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101 ESM	Ecological Services Manual - Habitat as a Basis for Environmental Assessment	4-80
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EXPLANATION OF MATERIAL TRANSMITTED:

Enclosed is the fourth release of the new Ecological Services Manual. It contains the following part:

101 ESM Habitat as a Basis for Environmental Assessment

This manual release is to be filed in your "Habitat Evaluation Procedures" binder.

Associate Director, Environment

FILING INSTRUCTIONS

Remove: Nothing.

Insert New Material: 101 ESM should be inserted between 100 ESM and 102 ESM in the Habitat Evaluation Procedures Binder.

Transmittal Memorandum: File behind the Transmittal Memorandum 3-80 at the back of the Habitat Evaluation Procedures Binder.

Habitat as a Basis for Environmental Assessment

101 ESM

Division of Ecological Services
U.S. Fish and Wildlife Service
Department of the Interior
Washington, D.C.

Preface

Since 1974, the U.S. Fish and Wildlife Service (USFWS) has been developing a habitat-based evaluation methodology entitled the Habitat Evaluation Procedures for use in impact assessment and project planning. This work has lead to the development of a series of documents published as part of the Ecological Services Manual of the USFWS (USFWS 1980). One of these documents, entitled "Habitat as a Basis for Environmental Assessment" (101 ESM), addresses the rationale for a habitat-based technique and discusses the conceptual approach to habitat assessment.

The Habitat Evaluation Procedures (102 ESM) describes how the concepts of habitat evaluation can be implemented in a standardized procedure for conducting impact assessments.

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

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1. Introduction

Natural resource management as we know it today is the result of a long evolutionary process influenced by changing public attitudes and legal mandates. The early history of this country portrayed an attitude of natural resource exploitation, with little regard for damages to the environment or losses to future generations of Americans. Fortunately, these attitudes toward natural resources in general, and to fish and wildlife in particular, have changed (Udall 1963; Trefethen 1975). Legislative actions have resulted from these changes, and in some instances, have been initiators of change (Bean 1978).

The purpose of this document is to describe the concepts behind, and the rationale in support of, a habitat-based impact assessment methodology currently available for use in certain aspects of fish and wildlife resource management. The document does not, however, conclude that habitat is the only basis for environmental assessments. Several assessment methods are discussed and compared to selected criteria in reaching the conclusion that a habitat approach is most appropriate within the current legal and institutional constraints on the USFWS. Other criteria can be used, and other equally valid arguments can be made in support of other approaches for impact assessment. This document does not specifically address non-habitat-based impact assessment methodologies such as the monetary and user-day approaches.

This document presents deductive reasoning in support of a habitat approach to impact assessment. It begins with a discussion of the legal mandates for impact assessments (101 ESM 2), progresses through a description of the ecological basis for impact assessments (101 ESM 3 and 4), and concludes (101 ESM 5) with the identification of an assessment technique which has evolved within the USFWS under the selective pressures of legal mandates and accepted ecological principles.

2. Legal Basis for Environmental Impact Assessments

This chapter identifies and describes the legal mandates for environmental impact assessment by reviewing recent Federal legislation affecting fish and wildlife resources. For a compilation of relevant Federal legislations enacted before those treated in this chapter, the reader is referred to Bean (1977) and Congressional Research Service, Library of Congress (1977).

2.1 The evolution of environmental policy. Convergence of natural resource conservation legislation and regulatory mandates to protect public health and welfare first became apparent in the late 1950's and 1960's. The conservation ethic, developed in the early part of the 20th century, evolved into a more holistic environmental perspective which recognized the interdependence of man and his environment. Environmental quality became an important attribute of the public welfare. Early Federal legislation, known as the Wildlife Coordination Act of 1934, later to become the Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661, *et seq.*), authorized the assessment of adverse environmental impacts associated with Federal water projects. Public concern for the protection of environmental quality, previously applied principally to Federal construction projects, was given application throughout all Federal agencies by the passage of the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321, *et seq.*). NEPA is the culmination of national concern in the 1960's for natural resource conservation, and public health and welfare legislation. NEPA set the tenor and policy basis for succeeding Federal and State environmental legislation, and established the Council on Environmental Quality.

2.2 Legal mandates for environmental impact assessments. NEPA is the landmark of environmental legislation and has served as the policy umbrella and mandate for numerous other Federal legislation. NEPA sets forth as its purposes: "To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation...." In passing NEPA, Congress recognized the dependence and inseparability of the public health and welfare of the Nation and environmental quality. NEPA applies to all the activities and programs of all Federal agencies. Furthermore, it requires all agencies to consider environmental values along with economic or developmental considerations. Regarding assessment activities, NEPA further stated that all Federal agencies shall:

> "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment," and

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"identify and develop methods and procedures, in consultation with the Council on Environmental Quality..., which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations."

Some of the more prominent legislative acts which mandate Federal agencies to environmental conservation include:

A. Archeological and Historic Preservation Act, 16 U.S.C. 469, et seq.
B. Clear Air Act, as amended, 42 U.S.C. 7401, et seq.
C. Clear Water Act (Federal Water Pollution Control Act), 33 U.S.C. 1251, et seq.
D. Coastal Zone Management Act, 16 U.S.C. 1451, et seq.
E. Endangered Species Act, 16 U.S.C. 1531, et seq.
F. Estuary Protection Act, 16 U.S.C. 1221, et seq.
G. Federal Land Policy and Management Act, 43 U.S.C. 1701, et seq.
H. Federal Nonnuclear Energy Research and Development Act, 42 U.S.C. 5901 et seq.
I. Federal Water Project Recreation Act, 16 U.S.C. 460-1(12), et seq.
J. Fish and Wildlife Coordination Act, 16 U.S.C. 661, et seq.
K. Forest and Rangeland Renewable Resources Planning Act, 16 U.S.C. 1601, et seq.
L. Land and Water Conservation Fund Act, 16 U.S.C. 4601 - 4601-11, et seq.
M. Marine Protection, Research and Sanctuary Act, 33 U.S.C. 1401, et seq.
N. National Environmental Policy Act, 42 U.S.C. 4321, et seq.
O. National Historic Preservation Act, 16 U.S.C. 470a, et seq.
P. National Forest Management Act, 16 U.S.C. 472, et seq.
Q. Rivers and Harbors Act, 33 U.S.C. 403, et seq.
R. Soil and Water Resources Conservation Act, 16 U.S.C. 2001, et seq.
S. Surface Mining Control and Reclamation Act, 30 U.S.C. 1201, et seq.
T. Water Resources Planning Act, 42 U.S.C. 1962, et seq.
U. Watershed Protection and Flood Prevention Act, 16 U.S.C. 1001, et seq.
V. Wild and Scenic Rivers Act, 16 U.S.C. 1271, et seq.

These Acts address the protection, inventory, conservation, or rehabilitation of the environmental resources of the Nation. Many of the above statutes represent organic legislation of Federal agencies such as the Water Resources Council, the Bureau of Land Management, and the Office of Surface Mining Reclamation and Enforcement.

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2.3 Variability in focus of environmental impact assessments. A common feature of all of the laws listed above is the necessity to inventory and quantify the status of air, water, land, and other ecological resources in order to assess, predict, or regulate resource changes resulting from various types of man-induced impacts. A comprehensive definition of environmental impact assessment has been suggested by the International Council of Scientific Unions (1975) as: "an activity designed to identify and predict the impact on man's health and well-being, of legislative proposals, policies, programs, projects, and operational procedures, and to interpret and communicate information about the impacts."

Unfortunately, many differences exist in the focus, scope, and resolution of environmental impact assessments. This stems largely from ambiguous and occasionally contradictory language of various Federal Acts and the lack of concensus among scientists working in this field. The problem is particularly pronounced in assessments dealing with ecological or wildlife impacts. This has contributed significantly to the variability of information gathered by agencies charged by statute with conducting impact assessments.

Congressional requirements to assess impacts on fish and wildlife resources are generally framed around four indicators of public interest: species-populations, biological integrity, environmental values, and habitat. The four indicators are identified in the language of some key environmental legislation. References to wildlife resources in legislative acts are often intentionally vague to allow for more definitive clarification in the regulations drafted by the implementing agency. Frequently, wildlife resources are not mentioned specifically, but are lumped under the general term "environmental resource values."

A. Species-population. The concept that fish and wildlife species or populations or other descriptors thereof can be the basis for determining and assessing impacts is most clearly illustrated in the language of the Clean Water Act. Section 304(a)(1)(A) "Information and Guidelines" states that criteria for water quality should include "extent of all identifiable effects on health and welfare including ...plankton, fish, shellfish, wildlife, plant life..." Section 316(a) requires applicants for a variance from thermal discharge guidelines to "assure the protection and propagation of a balanced, indigenous population of fish, shellfish, and wildlife...." This language reflects the interim goal of the Act under Section 101(a)(2) of achieving water quality "which provides for the protection and propagation of fish, shellfish, and wildlife...." Several other Acts could be interpreted as requiring a species-population approach, notably the Endangered Species Act, the Federal Nonnuclear Energy Research and Development Act, and the Surface Mining Control and Reclamation Act.

B. Biological integrity. Interestingly, the Clean Water Act also is associated with the biological or ecological integrity approach which attempts to evaluate impacts from an integrated ecosystem viewpoint. The goal of that Act [Section 101(a)] states "The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The ecological basis of this concept is further reflected in Section 304(a)(1)(C) which calls for water quality criteria based "on the effects of pollutants on biological community diversity, productivity, stability..." The Council on Environmental Quality regulations implementing NEPA defines the "effects" which are to be addressed in impact assessments (43 C.F.R. 1508.8): "Effects include ecological (such as effects on natural resources and on the components, structure, and functioning of affected ecosystems)...."

C. Environmental values. The equal consideration of environmental values and economic values to be derived or foregone from a given project or development activity is the essence of the "equal dignity" concept mandated by NEPA. The equal consideration or "values" approach to environmental impact assessment is best illustrated by the Water Resources Council's Principles and Standards (P&S) (38 F.R. 24778, 44 F.R. Part X, and 18 C.F.R. 713). The P&S establish procedures designed to measure and quantify the beneficial and adverse effect of water and land developments on two objectives: national economic development and environmental quality. P&S Section II (B) indicates that: "Beneficial and adverse effects are measured in monetary or nonmonetary terms." P&S establishes the approach to impact assessment based on estimating the monetary and nonmonetary "value" of the components of environmental quality. For example, such things as "biological resources," "ecological systems," "natural beauty," "historical resources," and "water and air quality," are to be compared with economic development factors such as power generation, employment, and flood control. Although philosophically admirable, the implementation of the values approach has been hampered by the difficulty of placing values on intangible and intrinsic environmental components which have unknown or nondeterminable market value.

D. Habitat. The fourth approach to environmental impact assessment is habitat analysis. The Federal Land Policy and Management Act declared that the policy of Congress with regard to the management of public lands under Section 102(a)(8) includes the provision of "food and habitat for fish and wildlife and domestic animals." Section 201(a) of the Act requires "an inventory of all public lands and their resource and other values... giving priority to areas of critical environmental concern." Areas of "critical environmental concern" are defined in Section 103 to include "important fish and wildlife resources."

The Fish and Wildlife Coordination Act requires the USFWS, in cooperation with State fish and wildlife agencies, to conduct surveys and investigations for the conservation of fish and wildlife resources. This Act pertains to Federal construction projects or federally-permitted or licensed projects affecting any stream or other body of water. The Act does not specify any particular assessment methodology. However, the USFWS's draft regulations (F.R. Vol. 44. No. 98. May 18, 1979) implementing this Act recognize the concept and specify the use of habitat values.

The Forest and Rangeland Renewable Resources Planning Act also directs the Department of Agriculture to conduct renewable resource assessments. "The evaluation shall assess the balance between economic factors and environmental quality factors. Program benefits shall include, but not be limited to, environmental quality factors, such as esthetic, public access, wildlife habitat, recreational ..." (16 U.S.C. 1606(d)). Similarly, the Soil and Water Resources Conservation Act calls for "appraisals" including, under Section 5(a)(1), "data on quality and quantity of soil, water, and related resources including fish and wildlife habitats."

The Endangered Species Act also recognizes the importance of habitat to the protection, preservation, and restoration of endangered and threatened species. Section 3(5)(A) defines the term "critical habitat" and Section 4(a)(1) empowers the Secretary of the Interior to "specify any habitat of such species which is then considered to be critical habitat." Section 7(a)(2) requires each Federal agency to ensure that its activities do not "result in the destruction or adverse modification of habitat of such species...." Section 7(b) and 7(c) provide for "biological assessments" and "biological opinions" to make such determinations.

Recent rules and regulations pursuant to the Surface Mining Control and Reclamation Act require the assessment of impacts to fish and wildlife resources. Section 779.20(a) of the Office of Surface Mining Reclamation and Enforcement (OSM) Regulations in 30 C.F.R. requires mining permit applicants to include "a study of fish and wildlife and their habitats." Introductory material to Section 779.20 (March 13, 1979 Federal Register publication, 44 F.R. 15037) of the OSM regulations indicates that the agency's interpretation of Section 515(b)(24) ("minimize disturbance and adverse impacts of the operation on fish, wildlife, and related environmental values..."), is that it includes habitat.

2.4 Variability in scope and resolution of environmental impact assessments. A fairly broad spectrum exists in Federal laws and policies with regard to the resolution and geographic scope of assessments, ranging from broad-based national assessments to site-specific plans. For example,

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Federal agencies' legislation addressing impact assessment as part of a regulatory or consultation function tend to require a high degree of resolution and site specificity (e.g., a mining site plan, a stream reach, a construction project site, a timber sale, or a grazing management unit). The Surface Mining Control and Reclamation Act and the Clean Water Act exemplify this category of resolution.

A second category involves legislation calling for basinwide or regional planning assessments with an associated lower degree of resolution. Examples of this type of assessment would include Water Resources Council 13A assessments, Federal Nonnuclear Energy Research and Development Act, P&S level A and B studies, and most NEPA Environmental Impact Statements (EIS's).

The third category or level of resolution includes impact assessments on a national or major geographic basis such as programmatic EIS's, national assessments, and inventories designed to tabulate the natural resources of "all public lands" or "all National forest and rangelands".

2.5 Elements common to all environmental impact assessments. The foregoing discussion pointed out that the legal mandates for environmental impact assessments vary in approach, scope, and resolution. However, at least two common points are recognized:

1) Interactions between physical, chemical, and biological components dictate environmental quality. Thus, to varying degrees, an ecosystem approach to impact assessments is defined.

2) Man has the capability of exploiting natural resources to a point at which his life support system may begin to break down. The legislation subsequent to NEPA provides recognition and reaffirmation of the NEPA goals that modern industrialized society must provide in law for the maintenance, conservation, or rehabilitation of the basic life support system, both for existing and for future generations.

Therefore it follows that certain elements should be common to all potential environmental impact assessment methods. These are:

1) The environmental impact assessment methodology should have the capability to quantify the extent and status of various natural resource components and their susceptibility to irreparable damage or loss. All chemical, physical, biological, economic, and social parameters that are relevant to the change expected to result from a proposed action, should be addressed.

2) The environmental impact assessment should objectively predict the quantitative and qualitative short and long term changes in physical, chemical, and biological features associated with alternative ways of achieving the proposed objective. The "goodness" or "badness" of each alternative is determined by the decisionmaker(s) and is not made a part of the assessment.

None of the environmental laws or regulations which require impact assessment prescribe a methodology to be used in the collection, compilation, analysis, or evaluation of natural resource information. The focus of subsequent chapters will be to describe the concepts behind, and the rationale in support of, a habitat-based impact assessment methodology currently available for use in certain aspects of fish and wildlife resource management.

3. Ecological Basis for Environmental Impact Assessments

The preceding chapter explored the legal basis for impact assessments and concluded that there are no clearly defined legal directives for the use of particular methodologies. The purpose of this chapter is to review the ecological basis for environmental impact assessments, and then to explore the general utility of various approaches that might be used to assess impacts on fish and wildlife resources.

3.1 The ecosystem as an organizational unit. Environment has been defined as "the sum total of all physical and biological factors impinging upon a particular organismic unit" (Pianka 1974:2). The "organismic unit" of interest may be an individual, a population of individuals, or a community of populations. The task of assessing impacts on the environment involves: (1) identifying the biological unit whose environment is to be assessed; (2) identifying the factors impinging upon the defined unit(s); and (3) determining how the proposed action will impact the defined unit(s) through alteration of the physical and biological factors impinging on it.

This three step approach which treats factors affecting individuals, populations, and communities is founded on the organizational concept of an ecosystem. An ecosystem approach to environmental assessment may be both natural and artificial. Treating organisms and their environments as functional units is a natural means of organizing efforts in impact assessment. However, artificiality may enter the process when attempts are made to operationally define ecosystems or to delineate actual ecosystem boundaries. Ecosystems can be of any physical size if they are defined by functional attributes (McNaughton and Wolf 1973). However, it should be recognized that setting spatial limits becomes arbitrary because ecosystems represent a continuance in time and space both operationally and conceptually (Johnson 1977).

Unfortunately, ecosystems are seldom treated as a functional continuant during impact assessment; instead the responsibilities and interests of most resource agencies lie with particular ecosystem components. For example, the U.S. Fish and Wildlife Service is specifically charged with the protection of fish and wildlife resources. Fish and wildlife resources are dependent on, and functionally related to, other ecosystem components. In this example, the ecosystem approach is valid as long as the interactions between fish and wildlife and other ecosystem components are defined and considered during an impact assessment. In many instances this integration does not occur and the impact assessment is nothing more than a brief summary of information.

3.2 Methods for assessing fish and wildlife components of ecosystems. Impact assessment requires documentation of the quantity and quality of existing resources, and prediction of how these resources will change in the

future both naturally, and as a result of man's actions. The choice of an assessment methodology should be governed by how well the technique meets certain criteria related to application and implementation of the assessment process. Some potential criteria include:

(1) The assessment method should document and display data in a manner which allows decisionmakers to compare present conditions with future options and alternatives.

(2) The assessment method should have predictive capabilities amenable to documenting changes in quantity and quality of fish and wildlife resources over time. It is not enough to document existing resources; the assessment method must be able to project changes in the resource base which would occur naturally or as a result of implementation of a proposed action by man.

(3) The assessment method must be practical to implement. Data availability, time, and monetary constraints must be considered in the practical application of any method.

(4) The assessment method must be sensitive enough to identify differing types and magnitudes of impacts ranging from enhancement, to no impact, some loss, or to total loss of the resource.

(5) The assessment method should generate data with biological validity, but in units readily understood by both the public and decisionmakers. These data should be amenable to integration with data from other disciplines, such as socioeconomic analyses.

(6) The assessment method should be complete and self-contained yet capable of being improved through the incorporation of new knowledge and techniques as the state-of-the-knowledge advances.

There are probably other criteria which would be applicable, but those presented represent the minimum which should be considered when selecting an assessment method. The following discussion addresses some potential assessment methods in light of how they either meet or fail to meet these criteria.

A. Assessment through analysis of energy flow. One of the most fundamental approaches to evaluation of ecosystems is through analysis of how energy flows through the system and how it is used by various components. Almost any proposed action by man can be summarized as impacting the ecosystem by alteration of energy flow through the system. An energy flow approach has been used as an effective analytic tool in various small and physically well defined systems

(Kormondy 1969; Odum 1971). Some inland aquatic ecosystems lend themselves to this approach (Odum 1957). Each trophic level, from primary producers such as plankton through various levels of consumers, exhibit fairly efficient and measurable energy transfers. However, available energy entering the system does not necessarily determine production of a given species or even a trophic level in terrestrial systems (Wagner 1969). A great deal of energy (nutrient pool) is "locked up" in inaccessible or inedible plant parts and therefore is unavailable to other ecosystem components for extended periods. Energy flow in ecosystems is perhaps more difficult to measure in practice than are aspects of the nutrients involved in its transfer. Biochemical cycle parameters such as transfer rates and pool size are costly to measure, and the interpretation of these data in an impact assessment context is difficult (Johnson 1977).

Systems analysis, systems simulation, and other promising tools have improved the ecologist's capabilities to measure and analyze energy flow in large systems on an experimental basis, but the resulting large scale models still only infrequently produce reliable predictions (Odum 1977). The use of such models also often requires data that are costly and time consuming to collect, and sometimes impractical to measure for each assessment activity.

B. Assessment through population estimation. Of practical value to the resource manager are methods of assessment which not only provide measures of impacts, but which also provide information on population size and production of species of public concern. Many EIS readers are concerned with how many animals will be lost due to the proposed action (Giles 1974). Therefore, methods which document future changes in supply of fish and wildlife resources available for both consumptive and nonconsumptive uses by man should be considered in the assessment process.

The ultimate quantification of changes in numbers of individuals (supply) would be derived from analyses of how various chemical, physical and biological parameters of the ecosystem interact to influence the energy balance of individual animals and, thus their probability of survival and contribution to future populations. However, for the fish and wildlife manager, often the only practical approach to assessment involves either direct or indirect methods of population estimation.

(1) Population estimation - direct approach. Direct population estimation usually involves some type of census which, by definition, implies a complete count of individuals within a

specific area (Overton and Davis 1969); however, virtually all real world situations must rely on estimation techniques. Direct estimation techniques are applicable to populations of individuals which are relatively sedentary (e.g., territorial males of many passerine species), or are concentrated on limited areas (e.g., wintering waterfowl or fish migrating through a fish ladder). However, many species do not lend themselves to accurate, direct population estimation because of mobility, secretive behavior, or habitat characteristics which make observation or counts difficult. Indirect estimation techniques must be used for these types of populations (Watt 1968).

(2) Population estimation - indirect approach. Most indirect methods of population estimation involve the use of indices. Two types of indices are commonly used to indirectly estimate population size. The first type involves a count (e.g., time-area count) taken in a manner which does not permit population estimation unless sampling probabilities are estimated. The second type of index is based on counts of some parameter (e.g., pellet group counts) associated with the species of interest. The strengths and weaknesses of both techniques have been discussed by Overton and Davis (1969).

Estimation of animal numbers at any one point in time is difficult whether direct or indirect methods are used. Several methods should be used (Watt 1968) to ensure accuracy, but this increases the costs of obtaining estimates. Most uses of population size estimates also include a spatial dimension (e.g., density = number of animals per unit area) which requires an estimate of the space utilized by the population under consideration (Krebs 1972).

Even the simplest population estimation model requires data from both the breeding population and their offspring for several consecutive years. Correlative models which reflect past population history are of limited predictive value (Watt 1968). Mechanistic models based on a biological understanding of the species are technically attractive, but the amount of data required to produce such a documented, predictive model is prohibitive for most ecological assessment purposes (Krebs 1972).

Population estimates alone are considered by many to be unreliable indicators of habitat value. Sampling errors, cyclic fluctuations of populations, and the lack of time series

data, all contribute to the problem. Thus, where changes in supply of selected fish and wildlife populations may be a quantity to which decisionmakers and the public easily relate, estimates of changes in numbers of individuals may be difficult and costly to obtain, and too time consuming to use for many impact assessments.

C. Assessment through habitat quality. Habitat has been defined to incorporate several interrelated concepts dealing with space, time, and function (Coulombe 1977). Basically, however, habitat is the place occupied by a specific population within a community of populations (Smith 1974), and often can be characterized by a dominant plant form or some physical characteristic (Ricklefs 1973). Each species requires a particular habitat to supply the space, food, cover, and other requirements for survival. Thus, species are the products of their habitats.

Much of the variability observed in numbers of species and numbers of individuals within populations results from differences in availability of food, cover, water, and other requirements, and in the structural characteristics of the habitat itself (Black and Thomas 1978). Different qualities of habitats produce different densities of various populations. Attempts to quantify habitat quality often involve the use of indices, applied at the individual, population, or community levels.

Some of the most frequently used types of indices are the so-called "condition indices" which involve measurements of some particular characteristic of an animal (e.g., bone marrow fat) to subsequently evaluate the condition of both the animal and its habitat (Giles 1978). Condition indices, like some forms of population indices, are most useful when taken over many years and then compared to some standard to obtain trend information. Such indices are of limited utility for prediction of impacts resulting from specific proposed actions which would alter factors interacting to yield the original index.

Various forms of diversity indices often are used to characterize habitats in an attempt to obtain some measure of quality (Asherin et al. 1979). One of the most common is the bird species diversity index used by avian ecologists. Such indices account for both numbers of species and numbers of individuals of each species present in a particular habitat (Balda 1975). However, diversity indices are insensitive to which species are present (Wiens 1978), often require detailed and expensive measurements which preclude their practical application by resource managers (Thomas *et al*. 1978), and

suffer from the same problems as all biological indices, namely, identification of the standard of comparison (Inhaber 1976). The methods of determination and ecological relevance of the diversity index has been seriously questioned (Hurlbert 1971); the plasticity of species and species groups in ecosystem structure makes the interpretation of diversity index data difficult (Johnson 1977).

3.3 A unifying approach. Each of the potential approaches to impact assessment described above (energy flow, populations estimation, and habitat quality) differ in their ability to meet previously identified criteria (101 ESM 3.2). Analysis of energy flow may be the most scientifically sound method, but is not practical at present because of time and monetary constraints which accompany most impact assessments. Both the population and habitat approaches meet the criteria with the following basic differences:

(1) Population approaches result in analyses with actual dimensions (e.g., number of animals per unit area).

(2) Habitat approaches may be somewhat easier to implement when considering typical time and monetary constraints.

What is needed in impact assessment is a unifying concept which integrates features common to both the concepts of habitat with its relative ease of implementation and population with its explicit units of measure, or "a land parameter measured in animal units" (Giles 1978:194).

Understanding the relationships between habitat and animals requires that both the supply of habitat resources available and the life requirements of the species be known (Moen 1973). The supply of resources available to a particular animal can be determined from various characteristics of the habitat after the animal's requirements are known. For the better studied species these basic requirements, e.g., food, water, cover, and others, are reasonably well known. The unifying concept between habitat quality (i.e., the ability of a habitat to supply life requirements) and numbers of animals a habitat can support is carrying capacity.

4. Carrying Capacity and Habitat as a Basis for Impact Assessments

The concept of carrying capacity integrates the habitat and population themes in a time dimension and, in doing so, provides a potential basis for impact assessments. The purposes of this chapter are to define and discuss the estimation of carrying capcity, and then evaluate the utility of incorporating the concepts presented in this document into a practical method for assessing the impacts of man's actions on fish and wildlife resources.

4.1 Definition of carrying capacity. Strictly speaking, carrying capacity is a population concept with the underlying theme of numbers of animals supported by some unit of area. In population ecology terms, it is "the density of organisms (i.e., the number per unit area) at which the net reproductive rate (R_o) equals unity and the intrinsic rate of increase (r) is zero" (Pianka 1974:82). Pianka goes on to explain that carrying capacity is "an extremely complicated and confounded quantity, for it necessarily includes both renewable and nonrenewable resources, as well as limiting effects of predators and competitors, all of which are variables themselves." Carrying capacity is the "K" in various versions of the Verhulst-Pearl logistic population-growth equation. Defined in this context, carrying capacity is the population density at an upper asymptotic level of population growth. After a population reaches this level it may fluctuate around K due to chance events. The asymptotic density is maintained by density-dependent environmental factors.

Wildlife resource managers often are more liberal in their perceptions of carrying capacity than are population ecologists and may use the term in a variety of contexts (Edwards and Fowle 1955). When confusion occurs, it can be traced to a lack of user definition and not to the integrating role of this useful concept. Giles (1978) has recently attempted to alleviate confusion by suggesting that carrying capacity be defined for a population with a user-specified quality of biomass (e.g., specified sex and age ratios). With this approach, carrying capacity is the quantity of the specified population for which a particular area will supply all energetic and physiological requirements over a long, but defined, period of time.

4.2 Estimation of carrying capacity. Carrying capacity (K in the Verhulst-Pearl logistic population growth equation) may be estimated empirically with regression techniques described by Watt (1968) and Poole (1974). These regression techniques require that population densities be recorded for various stages of population growth. The technique is based on observed population densities, thus it does not provide the ability to predict future changes in carrying capacity. For that latter reason, and others discussed in 101 ESM 3, population estimation is not a viable technique for impact assessment purposes.

Another technique for estimating carrying capacity is the traditional resource inventory. With this technique, carrying capacity is estimated

based on how well the habitat will meet the known physiological and behavioral needs of a species. Ecologists working with ungulates have historically based carrying capacity estimates on caloric and nutritional values of foods provided by the habitat. Examples of the data and calculations required are described by Moen (1973) and Mautz (1978). Others, including avian ecologists, have considered structural aspects of the habitat as important determinants of carrying capacity (Elton and Miller 1953). Carrying capacity estimates based on the resource inventory approach will nearly always be estimates of "potential," because the limiting effects of other species (competitors and predators) are difficult to explicitly include in the calculations.

4.3 <u>Application of habitat concepts to impact assessments</u>. Structural and physical features of habitat are measurable and because vegetational succession is predictable to a certain extent, future habitat values can be projected with some confidence. However, numbers of individuals fluctuate naturally over time and often independently of structural and physical features of available habitat. These fluctuations can be difficult to measure or predict and are often caused by epizootic diseases, excessive departures from normal weather patterns, or other stochastic events not directly related to habitat. More common however, are the effects of predation and competition on numbers of individuals utilizing a particular habitat (Wagner 1969; Partridge 1978). For example, predator-prey studies by Rogers et al. (1980) indicated that, in similar habitat, white-tailed deer densities were higher in the buffer zones between wolf pack territories than in the center of individual territories.

In regard to competition, avian ecologists are making rapid advances in deciphering the influence of competition on animal numbers. For example, a recent study (Williams and Batzli 1979a,b) indicated that the presence or absence of one particular species within a guild of bark foraging birds affected whether or not other guild members would use a particular habitat segment, how they would use it, and in what numbers. The implications of these studies and others are directly applicable to the objectives of impact assessment. Numbers of species and numbers of individuals often may change for unpredictable reasons, but habitat potential remains unchanged. Because of its relative stability, it is this habitat potential which should be documented by the wildlife manager interested in ecologically valid impact assessment.

Two factors support impact assessments based on habitat potential. First, the time scale for predictions can come close to matching the time span over which impacts will occur. For many impact studies performed by the USFWS involving long-term modifications of land use, the most useful information for decisionmaking is the long-term trend in fish and wildlife

resources. Predicted short-term (e.g., seasonal or annual) fluctuations in populations may have little influence on a land use decision. Secondly, the degree to which a predicted impact is considered significant is partially a function of socioeconomic preferences for the species involved. When recommendations for land use decisions are based on habitat potential it is possible to maximize the number of future management options, recognizing possible future changes in socioeconomic preferences.

4.4 Limitations of the habitat approach. The habitat approach, like any approach used for impact assessments, has limitations which define the limits of application and identify potential problem areas where good professional judgement is required. Performing impact assessments with a habitat approach, as described herein, basically limits application of the methodology to those situations in which measurable and predictable habitat changes are an important variable. Many impact studies (e.g., harvest management and predator control) cannot be adequately performed solely with a habitat approach but require other analytical capabilities.

The habitat approach presents a relatively static view of the ecosystem and forces a long-term "averaging" type of analysis. Although this is described as a positive attribute in earlier sections of this document, there is no assurance that wildlife populations will exist at the potential levels predicted by habitat analyses. A habitat approach may not include all of the many environmental or behavioral variables that often limit populations below the habitat potential. Moreover, socioeconomic or political constraints imposed by man may prevent the actual growth of certain species populations to their potential levels.

5. A Habitat-Based Impact Assessment Technique

The USFWS (1980) has developed a procedure for documenting predicted impacts to fish and wildlife from proposed land and water resource development projects. The procedure is based on the concepts of habitat potential discussed in 101 ESM 4. The purpose of this concluding chapter is to briefly discuss the procedure and identify its strengths and limitations when used in the impact assessment process.

5.1 The Habitat Evaluation Procedures. The Habitat Evaluation Procedures (HEP) have been developed (USFWS 1980) in response to the need to document the nonmonetary value of fish and wildlife resources. HEP evolved from an assessment method developed in Missouri (Daniels and Lamaire 1974) and is based on the fundamental assumption that habitat quality and quantity can be numerically described. Numerical description permits options and alternatives to be compared when numerical changes are the essence of impact assessment.

HEP is a species-habitat approach to impact assessment, and habitat quality for selected evaluation species is documented with an index, the Habitat Suitability Index (HSI). This value is derived from an evaluation of the ability of key habitat components to supply the life requisites of selected species of fish and wildlife. Evaluation involves using the same key habitat components to compare existing habitat conditions and optimum habitat conditions for the species of interest. Optimum conditions are those associated with the highest potential densities of the species within a defined area. The HSI value obtained from this comparison thus becomes an index to carrying capacity for that species.

The index ranges from 0.0 to 1.0, and for operational purposes in HEP, each increment of change must be identical to any other. For example, a change in HSI from 0.1 to 0.2 must represent the same magnitude of change as a change from 0.2 to 0.3, and so forth. Therefore, HSI must be linearly related to carrying capacity. This is an operational restriction imposed by the use of HSI in HEP. However, it is a restriction easily complied with; if the relationship between HSI and carrying capacity is unknown, it is assumed to be linear. If the relationship is nonlinear, it is converted to a linear function.

HEP attempts to incorporate concepts from both the population and habitat theories by evaluating habitat quality for specific species. Prior to the 1980 edition of HEP, this was done subjectively based on the professional judgement of a team of biologists. The habitat quality values were multiplied by area and aggregated to obtain a "habitat" score. In the 1980 edition of HEP, HSI values are obtained for

individual species through use of documented habitat suitability models employing measurable key habitat variables (e.g., percent canopy closure). The HSI values are multiplied by area of available habitat to obtain Habitat Units (HU's) for individual species. These values are used in the HEP system for comparative purposes. No aggregation of species' HSI (or HU's) occurs.

Many potential users tend to consider the HSI value as synonymous with the entire HEP system. This is not the case. HEP can be compared to a bookkeeping ledger; both passively display, and thereby document, values obtained from other sources. HEP is a data management system; it is the data it manages, i.e., the index of quality and the quantity of available habitat, which are of interest in impact assessment.

5.2 Attributes and limitations of the Habitat Evaluation Procedures. As with other approaches, HEP differs in its ability to meet the previously identified evaluation criteria (101 ESM 3.2) for an impact assessment methodology:

(1) Various forms are used in HEP to display and document HSI, area, and HU's for each evaluation species. Comparisons can be made either between two areas at one point in time, or for one area for several points in time, for any proposed action. However, the ability to document data and ultimately compare alternatives is not unique to the HEP system.

(2) The differences in quality (HSI) and quantity (area) between existing habitat conditions (baseline) and various projected future sets of conditions document project-related impacts to selected evaluation species. HEP currently does not provide guidance for performing future projections. Therefore, projected impacts are no better than the user's ability to predict future conditions.

(3) HEP can be applied at any level of assessment. However, data requirements and costs increase as more species are considered and their respective habitat models become more complex. HSI models not only provide an index value of quality, but also document which habitat variables were considered and their respective values. The level of detail for such "models" must fit the user's objectives for impact assessment.

(4) The identification of differing types and magnitudes of impacts is dependent on the validity and sensitivity of the HSI models used to generate data for HEP. As with other approaches, the results of an impact assessment employing HEP are no better than the reliability of resource data used.

(5) HU's serve not only as the principal units of comparison in HEP, but also as a standard vehicle of communication, integrating both quality and quantity of habitat. Changes in HU's represent potential impacts from proposed actions. Such changes are annualized in order to be comparable with the action agencies' benefit/cost analyses. Applications of annualized HU's include impact assessments, compensation studies, and human use analyses. In such analyses, one HU lost for a species must be directly comparable to one HU gained for that species. The latter association explains the requirement for a linear relationship between HSI and carrying capacity.

(6) HEP is a species-habitat-based assessment methodology. It is applicable only for the species evaluated and does not directly relate that species with other ecosystem components. HEP conceptually addresses only the issues of species populations and habitat, among the four indicators of public interest identified in 101 ESM 2.3. However, the degree to which these indicators are addressed by HEP is dictated by the HSI models. Through improved HSI models, it may be possible to more completely treat the remaining issues of biological integrity and environmental values.

In summary, the HU data developed are the essence of the HEP methodology. The identified changes in habitat quality and quantity provide the basis for biologists to compare alternatives for the evaluation species selected. HEP is a convenient means of documenting and displaying, in standard units, the predicted effects of proposed actions. It is a tool available to resource managers who must make knowledgeable decisions. For further information, the reader should consult the "Habitat Evaluation Procedures" (102 ESM) and "Standards for the Development of Habitat Suitability Index Models for Use with the Habitat Evaluation Procedures" (103 ESM).

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