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.