estuarine/coastal environments is due to two factors: first, the small number of models available for estuarine and coastal marine species and, second, the concern that species indigenous to estuarine and coastal marine habitats are inherently insensitive to changes in physical and chemical conditions used as variables in HSI models for these species. However, alternative methods that are standardized and widely accepted for assessing project compensation and alternatives are not available for estuarine settings.

#### Difficulties with HEP/HSI applications

5. The habitat may not be an issue, and the issues may not concern habitats. For example, the issue may be the effects of contaminated material on an organism.

6. Habitats may not be definable. In estuaries, habitats may not be distinctly defined areas, but they may be a physical or chemical gradient (Remane and Schlieper 1971). This is particularly true of water quality variables, such as salinity. Salinity distribution can be shifted by tides, freshwater runoff, winds, sea level changes, and estuarine geomorphology. These factors may vary or cycle on a number of different time scales from hours (tides) to seasons (freshwater runoff) to centuries (sea level change), but they all result in some change in the distribution of salinity and thus estuarine habitats. Estuaries are dynamic rather than static, and as a result, distributions of both salinity and organisms will not remain constant over the long term.

7. A detectable chemical or physical change may not occur. A detectable physical or chemical change may not result from the project or activity because the natural variability of estuarine and coastal marine systems may

mask a human-induced change. For example, a specific site may vary in salinity over a season from 0 to 35 ppt due to the inflows of spring flood waters. A salinity change of 1 to 5 ppt induced by a project activity would be masked by the 35-ppt variation during the spring runoff. Because of hourly, seasonal, and annual variation, extensive, long-term data sets (e.g., 10 years) may be needed to determine the value of a water quality habitat variable, such as salinity. A single point in time measurement will not represent the value of the habitat variable. In addition, short-term changes induced by a project may be masked by the variation in long-term data taken to define a variable. If a project changed salinity for 3 days in an area and this changed value was averaged with daily salinity measurements over a season, the average would be affected minimally. Small, long-term changes in salinity (1 to 4 ppt) may take extensive long-term data sets to detect.

8. A detectable biotic response may not occur. An animal will respond to a physical or chemical change by tolerating, adapting, perishing, or leaving.

9. Because estuaries are very dynamic systems, estuarine organisms have to contend with an ever changing environment. Some have broad tolerances for certain conditions. For example, in the model of the juvenile spot, *Leiostomus xanthurus* (Stickney and Cuenco 1982), both temperature and salinity can be modified by up to 15 units (i.e., by 15° C and 15 ppt) before any adverse effect is noted in the habitat suitability of this fish.

10. Over the long term, organisms may adapt to a change in a condition. This can be seen in the different food resources used by the same organisms in different estuaries or in different habitats. For example, a demersal fish, such as a flounder, may eat amphipods and bivalves in a sand substrate and shift to eating polychaetes in a silt substrate (Lunz and Kendall 1982).

11. Certain estuarine organisms with narrow tolerance ranges and limited motility, such as oysters, may perish or become less productive as a result of a project. However, if the project causes a shift in a variable (e.g., salinity), one location may become less suitable for an organism, whereas another may become more suitable. Both the length of time that an organism takes to colonize the "new" habitat and the species involved determine the magnitude of the impact and determine whether it is adverse or not. If a species is motile, such as a crab or fish, then it can simply shift its activity patterns to adjust to a physical or chemical change. The habitat may

become more or less suitable (i.e., frequented more or less often by the species).

### Use of HSI Models for Estuarine/Coastal Marine Species

#### Assumptions

12. Key assumptions are associated with HSI model technology (Table 1). Personnel should understand these assumptions before undertaking a HSI application. Discussions of these assumptions can be found in USFWS (1980) and Schamberger and O'Neil (1986).

#### Published HSI models

13. The USFWS has published models for estuarine fish and invertebrate species based on the corresponding variables listed in Table 2. HSI models have generally been developed for species that are economically, esthetically, scientifically, legally, and/or politically important. While these may be the species of importance to human beings, they may not necessarily be the species that are the best indicators of a physical or chemical change.

#### Species selection

14. Species with low mobility, specific habitat requirements, and easily documented presence or absence are best suited to habitat quality measurements (Schamberger and O'Neil 1986). In addition, a species should exhibit a preference for a range of certain habitat conditions such that its presence can be correlated with measured features of the habitat (Killgore and Miller 1985).

15. Use of fish species. The use of fish species in HEP assessments has advantages, such as the availability of life history information. In addition, fishes represent a variety of trophic levels, are easily identified, have social relevance, and have mandates for their protection (Karr 1981). However, fishes are less suitable for HEP assessments in estuarine habitats because the daily and seasonal movement of fishes confound correlations of presence or absence of the species with the habitat parameters. Presence data are also limited by the selective nature and the inefficiency of conventional fish sampling equipment, such as the otter trawl (Lunz and Kendall 1982). Estuarine fishes are generally adapted to living in a very dynamic environment. They are able to tolerate a wide range of chemical and physical conditions; therefore, they may be responsive or sensitive only to major,

Table 1

Key Assumptions and Limitations Associated with HSI Model Technology\*

- 
1. Published models and SI curves are hypotheses based on the best data available, not proven scientific fact.
  2. The models are conceptual simplifications and are not designed to pertain to all ecological factors that affect the overall success or standing crop of a species.
  3. The HSI is a measure of habitat quality that is assumed to be linearly related to carrying capacity.
  4. The HSI value is not an index of standing crop. Instead, it is an index of habitat quality based on variables in a model.
  5. The authors of models have chosen appropriate variables for assessing habitat quality.
  6. A model suitable for universal application does not exist, because it is not feasible to develop one in advance to cover all site-specific habitat assessment needs for a species.
  7. Model users have complete discretion and the professional responsibility to modify published models to render them technically acceptable for site-specific applications.
  8. Model users, not authors of published models, are responsible for defending results of site-specific applications.

---

\* Personal communication, 1986, Chris Onuff, National Wetlands Center, Slidell, La.

Table 2

List of Fish and Invertebrate Estuarine HSI Models and VariablesPublished by the US Fish and Wildlife Service

|                                | <u>Salin-<br/>ity</u> | <u>Water<br/>Temp.</u> | <u>DO</u> | <u>Vege-<br/>tation</u> | <u>Sub-<br/>strate</u> | <u>Water<br/>Depth</u> | <u>Turbi-<br/>dity</u> | <u>Other**</u> |
|--------------------------------|-----------------------|------------------------|-----------|-------------------------|------------------------|------------------------|------------------------|----------------|
| Striped<br>bass (11)*          | 1                     | 3                      | 2         | 1                       |                        |                        | 1                      | a, b, c        |
| Spotted<br>seatrout (5)        | 2                     | 2                      |           | 1                       |                        |                        |                        |                |
| Atlantic<br>croaker (6)        | 1                     |                        | 1         | 1                       | 1                      | 1                      | 1                      |                |
| Southern<br>flounder (4)       | 1                     | 1                      | 1         |                         | 1                      |                        |                        |                |
| Gulf<br>flounder (4)           | 1                     | 1                      | 1         |                         | 1                      |                        |                        |                |
| Red drum, larval<br>& juv. (5) | 1                     | 1                      |           | 1                       | 1                      | 1                      |                        |                |
| Spot, juv. (5)                 | 1                     | 1                      | 1         |                         | 1                      | 1                      |                        |                |
| Herring,<br>alewife (5)        | 1                     | 2                      |           |                         | 1                      |                        |                        | d              |
| Herring,<br>blueback (5)       | 1                     | 2                      |           |                         | 1                      |                        |                        | d              |
| Gulf menhaden (9)              | 3                     | 2                      | 1         | 1                       | 1                      |                        |                        | e              |
| Southern<br>kingfish (8)       | 1                     | 1                      | 1         |                         | 1                      |                        |                        | 2 c, e         |
| Littleneck clam (3)            |                       |                        |           |                         | 1                      |                        |                        | c, g           |
| Hard clam (6)                  | 1                     | 1                      | 1         |                         | 1                      |                        | 1                      | c              |
| American<br>oyster (8)         | 2                     |                        |           |                         | 2                      |                        |                        | h, i, j, k     |
| Pink shrimp (5)                | 1                     | 1                      |           | 1                       | 2                      |                        |                        |                |
| Brown shrimp (4)               | 1                     | 1                      |           | 1                       | 1                      |                        |                        |                |
| White shrimp (4)               | 1                     | 1                      |           | 1                       | 1                      |                        |                        |                |
| Dungeness crab<br>(draft)(10)  | 3                     | 5                      |           | 1                       | 1                      |                        |                        |                |

\* Number in parentheses equals the total number of variables in the model.

\*\* a = river discharge, b = freshwater volume input, c = current velocity,  
d = number of zooplankton, e = water color, f = benthic infauna production,  
g = substrate depth, h = abundance of living oysters, i = interval between  
killing floods, j = predator abundance, k = disease intensity.

catastrophic changes (as in the case of the juvenile spot mentioned previously). Fishes and other mobile fauna may respond to thresholds of conditions rather than linearly to a range of conditions as assumed in the models.

16. Use of macrobenthos and submergent vegetation. Macrobenthos and submergent vegetation are regarded as good environmental indicators because of their sedentary nature and thus their susceptibility to physical and chemical alterations. Because their sedentary existence requires a tolerance of short-term variation in environmental conditions, they reflect long-term "integral" conditions (Kendall 1983). In addition, they can be much more quantitatively and efficiently sampled. Some disadvantages of macrobenthos as indicator species, when compared to fishes, are: they have less life history information available, are more difficult to identify, and may not be as socially relevant (this may not hold true for certain macroinvertebrates deemed of importance to human beings, such as oysters and clams).

17. Social relevance of a species. If a physical or chemical change occurs, specific areas become more favorable for some species and less favorable for others. Such changes may not be considered a problem unless one species or community is valued more than another. The important question to ask is whether the predicted change will cause the resource(s) to change in a way that is defined to be adverse. In the case of macrobenthos, if the shift is to macrobenthic species of value as fish food and are readily available to important fish predators, then the change may not be perceived as adverse. Therefore, a link to socially relevant species must and should be made before a change is considered adverse or beneficial (Nichols and Hyman 1982).

18. Use of a habitat classification scheme. It is useful to select species in terms of a habitat classification scheme (Table 3). A general hierarchy of estuarine habitats can be found in Cowardin et al. (1979), and modification for the classification of subtidal benthic habitats can be found in Kendall (1983).

19. Use of guilds. Guilds may be useful in the selection of species (Roberts and O'Neil 1983) and may prevent duplication of species with similar habitat requirements. Duplication of ecologically similar species could lead to unnecessary effort and overestimation of impacts. Guilds may also help in the selection of better indicator species by identifying those species that are most representative of the general attributes of a guild or habitat.

Table 3  
Classification of Estuarine and Marine Habitats\*

| <u>System</u> | <u>Subsystem</u> | <u>Class</u>          | <u>Subclasses</u>                               |
|---------------|------------------|-----------------------|-------------------------------------------------|
| Marine        | Subtidal         | Rock bottom           | Bedrock<br>Rubble                               |
|               |                  | Unconsolidated bottom | Cobble-gravel                                   |
|               |                  |                       | Shell-sand**                                    |
|               |                  |                       | Sand                                            |
|               |                  |                       | Mud                                             |
|               | Intertidal       | Aquatic bed           | Organic<br>Rooted vascular                      |
|               |                  | Reef                  | Algal                                           |
|               |                  |                       | Coral                                           |
|               |                  |                       | Worm                                            |
|               |                  | Rocky shore           | Bedrock                                         |
|               |                  | Unconsolidated shore  | Rubble                                          |
|               |                  |                       | Cobble-gravel                                   |
|               |                  |                       | Sand-shell**                                    |
|               |                  |                       | Sand                                            |
|               |                  |                       | Mud                                             |
|               |                  |                       | Organic                                         |
| Estuarine     | Subtidal         | Rock bottom           | Bedrock<br>Rubble                               |
|               |                  | Unconsolidated bottom | Cobble-gravel                                   |
|               |                  |                       | Sand-shell**                                    |
|               |                  |                       | Sand                                            |
|               |                  |                       | Mud                                             |
|               | Intertidal       | Aquatic bed           | Organic<br>Algal<br>Rooted vascular<br>Floating |
|               |                  | Reef                  | Mollusk                                         |
|               |                  |                       | Worm                                            |
|               |                  |                       | Algal                                           |
|               |                  | Aquatic bed           | Rooted vascular<br>Floating                     |
|               |                  | Reef                  | Mollusk                                         |
|               |                  |                       | Worm                                            |
|               |                  | Streambed             | Cobble-gravel<br>Sand                           |
|               |                  | Rocky shore           | Mud                                             |
|               |                  |                       | Organic                                         |
|               |                  |                       | Bedrock                                         |
|               |                  |                       | Rubble                                          |

(Continued)

\* Adapted from Cowardin et al. (1979).

\*\* Added by Kendall (1983).

Table 3 (Concluded)

| <u>System</u> | <u>Subsystem</u> | <u>Class</u>         | <u>Subclasses</u>                                       |
|---------------|------------------|----------------------|---------------------------------------------------------|
| Estuarine     | Intertidal       | Unconsolidated shore | Cobble-gravel<br>Sand-shell**<br>Sand<br>Mud<br>Organic |

#### Variable selection

20. To make HSI models more accurate predictors of site-specific values of a selected measurable response, US Fish and Wildlife models must be modified. The published models identify variables that can be used as a basis for producing project-specific models (Terrell and Nickum 1984). Salinity, water temperature, dissolved oxygen, vegetation, and substrate are variables most commonly used in the published HSI models (Table 2). Additional variables with potential for application in estuarine habitats are listed in Table 4. Although the factors identified in Table 4 do structure benthic macroinvertebrate communities, some of these factors should not be included in HSI models (see discussion in following paragraph).

21. However, variables included in project-specific models should be limited to those (a) to which a species responds, (b) that have an easily measured and predicted value, (c) that likely will be changed by the project, and (d) that can be influenced by planning and management decisions (Terrell et al. 1982, Schamberger and O'Neil 1986). Water quality (e.g., salinity and/or temperature) may be an important part of an animal's habitat, but the natural variability in estuarine water quality parameters and wide tolerances of estuarine species limit their predictive value and ability to represent a habitat condition without extensive long-term measurements. Since water quality conditions are particularly complex in estuarine habitats, it may be better to deal with them as a separate issue and/or use indicator organisms to assess changes.

22. Elimination from the models of variables that do not meet the criteria listed in the previous paragraph may increase the sensitivity of the models to project-specific changes (Holling 1978, Terrell et al. 1982). The model is designed for a specific activity or project; therefore, it is not influenced by extraneous variables. In addition, reduction in the number of

Table 4  
Summary of Group Discussions on Abiotic Variables That Structure  
Benthic Macroinvertebrate Communities\*

| <u>Substrate</u>              | <u>Hydrographic Regime</u>        | <u>Physical-Chemical</u> |
|-------------------------------|-----------------------------------|--------------------------|
| Bathymetry                    | Current velocity<br>(near bottom) | Salinity                 |
| Particle size<br>distribution | Turbulence                        | pH, EH                   |
| Stability                     | Tidal range                       | Dissolved oxygen         |
| Compaction                    | Tidal cycle                       | Total organic carbon     |
|                               |                                   | Nutrients (P:N)          |
|                               |                                   | Contaminants             |
|                               |                                   | Temperature              |

\* Personal communication, 1980, USAE Fish and Shellfish Habitat Evaluation Workshop, Vicksburg, Miss.

variables will decrease the effort.\* Substrate, vegetation, current velocity, and depth (bathymetry) may be the most useful. Since current velocities may fluctuate extensively on a hourly, daily, and monthly basis, substrate size may be more useful than velocity measurements as an index of long-term current velocity conditions. Smaller substrate grain sizes generally represent lower current velocities.

#### Future Needs

23. Surveys by the US Waterways Experiment Station\*\* and the USFWS National Wetlands Center† indicate that HEP is being used more frequently in coastal marine and estuarine habitats. As the use of HEP increases, new models are needed to focus on species that are the best

\* O'Neil et al., op. cit.

\*\* D. A. Nelson. "A Survey of Coastal HEP Applications by the US Army Corps of Engineers" (in preparation), US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

† US Fish and Wildlife Service. 1985. HEP questionnaire and a compilation of responses, unpublished manuscript, Division of Ecological Services, Washington, DC.

indicators of a habitat and habitat changes. A more thorough understanding of the attributes and limitations of alternative species and variables is needed for estuarine and coastal marine systems because of their physicochemical complexity and variability. Existing models need to be modified to limit variables to those with meaning in the estuarine/coastal marine system. Selected variables need to be restructured to thresholds instead of ranges. Monitoring and evaluation of predictions as part of the HEP/HSI process are needed and are critical to improving and refining the use of habitat information for fish and wildlife planning. The HEP framework allows for almost any input that gives quantity and quality (converted to a 0.0 to 1.0 scale) of a habitat. The HSI models are only one type of input. To improve the flexibility of HEP in estuarine and coastal marine systems, alternative inputs into the HEP accounting system are needed (e.g., the Benthic Resource Assessment Technique described by Clarke and Lunz (1985)).

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