16 Assessment Endpoints

Assessment endpoints are an explicit expression of the environmental values to be protected, operationally defined as an ecological entity and its attributes (Suter 1989; EPA 1992a). The concept of assessment endpoints is similar to other concepts but the distinctions are important (Box 16.1). The process of selecting assessment endpoints can be thought of as a process for converting the risk manager's environmental goals into specific attributes of real entities, which can be estimated by measurement or modeling. This selection may be difficult or contentious because the number of ecological entities and attributes is effectively infinite. Endpoints may be defined for structural or functional attributes at the organism, population, community, or ecosystem levels of organization. Differences in the perceptions and values of the risk mangers, stakeholders, risk assessors, and public further complicate the process. For example, while the public is concerned about individual oiled birds following a tanker accident, assessors who are trained in ecology may insist that endpoints be defined in terms of avian population attributes. The criteria listed in Box 16.2 have been used to select ecological assessment endpoints. The first three are the EPA's criteria.

The selection of endpoints for an assessment requires balancing and reconciling of those criteria. In practice, policy goals and societal values are the dominant consideration. If an endpoint is not sufficiently important to influence the decision maker who, in a democracy, represents a society, it will be useless. Ecological relevance serves to augment and clarify the consideration of societal values. That is, if an endpoint attribute is not only societally important in itself but also influences other ecological attributes that are important, its significance is increased. However, an endpoint that has little ecological relevance must be included in the assessment if it has significant societal value. For example, neither the loss of peregrine falcons in the eastern United States nor their recent recovery has had any apparent influence on ecosystem attributes. Nevertheless, their societal value has justified the expenditure of millions of dollars for their restoration. The other criteria are practical screens. If a potential endpoint is not susceptible, it is irrelevant. If it has an inappropriate scale or is impractical, it must have a low priority. If it is valued but not operationally definable, it must be redefined.

Consistency with policy goals and societal values may be determined on the following basis:

- *Explicit goals*: As discussed in Chapter 11, the goals of an environmental management program should be identified at the beginning of the planning and problem formulation process. These goals are assumed to embody societal values. When clear goals are defined, the assessors must simply identify those entities and attributes for which risks must be defined to achieve the goals. However, clarification of goals is often necessary. For example, if the goal is to protect the production of Coho salmon, it is important to distinguish whether the goal is to protect the productivity of salmon for the fishery (which would include hatchery-produced fish) or of wild naturally spawning salmon populations.
- *Established policy and precedent*: If there is a published policy to protect certain environmental attributes or if an attribute has been the basis of regulatory or other management actions in the past, then it may be assumed to reflect societal values. Such precedents are the basis for the generic assessment endpoints discussed below and are

BOX 16.1
Related Concepts

While the concept of assessment endpoints is generally accepted in the practice of ecological risk assessment, other concepts serve an equivalent role in other contexts. It is often necessary for risk assessors to adapt these concepts. The following examples illustrate the necessary interpretation and adaptation of such concepts.

Uses: The term appears in the Great Lakes Water Quality Agreement, the US Clean Water Act, and elsewhere. While the term implies utilitarian values, it has been interpreted broadly. In particular, in implementation of the Clean Water Act, "use" has included use of the water by aquatic life as well as by humans.

Services (of Nature): Like "uses" this term is utilitarian. It commonly appears in the environmental literature to emphasize the many useful functions of ecosystems (Costanza et al. 1997; Daily et al. 1997). In Natural Resource Damage Assessments, injuries to natural resource services are identified and damages are paid to resource managers for loss of those services (Deis and French 1998; DOI 1986).

Indicators: Indicators are products of environmental monitoring programs that are intended to indicate the state of some property of the environment that is not measured but is of interest (National Research Council 1999). They may be indicative of an abstract property such as biotic integrity or ecosystem health or a real property that is difficult to measure such as mutation rate. Examples of indicators include the index of biotic integrity and the area of a nation that is forested. Indicators are used in local, regional, or national assessments of environmental status and trends (Office of Research and Development 1998; John Heinz III Center for Science Economics and the Environment 2002). If an indicator has value in itself, it may be used as an assessment endpoint.

BOX 16.2
Criteria for Selection of Assessment Endpoints for Ecological Risk Assessments (Suter 1989; EPA 1992a)

1. *Policy goals and societal values*: Because the risks to the assessment endpoint are the basis for decision making, the choice of endpoint should reflect the policy goals and societal values that the risk manager is expected to protect.
2. *Ecological relevance*: Entities and attributes that are significant determinants of the attributes of the system of which they are a part are more worthy of consideration than those that could be added or removed without significant system-level consequences. Examples include the abundance of a keystone predator species, which is relevant to community composition or the primary production of a plant assemblage, which is relevant to numerous ecosystem attributes.
3. *Susceptibility*: Entities that are potentially highly exposed and responsive to the exposure should be preferred, and those that are not exposed or do not respond to the contaminant should be avoided.
4. *Operationally definable*: An operational definition is one that clearly specifies what must be measured and modeled in the assessment. Without an unambiguous operational definition of the assessment endpoints, the results of the assessment would be too vague to be balanced against costs of regulatory action or against countervailing risks.
5. *Appropriate scale*: Ecological assessment endpoints should have a scale appropriate to the site or action being assessed. This criterion is related to susceptibility in that populations with large ranges relative to the site have low exposures. In addition, the contamination or responses of organisms that are wide-ranging relative to the scale of an assessment may be due to sources or other causes not relevant to the assessment.

Continued

BOX 16.2 (Continued)
Criteria for Selection of Assessment Endpoints for Ecological Risk Assessments (Suter 1989; EPA 1992a)

6. *Practicality*: Some potential assessment endpoints are impractical because good techniques are not available for use by the risk assessor. For example, there are few toxicity data available to assess effects of contaminants on lizards, no standard toxicity tests for any reptile are available, and lizards may be difficult to quantitatively survey. Therefore, lizards may have a lower priority than other better known taxa. Practicality should be considered only after evaluating other criteria. If, for example, lizards are included because of evidence of particular sensitivity or policy goals and societal values (e.g., presence of an endangered lizard species), then some means should be found to deal with the practical difficulties.

Source: From Suter, G.W. II, in *Ecological Assessment of Harardous Waste Sites: A Field and Laboratory Reference Document*, EPA 600/3–89/013, W. Warren-Hicks, B.R. Parkhurst, and Jr. S.S. Baker Jr., eds., Corvallis Environmental Research Laboratory, Corvallis, Oregon, 1989; US Environmental Protection Agency, Framework for ecological risk assessment, EPA/630/R-92/001, Washington, DC, Risk Assessment Forum, 1992.

often the basis for selecting assessment endpoints in practice. The primary problem with this approach is that it leads to continued neglect of potential endpoints, which have for various reasons been neglected in the past. For example, amphibians have received little attention even though many amphibians, particularly frogs, are attractive to the public and the recent decline in frogs has caused public concern.

- *Manifest societal values*: Some societal values are apparent to all. For example, society values the production of fish for food, trees for timber, and other marketable resources. Similarly, some populations and ecosystems are valued for their recreational uses. These utilitarian values are reflected in the use of phrases like services of nature (Daily et al. 1997) and use impairments (International Joint Commission 1989), to describe environmental goals. While market values fall in this category, other judgments about societal values may be controversial. Environmental assessors and managers often make ad hoc judgments about what the public values without evidence beyond their personal judgment. For example, the US Army BTAG (2002) wrote that "the public generally does not currently accept fungi, bacteria and species of invertebrates as appropriate assessment endpoints." They present no evidence to support this judgment or to refute the judgment of those assessors who have used earthworms, butterflies, mussels, crabs, and other invertebrates as endpoint entities. Ecological risk assessors should perform the research necessary to generate better evidence concerning public environmental values.
- *Departure from natural conditions*: A common assumption among environmental scientists is that mandates to protect the environment amount to a goal of preventing or minimizing any departure from a natural state. This implies that any attribute that may differ from the natural state is an appropriate endpoint. In some cases, the language of laws or regulations suggest that a natural state is desired and maintaining a natural state is clearly an appropriate goal for national parks, wilderness, or equivalent areas. However, most of the world is human modified. It may not be appropriate to determine what attributes best distinguish agricultural streams or suburbans from forest streams and make those our endpoints (Box 11.1). Further, natural systems are variable targets. If we deal with this by saying that anthropogenic effects can induce variance in ecological conditions as great as natural variability, then we may allow anthropogenic effects as

great as those caused by a hurricane, drought, or glaciation (Hilborn 1996). Hence, departure from natural conditions is not an appropriate expression of societal values in situations where the society has chosen to convert an ecosystem to a modified condition or when a long temporal perspective is required. However, it is appropriate when, as in the US Clean Water Act, goals are defined in terms such as "biological integrity of the Nation's waters." Under that mandate, biocriteria are typically defined in terms of detectable changes from the least disturbed ecosystems of the same type.

16.1 ASSESSMENT ENDPOINTS AND LEVELS OF ORGANIZATION

The appropriate level of organization of ecological assessment endpoints has been an ongoing source of controversy. Much of that controversy occurs because people do not recognize that assessment entity and attribute may be defined at different levels of biological organization (Section 6.1). It is important to remember the conceptual formula:

Assessment endpoint = attribute + entity.

Examples include:

- Survival of a kit fox in a territory containing a former sump for arsenic-treated water—an organism attribute associated with a hypothetical individual organism in a specially protected population.
- Survival of juvenile kit foxes on Elk Hills—an organism attribute associated with the organisms in an assessment population.
- Population growth rate on Elk Hills—a population attribute associated with an individual assessment population.
- Mean population growth rate for all kit foxes—a population attribute associated with a set of populations.
- Number of indigenous mammal species on Elk Hills—a community attribute associated with an individual community.

These examples show that attributes at each level of biological organization can occur in an individual entity (an individual organism or an individual population) or in multiple entities (the organisms in a population or multiple populations within a region).

An attribute at one level may be applied to an entity at a different level of organizations. For example, death may be an attribute of an organism (e.g., death of an individual fish), to the set of organisms in a population (e.g., 50% mortality of rainbow darters in a stream), or a community (e.g., 50% mortality of fishes in a stream). However, the application of an organism-level attribute to a population or community of organisms does not make it a population-level or community-level attribute. Population and community responses are not simply sums of organismal responses. For example, the decline in population abundance is not simply the proportional mortality, because of compensatory and depensatory effects of density on survival, fecundity, or susceptibility to disease or predation (Chapter 27).

The relationship of entities and attributes can be clarified by comparing risk assessment endpoints for humans and ecological entities (Table 16.1). Human health risk assessments are intended to protect organism-level attributes of individual humans (e.g., a 5×10^{-4} cancer risk to the reasonable maximally exposed individual), but health risk assessments often also consider risks summed across the members of an exposed population so as to elucidate the magnitude of potential effects (e.g., an incremental risk of five cancers in an exposed population of 10,000). In contrast, ecological risk assessments seldom use entities at the organism level. Rather, organism-level attributes typically are associated with an assessment population or community (EPA 2003c). In the United States, true population-level attributes are not

TABLE 16.1
Examples of Assessment Endpoints for Human and Ecological Risk Assessments

Entities	Human Health Risk Assessment	Ecological Risk Assessment
Organism-level attributes		
Individual organism	Probability of death or injury (e.g., risk to the maximally exposed individual)	Probability of death or injury (e.g., risk to an individual of an endangered species). Seldom used.
Population of organisms	Frequency of death or injury, Numbers dying or injured	Frequency of mortality or gross anomalies, Average reduction in growth or fecundity
Population-level attributes		
Individual population	Not used	Extirpation, production, or abundance
Set of populations	Not used	Seldom used (e.g., extinction rate or regional loss of production)

Source: From Suter, G.W., Norton, S.B., and Fairbrother, A., *Integr. Environ. Assess. Manag.*, 1, 397–400, 2005. (With permission.)

considered in human health risk assessments, because individuals are to be protected, and an effect on a human population is sufficient to lower its abundance or production would not be countenanced. However, in ecological risk assessments, risks to abundance, production, extirpation and other attributes of nonhuman populations, or sets of populations are assessed.

16.2 GENERIC ASSESSMENT ENDPOINTS

The plethora of potential assessment endpoints calls for some method to define and narrow the field of candidate endpoints while ensuring that important candidates are not overlooked. One way of addressing this problem is to define generic endpoints that may be reviewed for their relevance to the assessment at hand and, if appropriate, adapted to the case at hand. Two approaches are described in this section: one is based on policy judgments and the other on ecological functional classification of organisms. While the approaches are conceptually distinct, they may be reconciled when defining assessment-specific endpoints.

16.2.1 Generic Endpoints Based on Policy Judgments

The most straightforward approach to developing generic endpoints for managers in an agency or organization is to develop a list that is judged to be suitable for their context and purposes. Examples include sets of generic endpoints for contaminated sites in Alaska (ADEC 2000) and on the Oak Ridge Reservation in Tennessee (Suter et al. 1994). Policy-based generic endpoints may even be developed by ecologists based on their interpretation of entities and attributes that must be protected to meet the goals of environmental laws or regulations. An example of generic endpoints for a specific policy goal, sustainable freshwater ecosystems, is presented in Box 16.3.

The US EPA reviewed its policies and precedents in using ecological endpoints to define a set of generic ecological assessment endpoints (GEAEs) (EPA 2003c; Suter et al. 2004). The GEAEs are not prescriptive, but serve to indicate what sorts of ecological assessment endpoints have been mandated or used successfully in decision making. The entities are broadly defined in terms of conventional levels of biological organization, so as to be broadly useful, but the attributes are more specifically defined (Table 16.2). They are meant to help the process of endpoint selection by indicating endpoints that may be presumed to have policy

BOX 16.3
Generic Endpoints for Sustainable Freshwater Ecosystems

Decrease in Biodiversity
This concerns negative effects on

1. Overall species richness and densities
2. Population densities of ecological key species that are

   - critical determinants in trophic cascades (e.g., piscivorous fish, large cladocerans)
   - "ecological engineers," that have a large influence on the physical properties of habitats (e.g., marcrophytes)

3. Population densities of indicator species

   - with a high "information" level for monitoring purposes
   - protected by law and regionally rare or endangered species

Impact on Ecosystem Functioning and Functionality
This concerns negative effects on

1. Biogeochemical cycles and energy flow
2. Water quality parameters (e.g., persistence of contaminants, increased toxic algae, oxygen depletion)
3. Harvestable resources (e.g., drinking water, fish)

Decrease in Aesthetic Value or Appearance of the Water Body
This can be caused by

1. Disappearance of species with a popular appeal
2. Visible mortality of individuals or fishes, frogs, water fowl, and other vertebrates
3. Taste and odor problems
4. Decrease in water transparency and symptoms of eutrophication (e.g., algal blooms)

Source: From Brock, T.C.M. and Ratte, H.T., in *Community-Level Aquatic System Studies: Interpretation Criteria*, J.M. Giddings, T.C.M. Brock, W. Heger, F. Heimbach, S.J. Maund, S.M. Norman, H.T. Ratte, C. Schafers, and M. Streloke, eds., SETAC Press, Pensacola, FL, 2002, pp. 33–41.

support in the US EPA. A similar set of generic endpoints is developed for the ecological assessment of pesticides in Canada (Delorme et al. 2005).

Generic endpoints based on policy have the disadvantage of being based on the haphazard processes that generate public policy. While they tend to be incomplete and inconsistent, they have the advantage of being relevant to the decision processes from which they are derived.

16.2.2 Functionally Defined Generic Endpoints

Ecologists often approach the problem of choosing generic endpoints in terms of the familiar organization of ecosystems in terms of trophodynamics, i.e., they explicitly or implicitly create a food web and define each node as an endpoint entity. Reagan (2002) has made this

TABLE 16.2
The US EPA's (2003c) Generic Ecological Assessment Endpoints[a]

Entity	Attribute	Identified EPA Precedents
Organism-level endpoints		
Organisms (in an assessment population or community)	Kills (mass mortality, conspicuous mortality)	Vertebrates
	Gross anomalies	Vertebrates Shellfish Plants
	Survival, fecundity, growth	Endangered species Migratory birds Marine mammals Bald and golden eagles Vertebrates Invertebrates Plants
Population-level endpoints		
Assessment population	Extirpation	Vertebrates
	Abundance	Vertebrates Shellfish
	Production	Vertebrates (game/resource species) Plants (harvested species)
Community and ecosystem-level endpoints		
Assessment communities, assemblages, and ecosystems	Taxa richness	Aquatic communities Coral reefs
	Abundance	Aquatic communities
	Production	Plant assemblages
	Area	Wetlands Coral reefs Endangered/rare ecosystems
	Function	Wetlands
	Physical structure	Aquatic ecosystems
Officially designated endpoints		
Critical habitat for threatened or endangered species	Area Quality	
Special places	Ecological properties that relate to the special or legally protected status	e.g., National parks, national wildlife refuges, Great Lakes

[a]Generic ecological assessment endpoints for which US EPA has identified existing policies and precedents, in particular the specific entities listed in the third column. Bold indicates protection by federal statute.

approach the basis for defining general assessment endpoints (GAEs). He specifies three trophic categories (producers, consumers, and decomposers), which are further divided into functional components that serve to define generic endpoint entities. He argues that even complex ecosystems can be reduced to 20 such components. While ecologists disagree on how to define functional components (e.g., Reagan aggregates detritivores and scavengers; I would not) and what to include (e.g., he leaves out parasites and parasitoids), the process of defining the components is useful for developing the conceptual model as well as developing assessment endpoints. The attributes for these generic endpoint entities are limited to a few functional properties such as food and habitat. As the functions are assumed to be important, the justifications of the value of functionally defined generic endpoints tend to become circular. For example, carnivores are said to be important because of their role in predation (Reagan 2002).

A related approach was used to develop exposure guilds for ecological risk assessment at Los Alamos National Laboratory (Myers 1999). Rather than defining general functional components, this approach used functional characteristics of species such as diet and foraging strategy that are believed to control exposure to contaminants. A statistical cluster analysis was then applied to the functional characteristics of species to define the exposure guilds.

16.2.3 Applying Generic Endpoints

The process of developing assessment endpoints for an ecological risk assessment may be thought of as bringing together five types of information and answering questions related to each (EPA 2003c). Together, the questions address the criteria for ecological assessment endpoints. Generic endpoints constitute one type of information that answers one question:

- *Agent (stressor) characteristics*: What is susceptible to the stressor? For some agents, this question is straightforward. Benthic invertebrates are susceptible to dredging, birds are susceptible to granular pesticides, wetlands are susceptible to filling, and so on.
- *Ecosystem and receptor characteristics*: What is present and ecologically relevant? For site-specific assessments, this is the species, communities, or ecosystems at the site. For other assessments, the scenario should define the types of species, communities, and ecosystems that are likely to be exposed. For example, assessment of a new pesticide for corn would consider the species likely to be found in or adjacent to cornfields in the Midwest. In the absence of specific information about the particular importance of an entity, those that are present may be assumed to be ecologically relevant. The generic endpoints based on food webs or other functional relationships may be used to identify and organize these entities for endpoint selection.
- *Management goals*: What is relevant to the management goals? Statements of management goals should suggest the changes in attributes of ecological entities that would preclude achieving the goal.
- *Input by stakeholders*: What is of concern? If stakeholders are consulted or make their preferences known, their concerns about particular ecological effects should be considered. Although societal values at a national scale are reflected in government policies, values that are specific to a locale or resource are expressed by stakeholders.
- *Policies or precedents*: What is supported by policy or precedent? The GEAEs in Table 16.2 provide a set of entities and attributes that meet this criterion for the US EPA, which express national goals and values with respect to regulation of pollutants.

The answers to each of these questions would be a list of potential assessment-specific endpoints. None of the questions imply absolute requirements. For example, susceptibility to a novel agent may be unknown, and the concerns of stakeholders are often unknown and often do not include important potential endpoints. No generally applicable procedure is available for answering the questions. If consistency with US EPA policy and precedent is particularly important, one might go through the GEAE set and ask the other four questions with respect to each generic endpoint. Alternatively, all of the questions might be answered and the lists are integrated. In that case, the endpoints for a specific assessment may simply be those that are represented on most of the lists.

16.3 MAKING GENERIC ASSESSMENT ENDPOINTS SPECIFIC

In general, it is desirable to define the endpoints as completely as possible during the problem formulation so as to avoid ad hoc decisions during the analysis and the characterization phases. Some of the problems to be avoided in defining the endpoints are listed in Box 16.4. Also, if one of the generic assessment endpoints is chosen, or if the endpoint is broadly defined by the risk manager (e.g., community structure), it is necessary to define the entity and attribute more specifically.

Specific definition of the species and population: When, as is often the case, the assessment endpoint is defined in terms of attributes of organisms or populations of a species, it is necessary to select that species. In some cases, the value that defines the endpoint is associated with a particular species. Examples include endangered species, commercial, or recreational fisheries, and culturally significant species such as the bald eagle in the United States. In most cases, however, the endpoint values are not associated with a particular species. In such cases, it is necessary to choose one or more species that are representative of the endpoint (Box 16.5). An alternative, which is sometimes employed in land management, is to choose an umbrella species. They are species that have a high demand for large areas of relatively undisturbed habitat. It is assumed that if the umbrella species are protected, all other species will be protected as well. When endpoints are defined in terms of organisms or a population of a species it is necessary to define the spatial limits of the population (Box 16.6).

BOX 16.4
Common Problems with Assessment Endpoints

1. Endpoint entity is defined but not the attributes (e.g., bluebirds, rather than bluebird abundance).
2. Endpoint entity and attribute are mismatched (e.g., fish in Sierra Nevada streams, which naturally have few species, and species diversity).
3. Endpoint is a goal rather than an attribute (e.g., maintain and restore endemic populations).
4. Endpoint is vague (e.g., estuarine integrity rather than eelgrass abundance and distribution).
5. Endpoint is a measure of an effect that is not a valued attribute (e.g., midge emergence when the concern is production of fish which depends in part on midge production).
6. Endpoint is not directly or indirectly exposed to the contaminant (e.g., fish community when there is no surface water contamination).
7. Endpoint is irrelevant to the site (e.g., a species for which the site does not offer habitat).
8. Endpoint does not have an appropriate scale for the site (e.g., golden eagles on a 1000 m^2 site).
9. Value of an entity is not sufficiently considered (e.g., rejection of all benthic invertebrates at a site where crayfish are harvested).
10. Attribute does not include the value of the endpoint entity (e.g., number of species when the community is valued for game fish production).
11. Attribute is not sufficiently sensitive to protect the value of the endpoint entity (e.g., survival when the entity is valued for its production).

Source: Modified from US Environmental Protection Agency, Guidelines for ecological risk assessment, EPA/630/R-95/002F, Washington, DC, Risk Assessment Forum, 1998.

BOX 16.5
Representative Species

It is a common practice when selecting endpoints, particularly for wildlife, to designate a representative species (Hampton et al. 1998). That is, one may choose the meadow vole as a representative herbivore or red fox as a representative carnivore. This practice can lead to confusion unless it is clear what category of organisms is represented and in what sense the species are representated. For example, the meadow vole may represent all herbivores, all small mammals, all herbivorous small mammals, or all microtine rodents. A representative species may be representative in the sense that it is judged likely to be sensitive, because its activities are confined to the site (e.g., the vole rather than deer as representative herbivore), its behavior is likely to result in high levels of exposure (e.g., birds feeding on soil invertebrates rather than on herbivorous invertebrates), it is known to be inherently sensitive to the contaminant of concern (e.g., mink and PCBs), or it is predicted to be sensitive by application of extrapolation models (e.g., larger mammals based on allometric models). A species may also be representative in an ecological sense if it is the most abundant representative of the category of organisms on the site. Finally, a representative species may be chosen because it is particularly amenable to sampling and analysis or to demographic surveys.

The groups that the representative species represent are commonly defined in terms of higher taxa or broad trophic groups. However, if the characteristics that control exposure and toxicological or ecological sensitivity can be defined, endpoint groups may be defined by cluster analysis of those traits. This approach was applied to birds at Los Alamos, New Mexico, using only diet and foraging strategy to generate "exposure guilds" (Myers 1999). This approach is more objective than the typical subjective grouping of species, and the hierarchy of clusters provides a basis for increasing the level of detail in the analysis as the assessment progresses.

In general, it is not a good idea to select high-valued species as representative species, because it tends to confuse the roles of endpoint species and representative of a community or taxon. For example, if bald eagles occur on a site, they are likely to be an endpoint species protected at the organism level. If piscivorous wildlife as a trophic group is also an endpoint, then bald eagles might also be thought to serve to represent that group. However, because bald eagles cannot be sampled except under exceptional circumstances and they are not likely to be highly exposed due to their wide foraging area, it would be advisable to choose a species which is more exposed, more abundant on the site, or less protected as a representative (e.g., kingfishers or night herons). By using a different species to represent the trophic group, one could perform a better assessment of the trophic group and could clearly distinguish the two endpoints in the risk communication process.

When using a representative species, it is essential to determine how the risks to the represented category of organisms will be estimated. The method may range from assuming that all members of the category are equivalent to using mechanistic extrapolation models to estimate risks to all members of the category once risk to the representative species is demonstrated to be significant.

Source: From Suter, G.W. II, Efroymson, R.A., Sample, B.E., and Jones, D.S., *Ecological Risk Assessment for Contaminated Sites*, Lewis Publishers, Boca Raton, FL, 2000.

Specific definition of the community: When community endpoints are chosen, the community must be defined. For example, do we define the biota of a stream as a community or treat the fish, benthic macroinvertebrate, periphyton, zooplankton, and phytoplankton assemblages as communities? If we define the community as a food web, riparian species may be included. Communities are often defined in terms of the constituent assemblages, because the differences in sampling techniques inhibit quantification of the structure of entire communities. The spatial dimensions of a community are discussed in Box 16.6.

BOX 16.6
Defining Assessment Populations and Communities

As the conventional ecological meaning of "populations" and "communities" presents problems in practice, the US EPA (2003c) guidance on generic assessment endpoints introduces the terms "assessment population" and "assessment community." An assessment population is a group of conspecific organisms occupying an area that has been defined as relevant to an ecological risk assessment. An assessment community is a multispecies group of organisms occupying an area that has been defined as relevant to an ecological risk assessment.

Although ecological assessment endpoints often include population properties, such as abundance and production, and community properties, such as species richness, it is difficult to delineate populations and communities in the field. Recently, ecology has focused on temporal dynamics, spatial patterns and processes, and stochasticity that belie the notion of static, independent populations. An example of this is metapopulation analysis, which reveals that population dynamics are significantly determined by the exchange of individuals among habitat patches or differential movement across a landscape that continuously varies in suitability (Chapter 27) (Hanski 1999). Communities are subject to the same dynamics. For example, the species diversity of Pacific coral reefs is apparently determined by the availability of recruits from other reefs within 600 km (Bellwood and Hughes 2001). If the composition of coral reefs on islands, which would appear to be classic discrete communities, is in fact determined by regional dynamics, there is little chance of delimiting discrete communities in general.

Populations may be readily delimited if they are physically isolated within a broader species range (e.g., a sunfish population in a farm pond) or if the species consists of only one spatially discrete population (e.g., the endangered Florida panther, whose current range is restricted to southwest Florida). Otherwise, population boundaries are difficult to define because they are typically structured on multiple scales. Genetic analyses, which are needed to define discontinuities in interbreeding frequencies and thus to delimit populations, are not a practical option for most ecological risk assessments.

The practical problems are even greater for communities. Although the members of a population consist of a single species, it is not always clear whether a particular group of organisms constitutes an instance of a particular community type. This is because the species composition of communities varies over space and time.

To protect properties such as population production or community species richness, it is necessary to develop a pragmatic solution to these problems. An example of such a solution is the approach taken by the Nature Conservancy and NatureServe (formerly the Association for Biodiversity Information) to inventory and map biodiversity (Stein et al. 2000). Because it is not feasible to define discrete populations or communities, these organizations inventory and map occurrences of conservation elements, which may be defined at various scales, depending on the elements and circumstances. For example, a plant community occurrence may be "a stand or patch, or a cluster of stands or patches." An occurrence of a bird species would be defined differently, but analogously.

For individual assessments, the population or community entities to be protected must be defined during the problem formulation stage of risk assessment. These assessment populations and assessment communities should be defined in a way that is biologically reasonable, supportive of the decision, and pragmatic with respect to policy and legal considerations. For example, it would not be reasonable to define the belted kingfishers in a 20 m stream reach as an assessment population if that reach cannot fully support one belted kingfisher pair. On the other hand, even though the kingfisher's range is effectively continuous, it would not be reasonable to define the entire species as the assessment population, given that it ranges across nearly all of North America. Rather, it may be reasonable to define the kingfishers nesting on a watershed or a lake as an assessment population.

Continued

BOX 16.6 (Continued)
Defining Assessment Populations and Communities

Definitions of assessment populations may include nonbiological considerations as well. For example, for Superfund ecological risk assessments on the Oak Ridge Reservation of the US Department of Energy, populations of large terrestrial vertebrates were delimited by the borders of the reservation (Suter et al. 1994). This definition was reasonable not only because the Superfund site was defined as the entire reservation, but also because the reservation was large enough to sustain viable populations of deer, wild turkey, bobcat, and other endpoint species. Although the reservation is more forested than are the surrounding agricultural and residential lands, its borders are not impenetrable and are not ecologically distinct at all points. However, the pragmatic definition proved useful and acceptable to the parties. A similarly pragmatic approach would define an assessment community of benthic invertebrates as occupying the first fully mixed reach of a stream receiving an effluent.

The selection of a scale to define an assessment population or community involves a trade-off. If the area is large relative to the extent of the stressor, the effects of that stressor will be diluted. However, if the area is small, the assessment population or the community may be significantly affected but may seem too insignificant to prompt stakeholder concern or action by the decision maker. Hence, appropriate spatial scales must be determined during the problem formulation stage of individual risk assessments, taking into consideration both the ecological and the policy aspects of the problem; it must not be manipulated during the analysis to achieve a desired result.

Source: From US Environmental Protection Agency, Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment, EPA/630/P-02/004B, Washington, DC, Risk Assessment Forum, 2003.

Specific definition of structural attributes: Structural attributes such as abundance, deformity or number of species tend to be relatively clear. However, the definition often depends on the specific methods used to estimate the attribute.

Specific definition of functional attributes: Functional attributes are relatively seldom used, and their definitions tend to be unclear. Protection of wetland functions is the one functionally defined goal of the US EPA, but it is necessary to define which functions are appropriate in a particular case. They include nutrient retention, nutrient cycling, pollutant retention, water retention, groundwater recharge, provision of waterfowl habitat, etc. The choice may be made based on the circumstances. For example, water retention would be an important endpoint attribute for wetlands in watersheds that are subject to destructive floods. Similarly, nutrient retention would be important in watersheds such as those in the Mississippi and Neuse Rivers, which have contributed excess nutrients to coastal areas, causing anoxia.

Even a clear definition of an assessment endpoint as an entity and one or more attributes is often insufficient to support the assessment process. Particularly if the assessment will involve the measurements and observations, it is necessary to define the magnitude or frequency of effects that is considered potentially significant and therefore must be detectable or distinguishable from reference conditions with reasonable confidence.

16.4 ENDPOINTS BASED ON OBJECTIVES HIERARCHIES

When assessments are based on stakeholder processes, ecological risk assessments must address endpoints that are meaningful to those stakeholders. One means to develop such endpoints is to define and elaborate their goals through an objectives process (Reckhow 1999).

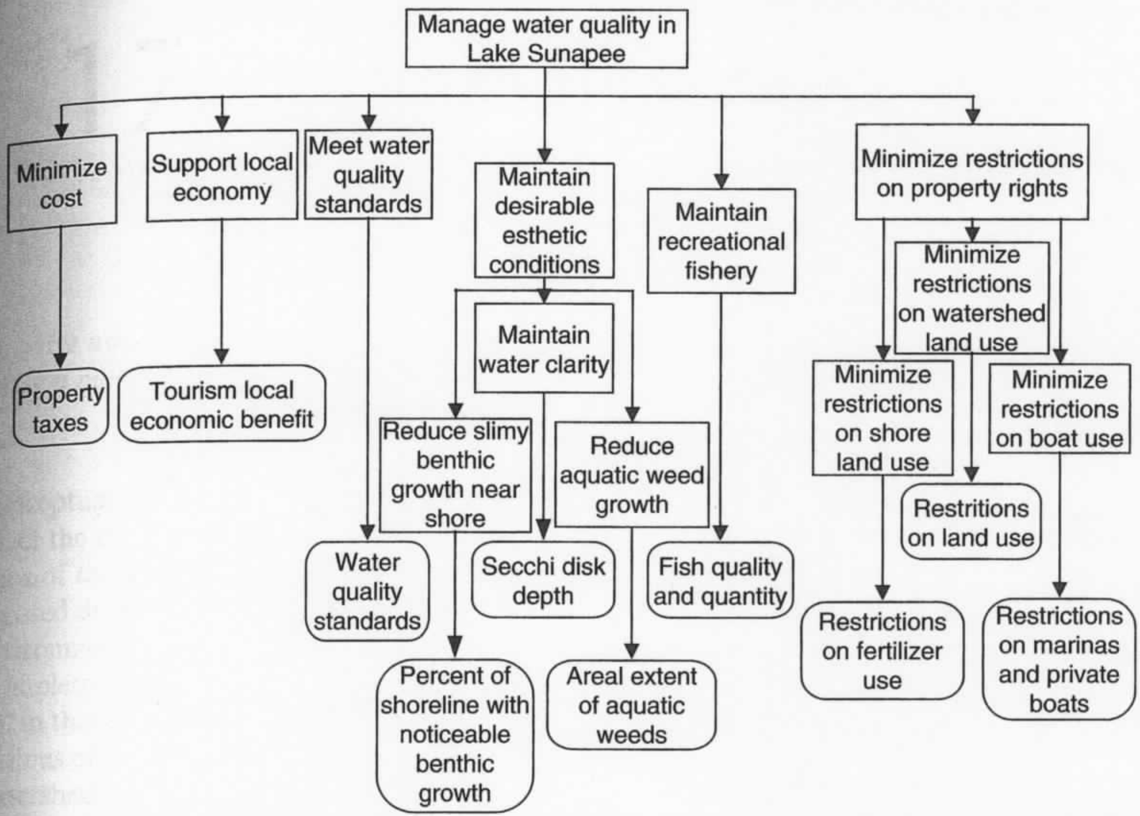

FIGURE 16.1 An example of an objectives hierarchy for an environmental decision. The overall objective appears at the *top*, the other *rectangles* are issue-specific objectives, and the *rounded rectangles* are specific operational objectives. (Redrawn and modified from Reckhow, K.H., *Hum. Ecol. Risk Assess.*, 5, 245, 1999.)

This technique, derived from decision analysis, begins with an overall objective and breaks down into constituent objectives until something is identified that can be measured or estimated (i.e., an endpoint). Figure 16.1 shows an objective hierarchy for water quality management in a lake that was experiencing eutrophication. Note that some are potentially appropriate endpoints for ecological risk assessment, and others relate to economic assessments, regulatory actions, and land use planning. This diversity of objectives is typical of multiattribute decision analysis (Chapter 36).