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Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment

Risk Assessment Forum
U.S. Environmental Protection Agency
Washington, DC 20460

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PREFACE

Ecological risk assessment is a process for evaluating the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. A critical early step in conducting an ecological risk assessment is deciding which aspects of the environment will be selected for evaluation. This step is often challenging because of the remarkable diversity of species, ecological communities, and ecological functions from which to choose and because of statutory ambiguity regarding what is to be protected. The purpose of this document is to build on existing EPA guidance and experience to assist those who are involved in ecological risk assessments in carrying out this step, which in the parlance of ecological risk assessment is termed "selecting assessment endpoints." The document describes a set of endpoints, known as generic ecological assessment endpoints (GEAEs), that can be considered and adapted for specific ecological risk assessments.

This document was prepared by a Technical Panel under the auspices of EPA's Risk Assessment Forum. The Risk Assessment Forum was established to promote scientific consensus on risk assessment issues and to incorporate this consensus into appropriate risk assessment guidance. To accomplish this, the Forum assembles experts from throughout EPA in a formal process to study and report on these issues from an Agency-wide perspective. The document reflects the Forum's long-standing commitment to advancing ecological risk assessment and is intended to supplement the use of the Forum's *Guidelines for Ecological Risk Assessment* (U.S. EPA, 1998a). Following the publication of the guidelines, the Forum surveyed ecological risk assessors from across the Agency to prioritize and select risk assessment topics for further development. Additional guidance on assessment endpoints emerged as one of the highest-priority topics. A subsequent EPA colloquium sponsored by the Forum to consider high priorities from the survey identified a need for Agency-wide generic ecological assessment endpoints and directly led to the development of this document.

The primary goal of this document is to enhance the application of ecological risk assessment at EPA, thereby improving the scientific basis for ecological risk management decisions. However, the document is not a regulation, nor is it intended to substitute for federal regulations. It describes general principles and is not prescriptive. Rather, it is intended to be a useful starting point that is flexible enough to be applied to many different types of ecological risk assessments. Risk assessors and risk managers at EPA are the primary audience; the document also may be useful to others outside the Agency.

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1. INTRODUCTION: PURPOSE OF THIS DOCUMENT

In the practice of ecological risk assessment, assessment endpoints are the valued attributes of ecological entities upon which risk management actions are focused (U.S. EPA, 1998a). Because not all organisms or ecosystem features can be studied, regulatory agencies and other risk managers must choose from among many candidate endpoints. A recommendation for improving ecological risk assessment and management within the U.S. Environmental Protection Agency (EPA, or the Agency) has been to develop a set of generic assessment endpoints that are based on environmental legislation and EPA's policies and precedents and that cover EPA's range of concerns for the protection of ecological entities and functions.

In response to that recommendation, this document presents a set of generic ecological assessment endpoints (GEAEs) that provides examples of endpoints applicable to a wide variety of assessment scenarios. It also provides guidance for using these GEAEs to develop robust, assessment-specific endpoints. The role of assessment endpoints within the ecological risk assessment is shown in the text box. The application of GEAEs to the process of generating and using assessment endpoints in ecological risk assessments is illustrated in Figure 1-1.

> **The role of assessment endpoints in EPA's framework for ecological risk assessment**
>
> Ecological risk assessments are preceded by a planning phase in which risk managers, risk assessors, and, as appropriate, interested parties define the management goals. The goals are broad statements of desired conditions such as "restore the wetlands" or "sustain the trout population."
>
> The planning phase is followed by the problem formulation phase, in which the assessors define the assessment endpoints based on the management goals. The assessment endpoints are specific entities and their attributes that are at risk and that are expressions of a management goal.
>
> The analysis and risk characterization phases of the risk assessment are devoted to estimating the nature and likelihood of effects on those endpoints.
>
> Finally, risk communication involves conveying those results and associated uncertainties as well as explaining their implications. These processes are explained in *Guidelines for Ecological Risk Assessment* (U.S. EPA, 1998a).

1.1. Definitions of Assessment Endpoints

An assessment endpoint is defined in *Guidelines for Ecological Risk Assessment* (U.S. EPA, 1998a) as "an explicit expression of the environmental value to be protected, operationally defined as an ecological entity and its attributes." An ecological entity for example, might be an

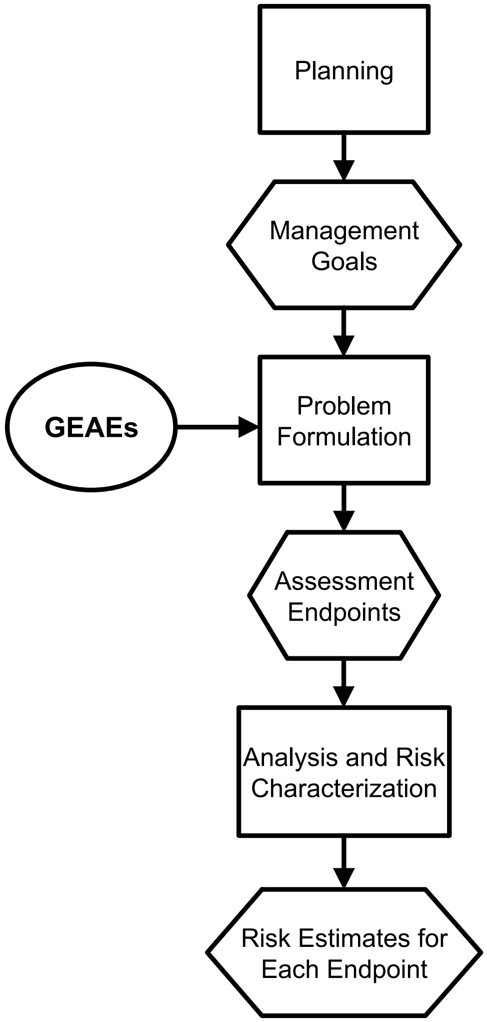

Figure 1-1. Application of generic ecological assessment endpoints (GEAEs) in risk assessment. The process of generating and using ecological assessment endpoints and showing how GEAEs are used along with management goals in the selection of assessment endpoints during problem formulation. Rectangles represent assessment processes and hexagons represent the products of those processes.

important fish species, such as coho salmon, with its attributes being fecundity and recruitment. Effects on assessment endpoints are estimated using measures of effects (see text box). The guidelines provide three selection criteria: ecological relevance, susceptibility (exposure plus sensitivity), and relevance to management goals. Selecting appropriate assessment endpoints is a critical step in ensuring that an assessment will be useful to risk managers in making informed and scientifically defensible environmental decisions.

GEAEs are assessment endpoints that are applicable to a wide range of ecological risk assessments (ERAs) because they reflect the programmatic goals of the Agency, they are applicable to a wide array of environmental issues, and they may be estimated using existing assessment tools. GEAEs do not comprise a complete list of what is or, by exclusion, what is not protected by EPA. They are not specifically defined for every conceivable case, and some ad hoc elaboration by users is expected (Section 3.3). Furthermore, they are not goals or objectives, but they should be related to goals or objectives when such are known. For example, a generic endpoint could be created for endangered species, but the specific species of concern would be defined during problem formulation, and attributes of the species could be selected to fulfill the goals of the Endangered Species Act, the recovery plan for the species, and the objectives of the particular assessment.

The relationship of measures of effects with assessment endpoints

Measures of effects (also known as measurement endpoints) are the results of tests or observational studies that are used to estimate the effects on an assessment endpoint of exposure to a stressor. For example, a conventional measure of effect from an acute lethality test is the median lethal concentration (LC_{50}), which might be used to estimate the risk of a fish kill (an assessment endpoint) from exposure to a spill of the tested chemical.

Measures of effect and assessment endpoints may be expressed at the same level of organization (organism level in this case). However, the same measure of effect may be used, with considerably greater uncertainty, to estimate risks to a population-level assessment endpoint (abundance of a fish species) or a community-level endpoint (number of species).

Published generic endpoints are available for regional assessments (Suter, 1990), population assessments (Suter and Donker, 1993), assessments of hazardous waste combustors (U.S. EPA, 1999a), and assessments of contaminated sites in Alaska (Alaska Department of Environmental Conservation, 2000). In addition, examples of ecological assessment endpoints evaluated within certain EPA programs have been highlighted in prior EPA documents (U.S. EPA, 1994, 1997a, c, 1998a). These examples are presented, as appropriate, in Appendix A.

1.2. Potential Uses for Generic Assessment Endpoints

The set of generic assessment endpoints proposed in Section 2 of this document should be useful for risk assessors and managers involved in planning and performing ecological risk assessments within various EPA programs and offices. In particular, this document can be consulted during the problem formulation stage of ecological risk assessments to assist in developing assessment endpoints that are useful in EPA's decision-making process, practical to measure, and well defined. In addition, the specific environmental laws, precedents, and other polices presented in Appendix A, which provide the supporting information for this initial set of generic endpoints of this document, should be equally useful in supporting assessment-specific endpoints.

Individual programs may have specific uses for these generic endpoints beyond ecological risk assessments. For example, water quality management programs may want to consider using this information during the process of refining designated aquatic life uses in state and tribal water quality standards, when re-evaluating or developing guidance for consistent and environmentally relevant monitoring programs, and in interpreting and implementing narrative water quality standards. In particular, this set of generic endpoints may be useful within the context of a total maximum daily load for a water body that has been listed for nonsupport of aquatic life, but where there are no numeric biocriteria in the state's water quality standards. This set of generic endpoints could be used to assist in the selection of appropriate ecological response variables or to judge the effectiveness of the pollutant reductions.

Ultimately, generic assessment endpoints could have several other uses within the Agency, such as in

- Giving risk managers a basis for action similar to commonly employed human health endpoints;
- Providing a threshold for prevention of environmental degradation by ensuring that certain values are at least considered for assessment;
- Complying with legal requirements;
- Improving the consistency of ecological risk assessment and management;
- Serving as models for site-, action-, or region-specific endpoints;
- Performing screening ecological risk assessments where endpoints may need to be developed rapidly with little input from risk managers;
- Providing clear direction for the development of methods and models;
- Facilitating communication with stakeholders by creating a set of familiar and clear generic endpoints; and
- Reducing the time and effort required to conduct assessments.

These uses are described more fully in Suter (2000).

It is important to emphasize that the generic assessment endpoints are not mandatory or applicable to all assessments. These particular generic endpoints should be used only when and where they are relevant. In many cases, it is likely that the endpoints derived from the generic assessment endpoints will be supplemented by other assessment endpoints that are relevant to the specific stressor or ecosystem. Over time, EPA anticipates that this initial set of generic ecological assessment endpoints will be periodically reviewed, modified, and supplemented as experience is gained in applying and interpreting them in a variety of natural conditions and regulatory contexts (see Section 4).

1.3. Criteria for GEAEs

Like assessment endpoints developed for specific risk assessments, the GEAEs presented in this report are intended to be useful in EPA decision making and to have a sound basis in ecological theory. The following criteria are used in this report for evaluating potential GEAEs; they are independent of specific assessment situations and in that way differ from the criteria that should be used in developing assessment-specific endpoints (see the text box in Chapter 3).

1. Generally useful in EPA's decision-making process. Usefulness may be indicated by the language found in statutes, treaties, and regulations that the Agency implements or with which it must comply. Judicial decisions also indicate how the values defined by statutes may be translated into generically useful endpoints. In addition, Agency guidance, guidelines, protocols, and official memoranda indicate potentially useful endpoints. Finally, various actions of the Agency that were based on ecological protection (i.e., Agency precedents) provide evidence of general utility for GEAEs. These various sources of environmental policy are summarized in U.S. EPA (1994, 1997a). Additional sources are referenced in Appendix A. Note that the reliance on available policy and precedent in this document should not suggest a similar restraint on risk assessors and managers in practice. EPA has a broad mandate to protect the environment that can support the use of novel endpoints in individual assessments (see Sections 3 and 4).

2. Practical. Methods used to estimate risks to the endpoint entity and attribute should be available and reasonably practicable in various assessment contexts. This requires methods that directly measure or observe the endpoint's attributes or that estimate them using a combination of measurements and models. However, this does not require that a GEAE be useful for all situations. Some GEAEs will not be implementable for some taxa or ecosystems, but they should be practical in many situations.

3. Well defined. At a minimum, a GEAE must include an entity and an attribute of that entity (U.S. EPA, 1998a). The entity and attribute should be clearly explained, so that they are understandable by the public and decisionmakers without appearing ambiguous to environmental scientists. A definition should be supported by a clear explanation of the endpoint's relationship with the Agency's management goals and programmatic applications.

Support for the first two criteria (usefulness and practicality) is presented in Appendix A and summarized in Table 2-2. The third criterion (that GEAEs be well defined) is supported by the definitions in Section 2.1 and supplemented by the background in Appendix A.

2. EPA's INITIAL SET OF GEAEs

This chapter presents EPA's initial set of GEAEs to be considered for the uses described in Section 1.2. As stated, these GEAEs are not exhaustive or mandatory but rather are provided to assist EPA programs and researchers and decisionmakers who are involved in protecting the nation's ecological resources, as described in Section 3. The entities and properties in the initial set of GEAEs are presented in Table 2-1. The specific taxa, communities, or ecosystems for which policy or precedents were identified are listed in the last column of the table. The GEAEs are defined in Section 2.1, and the basis for the terms "assessment community" and "assessment population," which are used in the definitions, is explained in Section 2.2. Information concerning laws, regulations, and precedents that support the selection and use of these GEAEs is presented in Appendix A and summarized in Table 2-2. A general discussion of the values related to these GEAEs is presented in Appendix B. Other potential GEAEs that were promising but did not fully meet the criteria in Section 1.3 are discussed in Section 4.

These GEAEs are not always biologically distinct, but the apparent overlaps are justified in pragmatic terms. For example, the generic endpoint "population extirpation" is an extreme case of the generic endpoint "population abundance." However, the extirpation of a population is qualitatively different from a simple percentage loss of abundance. The implications of reductions in fish abundance include a loss of fishing income, but extirpation means an end to the fishery. In addition, it is typically much easier to establish that extirpation has occurred (e.g., the fish are no longer caught) or will occur (e.g., the trout stream will be inundated by a reservoir, or the pH will be far beyond the lethal level) than to establish that some percentage reduction in abundance has occurred or will occur. This difference in implications for the assessment and decision-making processes justify treating extirpation and abundance as different endpoints.

Overlap of GEAEs

GEAEs are not necessarily discrete or mutually exclusive; therefore, there may be some redundancy in a set of GEAEs. For example, the condition of an ecological entity at one level of biological organization (e.g., organism) may influence the condition of other entities at that level and interdependent entities at higher levels of organization (e.g., population or community).

Also, a large change in one attribute may overlap with another attribute, as in the case of abundance and extirpation. Furthermore, GEAEs may relate to more than one environmental value (see Appendix B), which may be reflected in multiple statutes, regulations, public policies, or public perceptions (see Appendix A).

Similarly, kills of organisms have short-term effects on population abundance but do not necessarily have a significant or long-term effect on abundance. The methods for determining

Table 2-1. 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 EPA has identified existing policies and precedents, in particular the specific entities listed in the third column. Bold indicates protection by federal statute. See Table 4-1 for additional endpoints that could be considered by EPA in the future.

Table 2-2. Generic ecological assessment endpoints (GEAEs): summary of the policy support for their use and their practicality[a]

GEAE #	Entity: attribute(s)	Policy support	Practicality
Organism-level endpoints			
1	Organisms: kills (mass mortality, conspicuous mortality)	Supported by many EPA programs; e.g., EPA has restricted the use of pesticides (e.g., diazinon and carbofuran) due to incidents of bird mortality.	Likelihood of kills from chemical pollutants can be estimated from toxicity testing. Incidents may be easy or difficult to observe, but when seen, they suggest a common mechanism or stressor exerting a strong effect.
2	Organisms: gross anomalies	Gross anomalies in birds, fish, shellfish, and other organisms are a cause for public concern and have been the basis for EPA regulatory action and guidance (e.g., assessed at Superfund sites, incorporated into biocriteria for water programs).	External gross anomalies are readily observed and are commonly included in survey protocols for fish and forests. They are also reported in toxicity tests of fish, birds, mammals, and plants.
3	Organisms: survival, fecundity, growth	Many EPA programs rely on organism-level attributes of survival, fecundity, and growth in assessing ecological risks (e.g., water quality criteria, pesticide and toxic chemical reviews, Superfund sites). Organism-level species protection is mandated by the Endangered Species Act, Marine Mammal Protection Act, Bald Eagle Protection Act, and Migratory Bird Treaty Act.	Results of toxicity tests of the survival, fecundity, and growth of organisms are abundant and often can be extrapolated to endangered species and other species of concern. Information on the ranges of listed endangered species is available through state and federal governments.
Population-level endpoints			
4	Assessment population: extirpation	EPA has taken action or provided guidance to prevent extirpation of local populations (e.g., assessment of likelihood of extirpation of fish populations due to acid rain). See also the description for Assessment population: abundance.	Extirpation can be predicted using population viability analysis. Demonstrating extirpation may be easy or difficult, depending on the conspicuousness of a species. See also the description for Assessment population: abundance.

Table 2-2. Generic ecological assessment endpoints (GEAEs): summary of the policy support for their use and their practicality[a] (continued)

GEAE #	Entity: attribute(s)	Policy support	Practicality
5	Assessment population: abundance	Major environmental statutes mandate protection of animals, plants, aquatic life, and living things generally, which can be inferred to entail protection of populations. EPA policies for pesticides, toxic chemicals, hazardous wastes, and air and water pollutants are intended to protect assessment populations of organisms. Mammals, birds, fish, aquatic invertebrates, and plants are typically assessed.	Changes in abundance may be predicted using conventional toxicity data with statistical extrapolation models and population models. OPPT evaluated a population model to explore effects of chloroparaffins on fish populations. Measurement of abundance in the field may be easy or difficult, depending on the species.
6	Assessment population: production	See description for Assessment population: abundance. Additionally, a number of laws are intended to maintain production of various economically valuable species. EPA water programs (e.g., National Estuary Program) and air programs (e.g., criteria pollutant standards) have involved protecting production of resource species populations.	Changes in production may be predicted using conventional toxicity data as well as population-based approaches. For resource species such as tree or fish species, production changes may be measurable in the field but may require long periods of observation.
Community and ecosystem-level endpoints			
7	Assessment communities, assemblages, and ecosystems: taxa richness	EPA water quality biocriteria frequently incorporate measures of community taxa richness. Additionally, EPA testing for pesticides, toxic chemicals, and water pollutants is intended to assess impacts to communities as well as populations and organisms. Fish, aquatic invertebrates, and aquatic plant assemblages are often assessed.	Changes in communities can be inferred or modeled from conventional toxicity data. Measuring taxa richness and abundance of aquatic communities, at least for fish and macroinvertebrate communities, is practical and well established. Ecosystem models that assess effects of toxicants on community properties are available and can use data acquired from organism-level laboratory testing, but they have not been routinely applied to date.
8	Assessment communities, assemblages, and ecosystems: abundance	As in the case of taxa richness, water quality biocriteria incorporate measures of community abundance, and EPA testing protocols are intended to assess impacts to communities.	See description above for taxa richness within assessment communities.

Table 2-2. Generic ecological assessment endpoints (GEAEs): summary of the policy support for their use and their practicality[a] (continued)

GEAE #	Entity: attribute(s)	Policy support	Practicality
9	Assessment communities, assemblages, and ecosystems: plant production	EPA water quality policies address overproduction of aquatic plants (and concomitant eutrophication) due to excess input of nutrients. EPA policies for pesticides, toxic chemicals, water pollutants, and air pollutants (as in the case of ozone and acid rain) also target decreases in production of forests or other plant communities.	Methods for measuring plant production are well developed for both terrestrial and aquatic communities. Methods for predicting effects of nutrient addition are relatively well developed. Protocols for testing plant toxicity are available and include production metrics.
10	Assessment communities, assemblages, and ecosystems: area	Policy support exists for considering the area of wetlands, coral reefs, and endangered/rare ecosystems. Among the supports for wetlands protection are the Clean Water Act, the National Environmental Policy Act (NEPA), the Coastal Zone Management Act, Executive Order 11990, and the federal wetlands delineation manual.[b] Policies for protection of coral reefs are established by Executive Order 13089; additional support may be found in the Coastal Zone Management Act and the Marine Protection, Research, and Sanctuaries Act. Many U.S. coral reefs are protected by state or federal government. Fewer EPA precedents exist for endangered/ rare ecosystems, but a variety of EPA programs have considered them, e.g., Superfund and NEPA.	Assessing the area of communities is generally straightforward, although when clear boundaries between communities are absent, defining areas may be somewhat difficult. Methods for delineating wetlands are well established, and changes in wetland area are therefore relatively easy to measure and monitor over time. The area of coral reefs is also relatively easy to determine. In the case of endangered and rare ecosystem types, a ready data source is NatureServe[c], which maintains data on all known U.S. ecological communities, ranked from critically imperiled to secure. Prediction of change from one community or ecosystem type to another may be difficult.
11	Assessment communities, assemblages, and ecosystems: function	Policy support for ecosystem function is primarily limited to wetlands. The support for wetland protection cited above for community/ecosystem area generally applies to wetland function as well.	Loss of wetland function can be inferred from loss of wetland area. However, losses of function independent of area loss generally are not readily observable or predictable.

Table 2-2. Generic ecological assessment endpoints (GEAEs): summary of the policy support for their use and their practicality[a] (continued)

GEAE #	Entity: attribute(s)	Policy support	Practicality
12	Assessment communities, assemblages, and ecosystems: <u>physical structure</u>	The primary policy support for this endpoint derives from the Clean Water Act, which applies to aquatic ecosystems. Restoring and maintaining the physical integrity (along with the chemical and biological integrity) of the nation's waters is the primary goal of the Clean Water Act. EPA policies and monitoring guidance under the Act include measures of physical structure.	Protocols exist for measuring many of the physical characteristics of aquatic ecosystems. The impacts of many actions (e.g., channelization, dam construction) on the physical structure of water bodies can be readily predicted. Other effects (such as hydrology changes due to land use changes) are more difficult, but still possible, to model.
Officially designated endpoints			
13	Critical habitat for threatened and endangered species: <u>area</u>	The Endangered Species Act specifically mandates the protection of critical habitat for endangered species in addition to the species themselves. The area (quantity) of available habitat is commonly used in assessing risks to these species.	Information on habitat used by listed species is available from state and federal agencies, although critical habitat has not been officially designated for most listed species. Generally it is practical to determine effects on habitat area.
14	Critical habitat for threatened and endangered species: <u>quality</u>	Legal protection of critical habitat extends to the quality (suitability) of the habitat to endangered species, in addition to its extent.	Assuming that critical habitat can be identified (even if not officially designated), it generally should be practical to determine whether it has been or will be adversely modified.
15	Special places: <u>ecological properties that make them special or legally protected</u>	The Clean Air Act, NEPA, and other statutes require protection of special places such as national parks, wilderness areas, and wildlife refuges, and this is reflected in EPA policies. The Clean Water Act gives EPA a role in designating national estuaries and outstanding national resource waters, which receive additional protection.	Special places and their important ecological properties usually can be defined readily. The ability to predict or detect impacts to these properties will depend on the nature of the properties and whether impacts are direct or indirect.

[a]See Appendix A for details and references.
[b]Environmental Laboratory (1987)
[c]NatureServe's web address is <http://www.natureserve.org>.

that a kill has occurred are much simpler than the methods for determining that the abundance of a population has changed. In addition, the effects on the public of a kill (such as concerns over odor and disease) are not necessarily related to effects on the populations involved. For example, public response to a fish kill may not be related to the ability of the fish populations involved to recover rapidly. Therefore, kills are distinct from both population abundance and extirpation in terms of assessment approaches and management implications.

2.1. Definitions of the GEAEs Organisms

Organisms are the most distinct units of ecology, and attributes of organisms have been the focus of EPA's efforts to protect the environment. However, the use of organisms as endpoints does not necessarily imply that each individual is protected. Rather, "organisms" is a level of biological organization with certain attributes that may be the basis of management decisions. Although organisms of any species may be chosen as assessment endpoint entities, some species are protected at the organism level by statute, including (a) endangered and threatened species (those listed by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service as in danger of extinction under the Endangered Species Act), (b) marine mammals that are protected by the Marine Mammal Protection Act (whales and porpoises, seals, sea lions, and walruses, polar bears, sea otters, and manatees), (c) bald eagles and golden eagles, which are protected by the Bald Eagle Protection Act, and (d) nearly all birds in the U.S., including their eggs and nests, which are protected by the Migratory Bird Treaty Act.

> **1. Kills:** an event or multiple events involving numerous mortalities of organisms within an assessment population or community. Kills may also be referred to as mass mortality or conspicuous mortality. These events may be repeated and wide-spread, as in bird kills due to pesticide applications; repeated at a location, as in fish kills due to repeated treatment failures; or a single event, as in a seabird kill due to an oil spill. They may involve one or more species. Precedents for this GEAE have involved vertebrates.
>
> **2. Gross anomalies:** deformities, lesions, or tumors in animals; death or necrosis of plant leaves; or other overt physical injuries of organisms within an assessment population or community. The occurrence of these injuries may involve one or more species. Precedents for this GEAE have involved vertebrates, shellfish, and terrestrial plants.
>
> **3. Survival, fecundity, or growth:** survival (which may be reduced by direct lethality or by sublethal effects that diminish survival probabilities), fecundity (the production of viable young), and growth (increased mass or length) of some proportion of the animals or plants in an assessment population or community are the basic attributes of concern for nonhuman organisms. In addition to the specific legal protections at the organism level

for the groups discussed above, there are precedents for using these attributes for vertebrates, invertebrates and plants.

Assessment population. An assessment population is a group of conspecific organisms occupying an area that has been defined as relevant to an ecological risk assessment.

4. Extirpation: depletion of an assessment population to the point that it is no longer a viable resource or is unlikely to fulfill its function in the ecosystem. Precedents for this GEAE have involved vertebrates.

5. Abundance: numbers or density of individuals in an assessment population. Total abundance or abundances by age or size classes may be used. Precedents have involved vertebrates and shellfish.

6. Production: the generation of biomass or individuals in an assessment population due to survival, fecundity, or growth. Precedents have involved vertebrates (primarily game and resource species) and plants (primarily harvested species).

Assessment community, assemblage, or ecosystem. A community is a multispecies group of organisms occupying an area that has been defined as relevant to an ecological risk assessment. Groups that are limited to organisms in a taxon (a plant community or bird community) or that are in certain size classes within a taxon (macroinvertebrates or zooplankton) are termed assemblages. Ecosystems are equivalent to communities but include the physical and chemical features of the environment.

7. Taxa Richness: the number of native species or other taxa in an assessment community or assemblage. Precedents have involved aquatic communities and policies protecting coral reefs.

8. Abundance: the number of individuals in an assessment community or assemblage. Total abundance or relative abundances of individual species, other taxa, trophic groups, or other ecologically defined groups may be used. Precedents have involved aquatic communities.

9. Production: the generation of biomass or individuals in an assessment community or assemblage. Precedents for this GEAE have involved plant assemblages. The assemblage may include all plants in an area or water body, in a taxon (e.g., flowering plants), or in another definition (e.g., phytoplankton or above-ground herbs).

10. Area: the area of an ecosystem may be defined as extent of a particular type (e.g., Atlantic white cedar bog) or a particular category (e.g., palustrine wetlands). Area is a protected attribute of wetlands and coral reefs. There are precedents for protecting the areal extent of endangered or rare ecosystem types, which are ecosystems that are at high risk of extinction because they are rare or significantly declining due to destruction or transformation to another type. The ecosystem may be generic (e.g., old growth or virgin forests in the conterminous U.S.) or geographically specific (e.g., Hempstead Plains grasslands on Long Island, NY). The National Biological Survey (Noss et al., 1995) and the Association for Biodiversity Information, among others, have compiled information on rare and endangered ecosystem types.

11. Function: processes performed by ecosystems that are services to humans or other ecological entities. Function is a protected attribute of wetlands. Functional attributes of wetlands may include water storage, maintenance of high water tables, nutrient retention and cycling, sediment retention, accumulation of organic matter, and maintenance of habitats for wetland-dependent plants and animals.

12. Physical structure: precedents are limited to aquatic ecosystems. Physical structure encompasses the physical attributes or characteristics of water bodies, including hydrological characteristics, bathymetry, bank form, sinuosity, pool and riffle structure, bank and channel vegetation, and substrate type and composition. This endpoint includes the aesthetic and other values of aquatic ecosystem structure, not simply habitat quality for aquatic organisms.

Critical habitat for threatened and endangered species. Critical habitat is the specific area within the geographical area occupied by an endangered or threatened species on which are found physical or biological features essential to the conservation of the species and that may require special management considerations and protections (16 U.S.C. 1532(5)). Critical habitats, legally defined and specified by the U.S. Secretary of Interior, are listed in 50 CFR, Ch. 1, Sections 17.94–76. However, habitats that are critical to a threatened or endangered species should be protected when identified even if they are not listed.

13. Area of critical habitat for threatened and endangered species: the land coverage or equivalent aquatic extent (e.g., stream kilometers) that potentially supports the endangered or threatened species.

14. Quality of critical habitat for threatened and endangered species: the suitability of the habitat to support the endangered or threatened species.

15. Properties of Special Places. Special places are public and private areas of ecological or cultural significance that are not necessarily endangered or threatened but whose unique character or natural heritage is important—as revealed by laws or other actions that set them aside. Examples include World Heritage sites, national parks and natural landmarks, wilderness areas, national wildlife refuges, national conservation areas, wild and scenic rivers, estuarine and marine sanctuaries, private nature preserves (e.g., Nature Conservancy preserves and National Audubon Society sanctuaries), and state and local parks. For a more comprehensive list, see U.S. EPA (1991a). The ecological properties to be protected are those that make the place special, including those that are an important part of the historical or cultural heritage of a place (e.g., shortgrass prairie at Little Bighorn National Monument). Hence, this GEAE is relevant only to special places with ecological properties that are important to their designation. We would not, for example, apply this GEAE to a renovation of Grant's Tomb.

2.2. Assessment Populations and Communities

Because the conventional ecological meaning of "populations" and "communities" presents problems in practice, this document introduces the terms "assessment population" and "assessment community" (defined above). Although ecological assessment endpoints inevitably 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. Classically defined populations are discrete and interbreeding. Classically defined communities are discrete and their constituent species are relatively consistent and interact in predictable ways. Although these classical definitions have been important to the development of genetics, evolution, and ecology (e.g., Hardy-Weinberg equilibrium and the competitive exclusion principle), they have always had manifest limitations in practice.

More recently, ecology has become more focused on temporal dynamics, spatial patterns and processes, and stochasticity that belie the notion of static, independent populations. One example of this is metapopulation analysis, which reveals that population dynamics are significantly determined by exchange of individuals among habitat patches or differential movement across a landscape that continuously varies in suitability (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, 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 almost exclusively 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." However, an occurrence of a bird species would be defined quite differently.

We propose a similar approach for GEAEs. 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 steam 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 on a watershed or a lake as an assessment population.

Assessment populations may be defined by nonbiological considerations as well. For example, for Superfund ecological risk assessments on the U.S. Department of Energy's Oak Ridge Reservation, 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, and bobcat, among others. 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. For similarly practical reasons, one might define an assessment community of benthic invertebrates in 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 tradeoff. 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 community may be significantly affected but may seem too insignificant to prompt stakeholder concern or action by the decisionmaker. Hence, appropriate spatial scales should be determined during the problem formulation stage for individual risk assessments, taking into consideration both the ecological and policy aspects of the problem; it must not be manipulated during the analysis to achieve a desired result.

3. HOW TO USE THE GEAEs

In a risk assessment for a specific site, effluent, stressor, or action, it will be necessary to determine whether any of the GEAEs are applicable to the assessment and sufficient for the case, and if so, how they can be made specific to the case. These activities are performed as part of the problem formulation phase of risk assessment (U.S. EPA, 1998a).

Criteria for selection of assessment endpoints

EPA has provided criteria for developing assessment-specific assessment endpoints: ecological relevance, susceptibility, and relevance to management goals (U.S. EPA, 1998a, Section 3.3.2).

Ecological relevance pertains to the role of the endpoint entity in the ecosystem and therefore depends on the ecological context.

Susceptibility pertains to the sensitivity of the endpoint to the stressor relative to its potential exposure and therefore depends on the identity of the stressor and the mode of exposure.

Relevance to management goals pertains to the goals set by the risk manager and therefore depends on the societal, legal, and regulatory context of the risk management decision as well as the preferences of the individual risk manager and stakeholders.

These situation-specific criteria should be applied whenever GEAEs are converted to assessment endpoints in individual assessments.

3.1. Using GEAEs in Assessment Endpoint Selection

The set of GEAEs is intended to be helpful for identifying and specifically defining assessment endpoints for particular assessments. During problem formulation, risk assessors, scientists, risk managers, and any stakeholders identify endpoints that are relevant to the assessment, that are of sufficient importance to potentially influence the decision, and that reflect any goals that may have been set prior to the problem formulation (U.S. EPA, 1998a). The assessment-specific criteria for selecting assessment endpoints from the guidelines for ERA are used in that process (see text box).

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, as shown below. Together, the questions address the criteria for ecological assessment endpoints. The GEAEs constitute one type of information that answers one question. In addition, the table of GEAEs can be consulted while answering the other questions as a means of ensuring that commonly considered types of entities and attributes are considered.

1. *Stressor characteristics.* What is susceptible to the stressor? For well-understood stressors, this question is straightforward. Benthic invertebrates are susceptible to

dredging, birds are susceptible to granular pesticides, wetlands are susceptible to filling, and so on.

2. *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, an assessment of a new pesticide for corn would consider the species likely to be found in or adjacent to corn fields in the midwestern U.S. In the absence of specific information about the particular importance of an entity, those that are present may be assumed to be ecologically relevant.

3. *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.

4. *Input by interested parties.* What is of concern? If interested parties 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 the GEAEs, values that are specific to a locale or resource are expressed by interested parties.

5. *GEAEs and new policies or precedents.* What is supported by policy or precedent? The GEAEs defined in this report provide a set of entities and attributes that meet this criterion, which is an expression of national goals and values at the time of publication.

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 stressor may be unknown, and the concerns of interested parties are often unknown and often do not include important potential endpoints.

No particular procedure is prescribed for this process of answering the questions or for using the GEAE set. If consistency with 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, the questions might each be answered and the lists then integrated. In that case, the endpoints for a specific assessment may simply be those that are represented on most of the lists.

3.2. Making the Generic Endpoints Specific

To convert a GEAE into an assessment endpoint for a specific assessment, it is necessary to define the specific entity and attribute and the spatial and temporal context of the entity. This specificity is needed to make the endpoint relevant to the assessment and to determine which measurements and models are needed to estimate it.

Consider the first GEAE, kills of organisms, as an example. The generic entity is organisms. For a specific assessment endpoint, we must specify whether the endpoint entity corresponds to members of a specific taxon such as fish or birds, an assemblage such as macroinvertebrates, or a specific species such as sea otters. The generic attribute is kills, which should be defined more specifically and in terms that are appropriate to the assessment. For example, the definition of a kill would differ for a well-monitored experimental use of a pesticide versus public reports of mortalities, for oil spills versus lawn treatments, and for modeling studies versus observational studies. Possible definitions could include the number of organisms that must die during an episode for it to be considered a kill, the proportion of organisms visiting a site that would be expected to die, or the frequency of public reports of dead organisms associated with the stressor. Finally, the spatial and temporal contexts should be defined. For an effluent, the contexts may be the downstream reach within which mixing occurs and the period of a permit. For a pesticide, they may be the region within which the pesticide is used on a particular crop and the number of applications per year over the period of use. For an oil spill, they may refer to the area encompassed by the plume and the time until the plume is dispersed or degraded to the point that it no longer oils marine birds or mammals. Hence, an assessment endpoint derived from this GEAE might be episodic mortality of at least 10 fish of any species occurring in the 1 km reach downstream of the effluent release point.

The answers to the first four questions in Section 3.1 provide the basis for specific endpoint definitions; that is, they determine which specific organisms, populations, or ecosystems are susceptible and potentially exposed and which are of concern, the spatial and temporal scales that are relevant to management goals, and other relevant considerations.

More than one assessment endpoint may be derived from a GEAE for a particular assessment. For example, the GEAE population abundance may be used to generate assessment endpoints for each of several populations of concern, and the change in abundance and spatial context may be different for each. On the other hand, a site-specific concern may relate to more than one GEAE. In the example of the wetland discussed in the previous chapter, the site-specific problem formulation must determine whether the management concern and the evidence of wetland susceptibility are related to the area of the wetland, a functional attribute of the wetland, such as nitrogen retention, or both.

3.3. Other Ecological Assessment Endpoints

The GEAEs presented in this document are those that are thought to be currently generically useful in EPA and do not preclude the use of other endpoints. Other endpoints may be chosen because they reflect some particular environmental value associated with a site or held by a particular stakeholder or for some other reason they are particularly appropriate for a particular assessment (see Section 3.1). In addition, some endpoints that are not generically practical may be practical in a particular case because of peculiarities of the stressor or receptor, data availability, or availability of a model of the receiving system or because time and resources are available to assess a difficult endpoint. These additional assessment endpoints must meet the criteria in the EPA's guidelines.

3.4. Completing a List of Assessment Endpoints for a Specific Assessment

When a list of potential assessment endpoints has been developed, it may be necessary to review the list and reduce it to those that are important to the decision. Because of the limitations of time and resources, it is often advisable to limit the list of assessment endpoints to those that are most relevant and susceptible. There is likely to be some redundancy in the endpoints. Kills of organisms imply immediate changes in population abundance that may influence community abundances. If population or community properties are important to the decisionmaker, they should be retained. However, if kills are sufficient to warrant action, the extrapolations to higher levels of biological organization may be unnecessary and those endpoints may be dropped as unnecessarily redundant.

4. RECOMMENDATIONS FOR FURTHER PROGRESS

The main purpose of this report is to improve ecological considerations within EPA by developing an initial set of generically useful ecological assessment endpoints (see Table 2-1). However, these initial assessment endpoints are based on existing policy and practice rather than on an evaluation of all the potentially useful ecological assessment endpoints that may exist for the Agency now or in the future. Therefore, readers of this report are encouraged to (1) develop and maintain a continual, open process for reviewing, amending, and creating new GEAEs and (2) establish a means of keeping track of the many rationales and precedents used for making ecological risk-based decisions throughout EPA. In particular, as the GEAEs are applied to ecological risk assessments, the experiences should be documented and published as case studies. The remainder of this chapter provides more discussion about these two recommendations and concludes with a method of how you, the reader, can contribute to EPA's progress in this area by suggesting other useful assessment endpoints. Table 4-1 presents potential GEAEs for more immediate consideration by EPA.

4.1. Develop and Support a Continual, Open Process for Reviewing, Amending, and Creating New GEAEs

The initial GEAEs presented in this report include important ecological attributes to consider when conducting ecological assessments throughout EPA. However, the Agency should not remain static or constrain itself to these particular GEAEs. EPA should establish and maintain an adaptive and open process for reviewing and amending ecological assessment endpoints over time, as science and Agency experience evolve. Care must be taken so that new GEAEs are consistent with this document and the Agency's ecological risk assessment guidelines. The process and frequency of these updates or reviews must be approved by Agency management.

Both the technical panel and external peer reviewers of this document suggested that regular reviews of EPA's generic ecological assessment endpoints are important and that five-year intervals would be appropriate for updating them. There is consensus that broad participation is also vital. Members of future review panels should represent as many programmatic, regional, and support offices of EPA as possible, and they should consider external input from other government agencies, nongovernment organizations, academia, the general public, and the private sector.

Table 4-1. Potential GEAEs

Entity	Attribute
Organism-level endpoints	
Organisms (in an assessment population or community)	Physiological status (in addition to growth) Disease or debilitation (in additions to gross anomalies) Avoidance behavior Courtship behavior (e.g., birds) Migratory behavior (e.g., birds and salmonids) Nurturing and rearing behavior (e.g., nest abandonment)
Population-level endpoints	
Assessment population	Genetic diversity
Community and ecosystem-level endpoints	
Assessment communities, assemblages, and ecosystems	Trophic structure Energy flow Nutrient cycling (ecosystems in addition to wetlands) Nutrient retention Decomposition rates Sediment and material transport Area or function of estuaries and riparian ecosystems Resilience Vertical structure of plant communities Attributes that influence public health
Landscape-level endpoints	
Assessment landscapes (of multiple populations, communities, assemblages, and ecosystems)	Spatial pattern (random, clustered or uniform; dominance; contagion; contiguity or fragmentation; juxtaposition)

4.2. Develop a Database to Document and Keep Track of New Rationales, Precedents, and Assessment Endpoints

A readily accessible and searchable database of existing and new ecological assessment endpoints should be established and supported on a continual basis. This database could be for internal (and perhaps external) use and provide rationales and precedents (or histories) of how these ecological assessment endpoints have been used by EPA. For example, when a program or regional office finds scientific or societal justification for an ecological assessment endpoint, that office should consider it again in future assessments and share this knowledge with other offices throughout the Agency. Useful information could include how the ecological assessment endpoint affected decision making, whether some endpoints carry more weight than others, or whether they were ignored or too difficult to interpret or use. The technical panel recommends creating a centralized, web-based database for facilitating this process.

4.3. Potential GEAEs for Future Consideration

EPA is responsible for stating its mandates as clearly understood goals and assessment endpoints for ecological protection. As different stressors challenge our environment and our scientific understanding of ecosystems improves, new ecological assessment endpoints will need to be considered and incorporated into EPA's mission.

In Table 2-1, the technical panel recommends assessment endpoints that have some existing precedent or legal or regulatory basis for use within EPA. Such precedents, as presented in Appendix A, include treaties, statutes, regulations, judicial decisions, official memoranda, guidance or procedures, and other documentation. However, the technical panel remains concerned about otherwise valid and important ecological assessment endpoints being excluded from Table 2-1 and encourages users of this guidance to continually strive for further progress and innovation within the Agency to advance new and improved GEAEs. Therefore, on the basis of comments received from peer reviewers of this report as well as suggestions found in recent Agency publications (e.g., U.S. EPA 2002a), the technical panel also recommends the potential GEAEs presented in Table 4-1 for consideration by EPA scientists and managers. Note that some of these potential assessment endpoints are not entirely new, but rather are extensions the of the GEAEs listed in Table 2-1, and some may not yet satisfy the criterion of practicality, as defined in Section 1.3.

We encourage EPA's program and regional offices to regularly consider the GEAEs in Tables 2-1 and 4-1 and other potentially relevant assessment endpoints for purpose of guiding EPA's evolving ecological mission. However, in order to keep GEAEs meaningful,

Developing new assessment endpoints

One suggestion for developing new assessment endpoints is to consider the following dimensions associated with ecological systems and whether they are addressed in Agency risk assessment activities:

1. Levels of biological organization (e.g., potentially ranging from DNA to biomes).
2. Spatial scale (e.g., ranging from local to global boundaries).
3. Temporal scale (e.g., considerations of the timing, duration and/or frequency of biological activities or events).
4. Magnitude (e.g., the total number of ecological entities present, impacted, or remaining with respect to a known baseline or presumption of what should be there).
5. Taxonomic groups (i.e., beyond mammals, fish, and birds to other taxa such as amphibians, reptiles, invertebrates, bacteria, fungi, and flowering and nonflowering plants.
6. Range of ecological properties (e.g., resiliency in ecosystems).

The initial GEAEs presented in Table 2-1 incorporate or touch upon many of these dimensions, yet many other assessment endpoints could potentially be derived by increasing the range of just one of these dimensions or by integrating two or more of these dimensions in a new way.

the Agency should consider maintaining a conservative approach toward adding new ones. This can be done by consistently applying the criteria established in this guidance and by paying close attention to the distinction between assessment endpoints and measures of effect (i.e., measurement endpoints).

5. CONCLUSION

The development of this document revealed that the laws, policies, and precedents for protecting attributes of ecological entities are numerous and diverse. They provide a strong basis for defining assessment endpoints at the organism, population, and community/ecosystem levels of organization. They are defined and organized in a consistent fashion in this report as GEAEs.

GEAEs are widely applicable to various assessment scenarios and can provide a foundation for the development of endpoints for specific assessments during problem formulation. This set of GEAEs can be used by risk assessors and risk managers with the confidence that they are supported by established policies and precedents and thus will improve the scientific basis for ecological risk management decisions.

Risk assessors and risk managers throughout the Agency are encouraged to track the rationales for making ecological risk-based decisions, thereby providing a basis for reviewing and updating these GEAEs in the future.

APPENDIX A. SUPPORTING INFORMATION

This appendix serves as a reference for those who need to know the basis for a particular GEAE defined in Section 2. The GEAEs have been divided into three categories of biological organization—organism, population, and community/assemblage/ecosystem—and a fourth category containing endpoints (critical habitats and special places) that are most easily described separately. Each category is introduced by general information about how the GEAEs in that category have been used by the Agency. Additional supporting information divided into two sections, is then provided for each GEAE. The first section is Laws, Regulations, and Precedents, which discusses the authorities that support the use of each GEAE by EPA and gives examples of Agency actions that provide a further basis for their use. The second section is Practicality, which discusses the availability of methods to estimate risks to the endpoint and their applicability in various risk assessment contexts. Because assessment endpoints are defined as valued properties of the environment (U.S. EPA, 1998a), public values associated with the GEAEs are discussed in broad terms in Appendix B.

It should be noted that the specific laws and other policies cited below are not the only support for ecological endpoints. The many federal environmental laws and their implementing regulations provide a general mandate for environmental protection that goes far beyond the specific instances presented in this appendix. In particular, the National Environmental Policy Act of 1970 creates a broad mandate for federal agencies to protect and prevent degradation of the environment. Although nearly all environmental statutes refer to the environment as an entity to be protected, and many refer to more specific ecological entities such as fish, wildlife, and estuaries, few indicate an attribute to be protected or even the nature of the entity. In addition, terms are not necessarily used in a technical way. For example, the Clean Water Act refers repeatedly to "a balanced indigenous population of fish, shellfish and invertebrates." Clearly, the phrase does not refer to a biological population, which is formed of members of one species. Further, when referring to fish, does the act mean fish at the level of organism, population, or assemblage or as a taxon? Given these ambiguities, the wording of the statutes must be interpreted to define endpoints. The primary source of support for the following interpretations is precedent.

The precedents and other expressions of policy discussed below are a sample of those that have been used in assessments, guidance, protocols, and other Agency actions over the years. Although they are derived from particular laws and regulatory contexts, they may be interpreted as examples of what Congress and the Agency have meant by protecting the environment. For example, the Clean Air Act calls for specific protection of "national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value." This requirement can be interpreted as a mandate to the Agency to protect those special areas from pollution, not just from the threats from air pollution that were brought to the attention of Congress.

The following abbreviations and acronyms are used in this appendix:

CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
CWA	Clean Water Act
ESA	Endangered Species Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FR	Federal Register
LC50	Median lethal concentration
LD50	Median lethal dose
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
SSD	Species sensitivity distribution
TSCA	Toxic Substances Control Act

A.1. Organism-Level Endpoints

Major EPA statutes such as the CAA, CWA, CERCLA, FIFRA, TSCA, and RCRA require that EPA consider and protect organism-level attributes or various taxa of organisms, including fish, birds, and plants and, more generally, animals, wildlife, aquatic life, and living things. The toxicity information that is available to EPA in administering these statutes is dominated by organism-level attributes such as mortality. Organism-level attributes tend to be more practical to measure or predict than attributes at higher levels of organization for most EPA assessments. Consequently, EPA's ecological assessments historically have focused on organism-level endpoints. Note that these endpoints do not normally imply protection of each individual organism, but rather the protection of these critical attributes of organisms within assessment populations or communities. As will be described, however, certain special categories of organisms, such as endangered species and marine mammals, have been afforded protection on an individual basis.

In ecological assessments, EPA considers organism-level effects in a variety of taxa. For example, tests required for pesticide regulation can include effects on survival, growth, and reproduction (GEAE #3) of aquatic invertebrates, fish, birds, mammals, and both terrestrial and aquatic plants. Effects on a similar range of taxa are considered under TSCA (Lynch et al., 1994; Zeeman et al., 1999) and in deriving water quality criteria under the CWA. Less commonly, other taxa, such as earthworms (e.g., at certain Superfund sites), honeybees (e.g., for certain pesticides), and reptiles and amphibians are considered .

Connections between organism and higher-level endpoints

Not only are organism attributes potentially important in themselves, but they are also important because they are protective of higher-level attributes. That is, we commonly assume that if we protect important attributes of organisms in a population or community, the population and community attributes will be protected as well. EPA's principles for ecological risk assessment and risk management at Superfund sites (U.S. EPA, 1999b) illustrate a common usage of organism-level endpoints at EPA:

"Except at a few very large sites, Superfund ERAs [ecological risk assessments] typically do not address effects on entire ecosystems, but rather normally gather effects data on individuals in order to predict or postulate potential effects on local wildlife, fish, invertebrate, and plant populations and communities that occur or that could occur in specific habitats at sites…. Levels [of chemicals] that are expected to protect local populations and communities can be estimated by extrapolating from effects on individuals and groups of individuals using a lines-of-evidence approach."

When organism-level information is not sufficient, it may be necessary to assess higher-level attributes directly, by employing population or community models or measurements.

A.1.1. GEAE #1. Kills of Organisms

Laws, Regulations, and Precedents: Kills

The regulation of chemicals to prevent kills of organisms, in the absence of effects on populations or communities, has been sustained by federal courts. For example, the use of the pesticide diazinon on golf courses and sod farms was prohibited after documentation of widespread and repeated bird kills (U.S. EPA, 1988a). Subsequently, EPA cited continuing bird kills as a factor in the agreement with pesticide manufacturers to phase out all outdoor residential uses of diazinon (U.S. EPA, 2001a). Bird kills were also the basis for phasing out most uses of another pesticide, granular carbofuran (U.S. EPA, 1991b; Houseknecht, 1993). Kills of birds and other wildlife in oil pits are considered evidence of "imminent and substantial endangerment to the environment" under RCRA §7003 (U.S. EPA, 2003a). Fish kills have also been considered a concern by EPA; for example, Region 5 considers fish kills and other excess mortality to be obvious impacts under RCRA (U.S. EPA, 1994).

Under FIFRA reporting requirements for adverse effects of pesticides (40 CFR Part 159), EPA categorizes kills (and other adverse incidents) involving multiple organisms as more severe events than single organism incidents and imposes additional reporting requirements on pesticide registrants for such events. More severe wildlife incidents are defined as those involving at least 1000 individuals of a schooling fish species or 50 individuals of a nonschooling species; 200 individuals of a flocking bird species, 50 individuals of a songbird species, or 5 individuals of a predatory species; or, for mammals, reptiles, and amphibians, 50 individuals of a relatively common or herding species or 5 individuals of a rare or solitary species. (Note that incidents involving numbers of organisms below these thresholds still must be reported, but the requirements are different than those for more severe incidents. Also note that these criteria do not apply outside FIFRA.)

Practicality: Kills

The likelihood of kills is relatively readily estimated using the common acute lethality tests that generate LC50s and LD50s. The number of species involved in kills may be estimated from SSDs of LC50s or LD50s, as in the calculation of the acute National Ambient Water Quality Criteria (U.S. EPA, 1985a; Posthuma et al., 2002). The occurrence of kills in the field may be readily observed in the cases of conspicuous organisms and open habitats, but in other cases, such as with small birds in crops or fence rows, kills may be unobserved and difficult to document. Recently, a model has been developed to predict the probability of bird kills for a particular use of a cholinesterase-inhibiting pesticide using SSDs of LD50s and field studies (Mineau, 2002).

A.1.2. GEAE #2. Gross Anomalies of Organisms

Laws, Regulations, and Precedents: Gross Anomalies

Gross anomalies in birds, fish, shellfish, and other organisms are cause for public concern and have been the basis for EPA regulatory action and guidance. For example, crossed bills and other deformities in piscivorous birds are a basis for the proposed remediation of the PCB-contaminated sediments at the Fox River/Green Bay Superfund site (Wisconsin Department of Natural Resources, 2001; U.S. EPA, 1998b) and were a basis for the designation of the system as an Area of Concern by the Great Lakes National Program Office (U.S. EPA, 2001b). EPA actions to restrict the use of tributyltin as an antifoulant on boats (U.S. EPA, 1988b), as well as the restrictions imposed by the Organotin Antifouling Paint Control Act of 1988, were triggered by the observed induction of gross deformities in mollusks that threatened the marketability of oysters, reduced the fecundity of the deformed organisms, and suggested the potential for other effects.

Natural resource damage regulations for CERCLA, the CWA, and the Oil Pollution Act include gross anomalies among the designated injuries (43 CFR §11.62(f)), and deformities, erosion, lesions and tumors in fish (DELT anomalies) are used in the biocriteria of many state water quality standards and in Agency guidance (Yoder and Rankin, 1995; U.S. EPA, 1996). Changes in development, which can be manifested in physical anomalies, have been identified as an environmental effect of regulatory concern under TSCA (U.S. EPA, 1983).

Anomalies in plants and plant injuries have also been the basis for EPA action. For example, EPA established a secondary ambient air quality standard for ground-level ozone partly on the basis of visible foliar injury to commercial crops and natural vegetation, stating that "foliar injury is occurring on native vegetation in national parks, forests, and wilderness areas, and may be degrading the aesthetic quality of the natural landscape, a resource important to public welfare" (U.S. EPA, 1997b). EPA has also used visible injury of plants as a basis for regulating air emissions of aluminum reduction plants and sulfuric acid production units (U.S. EPA, 1994).

Practicality: Gross Anomalies

External gross anomalies are readily observed, as are some internal anomalies with external manifestations such as severe scoliosis or large tumors. Gross anomalies are commonly included in biological survey protocols for fish and in forest health surveys. They are also included as endpoint responses in some chronic tests of fish and birds.

A.1.3. GEAE #3. Survival, Fecundity, and Growth of Organisms

As discussed in Section A.1., EPA's ecological assessments have considered effects on survival, fecundity, and growth in a variety of taxa. Although actions based on survival may be the most common, EPA has also made regulatory decisions on the basis of effects on fecundity and growth of organisms identified in ecological risk assessments. For example, the pesticide chlorofenapyr was not approved by EPA on the basis of Agency concerns over reproductive risks to birds. Additionally, federal statutes and other precedents confer special status on particular kinds of organisms: endangered and threatened species, marine mammals, bald and golden eagles, and migratory birds. The remainder of this section concentrates on the basis for the special status of these organisms within the organism-level endpoints.

Laws, Regulations, and Precedents: Survival, Fecundity, and Growth

Endangered and threatened species. The ESA protects threatened or endangered species from taking, which is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (16 US Code, §1532, and 50 CFR, parts 14, 17, and 23). Under the act, the term "species" includes "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." The ESA states that it is "to be the policy of Congress that all Federal departments and agencies shall seek to conserve endangered species and threatened species" and that "Federal agencies shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species" (16 US Code, §1531). Hence, the provisions of the ESA are applicable to EPA actions, and both the prohibition against harming individual members of threatened or endangered species and the affirmative obligation to conserve those species would seem to include toxic effects. Additionally, the CAA (§112) specifically requires EPA to prevent adverse effects to endangered species in regulating hazardous air pollutants.

Like other federal agencies, EPA has published regulations and taken actions to protect endangered species. For example, EPA has consulted with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to prevent jeopardy to endangered species, as required by the ESA, for actions such as setting water quality standards and regulating pesticides. In these consultations, the attributes of concern have generally been survival, fecundity, and growth, although other attributes may be important in specific cases. The NCP specifies that the ESA is a federal "applicable or relevant and appropriate requirement" with which Superfund remedial actions should comply under CERCLA §121(d)(2)(A), and examples of Superfund ecological risk assessments that used endangered species as endpoints include the Asarco Tacoma site (chinook salmon and bull trout) (Hillman and Rochlin, 2001), the Metal Bank of America site (shortnose sturgeon) (Wentsel et al., 1999), and the Montrose, Iron Mountain Mine, Fort Ord and Monterey Marine Sanctuary, Camp Pendleton-Santa Margarita River, and Pearl Harbor sites (U.S. EPA, 1994).

Marine mammals. The Marine Mammal Protection Act protects marine mammals from taking, which is defined as

> to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal….The term 'harassment' means any act of pursuit, torment, or annoyance which (I) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering. (US Code, §1362)

Although the act does not specifically address toxic effects on marine mammals, the special protection afforded these species by the act implies a particular concern for their well-being. Also, the law clearly protects properties of marine mammals at the organism level.

As with threatened and endangered species, the NCP specifies that the Marine Mammal Protection Act is a federal "applicable or relevant and appropriate requirement" with which Superfund remedial actions should comply under CERCLA, §121(d)(2)(A), and it cites marine mammals as examples of specific natural resources to be protected under CERCLA, Part 101, §16.

Bald and golden eagles. Prohibited actions under the Bald and Golden Eagle Protection Act include to "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or in any manner any bald eagle commonly known as the American eagle or any golden eagle, alive or dead, or any part, nest, or egg thereof of the foregoing eagles…" (16 US Code, §668). To take, as defined by regulation, includes "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect" bald eagles or golden eagles, including any "part, nest, or egg of such bird[s]" (50 CFR §10.12).

Deaths of bald eagles due to secondary poisoning were an endpoint in EPA's assessment of granular carbofuran (U.S. EPA, 1991b), which led to the phaseout of most uses of this pesticide. Also, EPA's ecological risk assessment for PCBs in the Hudson River included survival, growth, and reproduction of piscivorous birds as an assessment endpoint, with the bald eagle selected as one of the representative species of piscivorous birds (U.S. EPA, 2000).

Birds. The Migratory Bird Treaty Act of 1918 prohibits or regulates a number of activities, including pursuing, taking, hunting, capturing, killing, possessing, selling, transporting, or purchasing migratory birds, including their eggs and nests (16 US Code, §703). This act, based originally on a treaty between the United States and Great Britain (including Canada), has since been extended by migratory bird conventions with Mexico, Japan, and the Soviet Union. Because nearly all species of birds native to the United States are protected by the act (U.S. Fish and Wildlife Service, 2001), the endpoint may be assumed to apply to native birds in general. Although the Migratory Bird Treaty Act does not specifically address toxic effects on birds, the special protection afforded these species by the act implies a particular concern for their well-being. Also, the law clearly protects birds at the organism level. Furthermore, by Executive Order 13186, all federal agencies are required to "support the conservation intent of the migratory birds conventions by integrating bird conservation principles, measures, and practices into agency activities and by avoiding or minimizing, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions" and to "prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable" (Clinton, 2001).

EPA policies and precedents affirm the use of survival, growth, and reproduction of birds in ecological assessments. The NCP specifies that the Migratory Bird Treaty Act is a federal "applicable or relevant and appropriate requirement" with which Superfund remedial actions should comply under CERCLA §121(d)(2)(A), and examples of Superfund ecological risk assessments that used birds as endpoints include the Baird and McGuire site (survival and reproduction of songbirds) (Menzie et al., 1992) and the United Heckathorn site (reproductive effects on birds) (Wentsel et al., 1999). EPA's ecological risk assessment for PCBs in the Hudson River included survival, growth, and reproduction of insectivorous birds, waterfowl, and piscivorous birds as assessment endpoints (U.S. EPA, 2000). EPA regulations authorize the Agency to require pesticide registrants to submit tests on avian mortality and impaired avian reproduction caused by pesticides. Results from these tests, in conjunction with other available information, are used by EPA in making pesticide registration decisions. Also, EPA's involvement in bird conservation initiatives such as Partners in Flight and the North American Bird Conservation Initiative provides further support for using birds in assessment endpoints (U.S. EPA, 2002b).

Practicality: Survival, Fecundity, and Growth

Because the vast majority of standard toxicity tests determine effects on the survival, fecundity, and growth of organisms, direct toxic effects on this endpoint are readily predicted. In addition, extrapolation models are available that can estimate effects on this endpoint for particular organisms and exposure routes of concern on the basis of tests conducted on other species, life stages, or exposure durations or routes.

It is rarely possible to obtain toxicity data for threatened and endangered species, but SSDs, intertaxa regressions, or other interspecies extrapolation models should serve to estimate effects of these species (Suter, 1998; Posthuma et al., 2002). EPA research has confirmed that endangered species are not inherently more sensitive than other species to toxic effects (Sappington et al., 2001), although, from a population standpoint, they may be at greater risk due to their low abundance.

Effects on marine mammals are relatively difficult to observe in the field. However, die-offs of pinnipeds and cetaceans are readily observed when their conspicuous carcasses appear on beaches. The toxicology of marine mammals is poorly known, and, for obvious reasons, marine mammals are not included in routine toxicity testing. However, effects on all mammals are routinely estimated from tests performed with rodents. Exposure of marine mammals is also poorly known and is not routinely estimated, even though these mammals can accumulate high levels of persistent pollutants.

Eagles are highly conspicuous, and dead or debilitated eagles are more likely to be reported by the public than are most birds. In addition, federal, state, and private organizations monitor eagles at various scales. Toxic effects on eagles may be predicted from standard avian toxicity tests or, more confidently, from tests with kestrels, with avian allometric models used to extrapolate toxicity results to eagles.

In general, the biology of birds is well known, and well-developed methods exist for surveying bird populations and communities. Both acute and chronic test protocols for birds are available, and avian toxicity data are available for most pesticides and many other chemicals. However, because birds are highly mobile, often migratory, and often territorial, it is usually difficult to demonstrate chronic effects on these organisms in the field.

A.2. Population-Level Endpoints

As described in Section A.1., most environmental statutes authorizing EPA activities call for protection of a diverse array of organisms. These statutes generally can be inferred to protect population-level endpoints in addition to organism-level endpoints, even if populations are not specifically cited by law. EPA's principles for ecological risk assessment and risk management at Superfund sites exemplify EPA's concern about population-level endpoints: "Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota" (U.S. EPA, 1999b).

Predicting population-level impacts generally is not as straightforward as estimating organism-level effects and, as a result, explicit estimates of population effects are less common in EPA ecological assessments. Adverse effects on organisms are often inferred to indicate risk to populations and hence a cause for concern under certain EPA programs, such as Superfund. Similar inferences are made for chemical reviews under TSCA. In examining environmental effects of concern under TSCA, an EPA position paper reviewed a number of statutes spanning the period of 1785 to 1978 to determine society's environmental values (U.S. EPA, 1983). EPA concluded that such laws were passed to prevent any reduction, degradation, or loss in the quality, quantity, or utility of a resource that is valued by the public. It also concluded that chemicals could adversely affect these resources by causing an undesirable change in the population structure of a species by affecting rates of mortality, reproduction, or growth and development. Thus, organism-level attributes such as mortality can be inferred to affect population-level attributes valued by society. Less commonly, EPA prepares quantitative estimates of population effects based on organism-level effects or other information.

Population-level endpoints have been assessed at EPA for commercially or recreationally valuable species such as fish, birds, and shellfish.

A.2.1. GEAE #4. Extirpation of an Assessment Population

Extirpation can be viewed as an extreme case of a change in abundance or production of an assessment population, and thus its selection is supported by the factors cited in Section A.2.2. Additionally, extirpation of an assessment population may have qualitatively more significant impacts on ecological function and environmental values than just reduction in the size of the assessment population, as reflected in an alternative term for this population attribute: functional extinction.

Laws, Regulations, and Precedents: Extirpation

Several EPA precedents exist for assessing population extirpation. For example, EPA examined the likelihood of extirpation of fish populations in northeastern lakes under the acid deposition program and vetoed a permit for a dam and reservoir project under Section 404 of the CWA, in part on the basis of the projected extirpation of populations of birds of special interest (U.S. EPA, 1994). Absence of a species normally occurring in the habitat has been used as evidence of ecological risk at Superfund sites. Where designated aquatic life uses have been specified in state water quality standards, extirpation of a naturally occurring species may be considered as evidence that the waterbody is not attaining its designated uses.

Practicality: Extirpation

Field observations to determine whether a species is present usually are not difficult to conduct, but ease of observation depends upon the species, and care must be taken in interpreting results. Failure to observe a species that is expected to occur in low numbers even in the absence of stressors, that is subject to substantial natural fluctuations in abundance, or that is inconspicuous may not be indicative of extirpation. Demonstrating extirpation at a site also requires evidence that the species was formerly present.

In some cases, risk of extirpation can be inferred from toxicity data. Very high exposure in the field in comparison to exposures where toxic effects have been observed in laboratory tests suggests a high likelihood of extirpation and, conversely, very low exposure implies that extirpation is unlikely. Population modeling (such as population viability analysis) or ecosystem modeling may be required to estimate the likelihood of extirpation in cases where exposure is lethal to only a portion of individuals, where effects on reproduction are expected but limited, or where effects are indirect. Population modeling typically requires species-specific data on parameters not routinely available in ecological risk assessment, such as age-specific reproduction rates. However, population models are available and well developed and have been used to predict extirpation, particularly of fisheries (Barnthouse, 1993; Pastorok et al., 2002). See also Section A.2.2.

A.2.2. GEAE #5. Abundance of an Assessment Population

Laws, Regulations, and Precedents: Abundance

Abundance is the most common population-level endpoint considered by EPA. On occasion, EPA evaluated population models to explore effects on abundance by chemicals regulated under TSCA. For example, EPA explored the risks of chloroparaffins to a rainbow trout population using a projection matrix model (U.S. EPA, 1993a). Maintenance of populations of piscivorous birds and mammals was the ecological assessment endpoint for the Mercury Report to Congress (U.S. EPA, 1995).

Additionally, more than 25 estuaries have been selected as national estuaries by EPA, as authorized by the CWA. Restoring or protecting populations and production of fish and shellfish for commercial and recreational use typically is among the goals of individual national estuary programs. Similarly, a goal of the Chesapeake Bay Program (a partnership among EPA and the states adjoining the bay) is restoring, protecting, and enhancing fish and shellfish, with measures including populations of oysters and priority migratory fish species such as striped bass.

Practicality: Abundance

Changes in population abundance may be predicted using conventional toxicity data with statistical extrapolation models and population models (Suter, 1993; Pastorok et al., 2002). This approach can produce reasonable results, and has been validated in controlled conditions. For example, Kuhn et al. (2001) compared a mysid shrimp population prediction from a stage-based projection matrix model with a 55-day laboratory population study involving shrimp exposed to p-nonylphenol. The population model was able to project within a few micrograms per liter the concentration where population-level effects would begin to occur (16 μg/L projected from the model vs. 19 μg/L measured from the assay). Although such projection matrix models are practical, they require more effort than is normally applied to routine ecological risk assessments.

Population abundance may also be estimated using individual-based population models or, as discussed in Section A.3, ecosystem models. Measurement of population abundance in the field may be easy (e.g., for flowering plants) or difficult (e.g., for pelagic cetaceans). However, even when measurement is easy, distinguishing changes in abundance may be quite difficult due to temporal variance, and distinguishing differences from reference populations may be difficult due to differences in habitat quality as well as stochastic variance. The literature in ecology concerning the measurement and monitoring of various plant and animal populations is voluminous.

A.2.3. GEAE #6. Production of an Assessment Population

Laws, Regulations, and Precedents: Production

Much of the support for GEAE #5, abundance of an assessment population, also applies to this endpoint. For example, the CWA sets a national goal of "protection and propagation of fish, shellfish, and wildlife," which implies both abundance and production, and efforts under the National Estuary and Chesapeake Bay programs to protect resource species involve both abundance and production. Additionally, numerous federal laws and treaties have the purpose of maintaining or increasing the production of game birds and mammals, commercial fish, and timber species. Examples include the Migratory Bird Hunting Stamp Act (48 Stat. 451), Wildlife Restoration Act (50 Stat. 917), Fish Restoration and Management Act (64 Stat. 430), Convention on Great Lakes Fisheries (6 UST 2836), and Fish and Wildlife Act of 1956 (70 Stat. 1119). Relevant provisions include requirements to "develop measures for maximum sustainable production of fish" (70 Stat. 1119) and "make possible the maximum sustained productivity of Great Lakes fisheries" (6 UST 2836).

Prevention of adverse effects to public welfare, including (but not limited to) effects on soils, water, crops, vegetation, animals, and wildlife is mandated under Section 108 (§109) of the CAA (National Ambient Air Quality Standards). EPA has included production of an assessment population, among other endpoints, as an indicator of public welfare. For example, EPA revised the secondary ozone standard to provide increased protection against ozone-induced effects on vegetation, such as agricultural crop loss and damage to forests (U.S. EPA, 1997b). Also, EPA regulations authorize the Agency to require pesticide registrants to submit tests on pesticide effects on plant mortality and plant growth inhibition. Results from these tests, in conjunction with other available information, are used by EPA in making pesticide registration decisions. Changes in production of specific legume species were endpoints in a TSCA assessment of release of recombinant rhizobia (McClung and Sayer, 1994; Orr et al., 1999).

Practicality: Production

Plant production is relatively easily and commonly measured in the field. Production of animals is more difficult to measure in the field, but well-developed techniques exist and are commonly employed for fisheries, game species, and pest insects. Toxic effects on production may be estimated from chronic tests that include survival, fecundity, and growth. The combined effects on population production of these organismal responses may be estimated using population or ecosystem models.

A.3. Community and Ecosystem-Level Endpoints

Abundant statutory and regulatory support exists for environmental protection at levels above the organism and population levels. This support stems both from the recognition that maintaining particular organisms of concern involves their preserving surrounding environment and from appreciation for the ecosystem as a whole. In the case of direct assessment of community-level endpoints, taxa richness (GEAE #7) and abundance (GEAE #8) are the two most commonly addressed attributes. Production (GEAE #9) of plant communities (as with production of plant populations, GEAE #6) has also been considered by EPA in some cases.

Example of support of community/ ecosystem-level endpoints: Superfund

EPA's principles for ecological risk assessment and risk management at Superfund sites state that "Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota." Community effects can either be measured directly (e.g., as in benthic species diversity) or estimated indirectly (e.g., from toxicity tests on individual species) (U.S. EPA, 1999b).

Perhaps the simplest and most widely used ecosystem-level endpoint is the area (extent) of an ecosystem (GEAE #10). Physical structure (GEAE # 12) is also commonly used as an endpoint in assessing aquatic ecosystems. The authors found little precedent at EPA for using attributes based on ecosystem function, such as primary production, energy flow, total biomass, and nutrient cycling, except in the case of wetland ecosystems (GEAE #11). Such endpoints may have limited use to date, because they are somewhat abstract and not as directly linked to management values as other endpoints. Several such endpoints are listed in Table 4-1 as potential GEAEs for future EPA consideration.

Further details about the support for community- and ecosystem-level endpoints are presented in this section in two ways. First, support spanning multiple attributes of community/ecosystem-level GEAEs is described for four general categories of ecosystems for which significant precedent exists: aquatic ecosystems, wetlands, coral reefs, and endangered/rare ecosystem types. Next, supporting information is presented for each of the six community/ecosystem-level GEAEs.

Aquatic Ecosystems

To date, the most common application of community- and assemblage-level endpoints at EPA has been to aquatic communities, particularly fish and macroinvertebrates. Section 101(a)(2) of the CWA calls for an interim goal of water quality that provides for the protection and propagation of fish, shellfish, and wildlife. Section 304(a) of the Water Quality Act of 1987 directs EPA to develop and publish water quality criteria and information on methods—including biological monitoring and assessment methods—that assess the effects of pollutants on the aquatic community. Aquatic community components and attributes addressed include “biological community diversity” and “productivity.” Taxa richness (GEAE #7) and abundance (GEAE #8) of species or trophic groups of fish and macroinvertebrate communities are used in the biocriteria of many states and in Agency guidance (Yoder and Rankin, 1995; U.S. EPA, 1996, 1999c).

Potential community-level impacts also have been inferred and considered a basis of concern by EPA programs, based on organism-level responses. The U.S. Ambient Water Quality Criteria for Protection of Aquatic Life are based on SSDs, with the criteria set at the fifth percentile (U.S. EPA, 1985a); hence, they can be interpreted as protecting at least 95% of the species in a community. The assessment community is also commonly used in EPA programs under TSCA. The Quotient Method is typically applied to the most sensitive organismal response, as well as uncertainty factors, to infer effects on a community. Organisms are chosen to represent a variety of taxonomic groups.

Ecosystem models are particularly useful for assessing secondary (indirect) effects of toxicants on community properties (Bartell et al., 1992; Pastorok et al., 2002). Models have been used to explore community-level effects, as in the case of evaluating the primary and secondary effects of chloroparaffins to top predator fish (Bartell, 1990; U.S. EPA, 1993a). Although there are relatively few examples of application of ecosystem models to the regulation of chemicals, generic models such as AQUATOX can serve to illustrate how direct and indirect effects propagate through ecosystems (U.S. EPA, 2003b).

Wetlands

The CWA forms the primary statutory basis for protection of wetlands and, thereby, the area (GEAE #10) and function (GEAE #11) of wetland communities/ecosystems. In meeting the CWA’s objective of restoring and maintaining the integrity of the nation’s waters, under Section 404 of the act, wetlands are considered waters of the United States and are protected from discharge of dredged and fill material through a permit program jointly administered by the U.S. Army Corps of Engineers and EPA. Wetlands are defined for regulatory purposes as areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support—and that under normal circumstances do support—a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (33 CFR §328.3 [b]). The CWA provides authority for the Corps to require permit applications to avoid and minimize wetlands impacts and requires EPA to develop, in coordination with the Corps, the criteria used for Section 404 permit decisions. When damages to wetlands are unavoidable, the Corps can require permitees to provide compensatory mitigation.

Additionally, Executive Order 11990, Protection of Wetlands, states that "Each agency shall provide leadership and shall take action to prevent the destruction, loss or degradation of wetlands and to preserve and enhance natural and beneficial values of wetlands in carrying out the agency's responsibilities" (Carter, 1977). As an extension of this order, President George H. W. Bush in 1989 and succeeding presidents have adopted a national policy of no net loss of wetlands in recognition of the significance of wetland areas and their ecological functions. The 1972 Coastal Zone Management Act also calls for the protection of coastal wetlands.

EPA has prepared various regulations and guidance documents supporting the wetlands protection goals of the CWA and Executive Order 11990. For example, "Guidelines for Specification of Disposal Sites for Dredged or Fill Material" (40 CFR, Part 230, Subpart E) recommends consideration of potential impacts on special aquatic sites, including wetlands, referencing changes that result in loss of wetland status due to permanent flooding or conversion to dry land as well as loss of functions of water purification, water storage, and provision of wetland habitat.

The large number of Superfund sites located in or adjacent to wetlands has lead EPA's policy and emphasis toward a greater concern regarding the impact of contamination from these sites on the extent and ecological functions of wetlands. OSWER highlights the importance of wetlands protection in the directive, "Policy on Floodplain and Wetland Assessment for CERCLA Action" (U.S. EPA, 1985b). Under this policy, Superfund action should meet the substantive requirements of Executive Order 11990 as well as the those of the Floodplain Management Executive Order (E.O. 11988). Section 404 of the CWA is also considered a federal "applicable or relevant and appropriate requirement" with which Superfund remedial actions should comply under CERCLA Section 121(d)(2)(A). Other Superfund policies that involve consideration or protection of wetlands include the Hazard Ranking System (U.S. EPA, 1990a, 1992a), the Superfund removal process guidance (U.S. EPA, 1992b), a Memorandum of Agreement between EPA and the U.S. Department of Army (U.S. EPA, 1990b), and the OSWER directive, "Controlling the Impacts of Remediation Activities In or Around Wetlands" (U.S. EPA, 1993c).

EPA's "Procedures for Implementing the Requirements of the Council on Environmental Quality on the National Environmental Policy Act" (40 CFR §6.108) singles out wetlands by stating that "if the proposed action may have significant adverse effects on wetlands" an environmental impact statement is required. EPA's regulations for State and Local Assistance (40 CFR, Part 35, Appendix A to Subpart H) require that project proposals demonstrate compliance with Executive Order 11990.

Coral Reefs

At present, coral reefs have not attained the same legal and regulatory stature under EPA programs as have wetlands, perhaps in part because few EPA actions involve coral reefs. However, support for their protection has been increasing in recent years. Taxa richness (GEAE #7) and area (GEAE #10) are the attributes of coral reef communities/ecosystems most commonly targeted for assessment and protection. Executive Order 13089 established special protection for coral reefs (Clinton, 1998). In particular, "All Federal agencies…shall…utilize their programs and authorities to protect and enhance the conditions of such ecosystems." This Executive Order names the EPA Administrator as a member of the Coral Reef Task Force, which is responsible for implementing the order. An EPA memorandum to the field specifically applies the order to EPA's responsibilities under Section 404 of the CWA, Sections 102 and 103 of the Marine Protection and Sanctuaries Act, and Section 307 of the Coastal Zone Management Act (Fox and Westphal, 1999). The order is also considered a federal "applicable or relevant and appropriate requirement" with which Superfund remedial actions should comply under CERCLA Section 121(d)(2)(A).

"Guidelines for Specification of Disposal Sites for Dredged or Fill Material" (40 CFR, Part 230, Subpart E) recommend consideration of potential impacts on special aquatic sites, including coral reefs. The guidelines refer to loss of productive colonies and subsequent loss of coral-dependent species.

Diversity is the only ecological attribute defined as a value of coral reefs in the National Action Plan to Conserve Coral Reefs (U.S. Coral Reef Task Force, 2000). A practical operational definition of that attribute is taxa richness. This document also mentions "shoreline protection, areas of natural beauty, recreation and tourism, and sources of food, pharmaceuticals, jobs, and revenues" as services of coral reefs. These services could be protected by preserving the area and taxa richness of coral reefs.

CITES, to which the United States is a party, restricts international trade in corals and other reef organisms. All coral reefs in Florida are protected by either the U.S. or the state government. Other specifically protected reef communities are found in Puerto Rico, Hawaii, the U.S. Virgin Islands, Guam, Northern Marianas, and American Samoa.

Endangered or Rare Ecosystems Types

Support for the protection of endangered and rare ecosystems (particularly in the case of terrestrial ecosystems) is less extensive and more indirect than it is for the classes of communities/ecosystems described above, but it can be identified in a variety of programs. Area (GEAE #10) is the primary attribute assessed for these ecosystems. Additionally, note that inherent in the definition of the area of endangered and rare ecosystems may be attributes such as taxa richness (GEAE #7) and abundance (GEAE #8), and, consequently, the loss of these attributes could constitute loss of area of the ecosystem type as it is converted to a different ecosystem type.

Several lines of support for protecting endangered and rare ecosystems are apparent in Superfund programs. The NCP specifies that, "evaluations shall be performed to assess threats to the environment, *especially sensitive habitats*" (emphasis added) (U.S. EPA, 1989). The Hazard Ranking System for Superfund (U.S. EPA, 1990a) gives as an example of "sensitive environments," "particular areas, relatively small in size, important to maintenance of unique biotic communities." The Superfund removal process guidance (U.S. EPA, 1992b) recommends that the On-Scene Coordinator undertake special considerations for actions that include sensitive ecosystems, which may be interpreted as calling for protection of endangered or rare ecosystem types.

Other EPA programs also consider endangered ecosystems. For example, the protocol for screening-level ecological risk assessment for hazardous waste combustion facilities calls for special consideration of areas having unique and/or rare ecological receptors and natural resources (U.S. EPA, 1999a). EPA Regions 4, 5, 6 and the Great Lakes Program Office are developing approaches for identifying high-quality areas (critical ecosystems) for enhanced environmental protection and restoration. EPA Region 4 has been involved in the development of the Southeastern Ecological Framework as a decision support tool useful in integrating program resources for protecting and sustaining ecological processes.

EPA Region 5 is also developing an approach for prioritizing and targeting high-quality areas in the Midwest (Mysz et al., 2000). Two of the criteria for identifying these areas, also called "critical ecosystems," are (1) the presence of an indigenous ecosystem and biological community types (used as an indicator of relative ecological diversity), and (2) the numbers and rarity of native species and natural features (used as indicators of surviving relict native ecosystems).

In addition, the EPA Great Lakes program, in collaboration with Environment Canada, has developed Biodiversity Investment Areas as natural areas along the Great Lakes shoreline whose high ecological value warrant exceptional attention to protect them from degradation. EPA Region 6 is using a GIS screening tool to assist in prioritizing ecological areas of concern for programs such as NEPA (Osowski et al., 2001).

In carrying out its responsibilities for reviewing environmental impact statements under NEPA, EPA has developed guidance that calls for special attention to human activities in imperiled ecosystems and identifies mitigation measures to reduce adverse impacts (U.S. EPA, 1993b). Approximately a dozen "principal habitats of concern" were identified within each of six major U.S. habitat types. Ecological concerns raised by EPA to other federal agencies in review of NEPA documents have included impacts to endangered or rare ecosystems (U.S. EPA, 1994).

A.3.1. GEAE #7. Taxa Richness of Assessment Communities, Assemblages, and Ecosystems

Laws, Regulations, and Precedents: Taxa Richness

As described in Section A.3., the most extensive support for use of this endpoint at EPA comes from measures to assess and protect the taxa richness of aquatic communities as part of water quality protection programs under the CWA. Use of taxa richness as an attribute can be inferred by programs under TSCA and other statutes to assess risks to a range of species across an aquatic community. Aquatic community composition is presented as an example of an assessment endpoint in Superfund ecological risk assessment guidance (U.S. EPA, 1997c), and community diversity or species richness is a generic endpoint for ecological risk assessments of hazardous waste combustors (U.S. EPA, 1999a). Support for taxa richness of coral reef communities/ecosystems is also described in Section A.3.

EPA regional offices have considered the effects of federal projects on species diversity in decisions under NEPA, such as in an assessment of the impacts of the loss of bottomland hardwood forest on species composition of the wildlife community due to levee construction (U.S. EPA, 1994).

Practicality: Taxa Richness

Species or taxa richness is the simplest, least controversial, and most easily interpreted expression of community diversity. Changes in taxa richness are readily observed in standard biological surveys. If it is assumed that significant toxic effects are likely to result in local extirpation of a species, changes in taxa richness may be predicted using SSDs or regression models that relate all species of a community or assemblage to a test species. If indirect effects are expected to result in the loss of species, ecosystem models may be used to predict species losses.

In the case of coral reefs, the taxa richness of corals are relatively easily determined. The taxa richness of some other assemblages (e.g., fishes and sessile noncoral invertebrates) is also practical to determine. Methods for assessing the condition of coral reefs are discussed in Jameson et al. (1998). Prediction of the effects of pollutants on coral reefs is difficult due to the paucity of toxicological information for corals.

A.3.2. GEAE #8. Abundance of Assessment Communities, Assemblages, and Ecosystems

Laws, Regulations, and Precedents: Abundance

This endpoint shares with GEAE #7 the support described in Section A.3 for aquatic communities. Abundance of fish and macroinvertebrate taxa and trophic groups in sampled communities is used in the water quality biocriteria of many states and in Agency guidance. Community abundance can be inferred to be an element of ambient water quality standards and of chemical evaluations under TSCA. Aquatic community composition (including a metric describing abundance) is presented as an example of an assessment endpoint in Superfund ecological risk assessment guidance (U.S. EPA, 1997c).

Practicality: Abundance

Abundance of communities or assemblages, as a whole or by species, taxon, or trophic group, is available from most routine biological surveys. Although one can readily infer from standard toxicity tests that some changes in abundance are likely to occur, they are difficult to predict quantitatively. As discussed in Section A.3, community properties may be estimated from standard toxicity test data using ecosystem models.

A.3.3. GEAE #9. Production of Assessment Communities, Assemblages, and Ecosystems

Laws, Regulations, and Precedents: Production

This endpoint shares a basis in laws, regulations, and precedents with GEAE #6, production of plant populations, through FIFRA, TSCA, and CAA programs. For example, the secondary ambient air quality standard established by EPA to protect public welfare for ground-level ozone (U.S. EPA, 1997b) cites growth and yield reductions in tree seedlings and mature trees and impacts on forest stands and community structure due to these reductions.

Superfund directives and guidance identify plant production, such as productivity of wetlands vegetation, as candidate assessment endpoints (Environmental Response Team, 1994a, b, c, d). Community productivity and, in particular, herbaceous plant productivity, is a generic endpoint for ecological risk assessments of hazardous waste combustors (U.S. EPA, 1999a). EPA actions to control acid rain and its precursors have been based on concerns over the damage to high-elevation forests—among other effects—attributed to acid rain.

As stated in Section A.3., the CWA (§101(a)(2)) calls for an interim goal of water quality that provides for the protection and propagation of fish, shellfish, and wildlife. Section 304(a) of the act also lists effects of pollutants on plant life and on rates of eutrophication (excessive plant production due to nutrient pollution) as factors to consider in establishing pollutant limits. Eutrophication has been the basis for many federal and state regulatory actions and voluntary control programs, including the establishment of total maximum daily loads (TMDLs) for nutrients (U.S. EPA, 1999d), controls on nutrient discharges from sources such as publicly owned treatment works and confined animal feeding operations, and restrictions on phosphorus in detergents.

Practicality: Production

Eutrophication has long been a major concern of environmental managers, particularly with respect to sewage outfalls, so the models for predicting effects of nutrient additions are relatively well developed. Similarly, studies of fertilizer addition to crops, pastures, and commercial forests are numerous and provide a good basis for predicting the effects of terrestrial nutrient additions on plant production. In addition, methods for measuring plant production are well developed for both terrestrial and aquatic communities. Protocols for testing toxic effects on terrestrial and aquatic plants focus on various measures of production. However, toxicity data are less abundant for plants than for animals.

A.3.4. GEAE #10. Area of Assessment Communities, Assemblages, and Ecosystems

Laws, Regulations, and Precedents: Area

The most extensive support for use of community/ecosystem area as a GEAE at EPA involves protection of wetlands. As discussed in Section A.3, the CWA affords special protection to wetlands, and a number of EPA programs reflect this emphasis. Within the Superfund program, for example, unavoidable impacts to on-site and adjacent wetland resources from current or potential exposure to hazardous substances and from implementation of select response actions are addressed within the Record of Decision for that site. Records of Decision for the New London Submarine Base in New London, Connecticut (U.S. EPA, 1998c), Loring Air Force Base in Limestone, Maine (U.S. EPA, 1997d), and Pease Air Force Base in Portsmouth/Newington, New Hampshire (U.S. EPA, 1997e) include remedies involving compensatory wetland mitigation. Mitigation actions are tracked by long-term monitoring plans and restoration efforts are monitored over a specified time period to ensure success.

Efforts to assess and to control risks to coral reefs—and to rare/endangered ecosystems generally—also serve as precedents for the use of area as a GEAE (see Section A.3), although these programs are not currently as extensive at EPA as are those for wetlands.

Practicality: Area

Wetlands are classified and mapped by the National Wetlands Inventory of the U.S. Fish and Wildlife Service, but determination of wetland boundaries at a given site may be difficult, particularly in areas of low topographic relief. The 1987 *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory, 1987) is the current federal delineation manual used in the CWA Section 404 regulatory program for the identification and delineation of wetlands. Most effects on wetland area are readily predicted or observed, because they occur due to processes such as dredging, filling, draining, or inundation.

The area of coral reef is relatively easily determined. Methods for assessing the condition of coral reefs are discussed in Jameson et al. (1998). Prediction of the effects of pollutants on coral reefs is difficult due to the paucity of toxicological information for corals.

An endangered or rare ecosystem type might be diminished by physical destruction, which is readily observed and quantified, or by physical conversion to another type of ecosystem (e.g., due to selective logging or grazing), which can also be readily observed and quantified if the type is clearly defined. The prediction of loss of an ecosystem type due to extirpation of many or most of the constituent organisms (e.g., due to an herbicide application or oil spill) is practical because it would involve severe toxicity. However, loss of a type due to more subtle effects, such as changes in species composition due to differential susceptibility to a stressor, could be difficult to predict. Information useful in identifying rare and endangered ecosystem types is available from NatureServe (http://www.natureserve.org), a nonprofit organization that works with natural heritage programs throughout the United States and elsewhere in the Western Hemisphere. NatureServe maintains databases on all known ecological communities in the United States, ranked from critically imperiled to secure. According to NatureServe, the completeness of inventory and classification work varies widely among states, provinces, and regions.

A.3.5. GEAE #11. Function of Assessment Communities, Assemblages, and Ecosystems

Laws, Regulations, and Precedents: Function

Although the importance of ecosystem function is widely recognized, precedent for its use as an independent endpoint at EPA is limited, except in the case of wetlands. Protection of functional attributes of wetlands is specifically targeted, for example, in EPA's "Guidelines for Specification of Disposal Sites for Dredged and Fill Material" (40 CFR, Part 230), implementing Section 404(b)(1) of the CWA. Commonly recognized functions of wetlands include storage and filtration of water and maintenance of habitat for fish and wildlife.

Practicality: Function

Losses of wetland functions can be inferred from loss of wetlands area (see GEAE #10, A.3.4), but they are less readily observed or predicted if not accompanied by the loss of wetland area. The hydrogeomorphic method (Brinson, 1993) is one approach for assessing wetlands function. EPA, the Corps, and other federal agencies have agreed to formally adopt this method to improve the assessment of wetlands function in support of the CWA Section 404 Program (62

FR 33607, June 20, 1997). Toxic effects on wetland functions or on the type of wetland community are difficult to predict.

A.3.6. GEAE #12. Physical Structure of Assessment Communities, Assemblages, and Ecosystems

Laws, Regulations, and Precedents: Physical Structure

Policy support for physical structure of ecosystems as a GEAE stems from the CWA's goals of protecting aquatic ecosystems. The CWA (§101(a)) states that, "The objective of this Act is to restore and maintain the chemical, *physical* [emphasis added], and biological integrity of the Nation's waters." The importance of physical structure is reflected by EPA regulations implementing the CWA that note the following conditions of a water body that may preclude attainment of desired beneficial uses (40 CFR §131.10 (g)):

- "natural, ephemeral, intermittent or low flow conditions of water levels"
- "dams, diversions or other types of hydrologic modifications"
- "physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality"

Protocol for Developing Sediment TMDLs (U.S. EPA, 1999e) lists channel modification, pool filling, filling of substrate with fine sediments, and other effects on physical structure as sediment issues that can result in loss of designated uses. These changes in stream ecosystems are themselves changes in the ecosystem attributes that result in the lost recreational/aesthetic or other uses, not simply stressors that affect biological endpoints.

Physical structure has been a factor in setting the designated use of streams in state water quality standards. For example, in Ohio, a designated use of Modified Warmwater Habitat applies to streams with extensive and irretrievable physical habitat modifications.

Practicality: Physical Structure

Physical characteristics often are readily observed or measured at sites being assessed and are usually recorded in biological surveys. Protocols exist for measuring many aquatic habitat attributes (e.g., U.S. EPA, 1999c). In addition, most of the actions that modify the physical structure of waterbodies (e.g., channelization, dam construction and operation, water withdrawals, and culvert installation) have obvious effects on structure that are readily predicted.

Other effects, such as changes in hydrology resulting from changes in land use, are more difficult—but still possible—to model.

A.4. Officially Designated Endpoints

The GEAEs in this section do not fall neatly into the organism-population-community-ecosystem hierarchy used to organize the other GEAEs, but they are important to EPA nonetheless. Habitat for endangered species (GEAEs #13 and #14) is highlighted because of the specific protections it receives under the ESA. Habitat has not been chosen as a GEAE for other categories of organisms because it is the organisms that are valued directly, whereas by definition habitat is that which supports organisms and thus is valued indirectly. (Habitat here is distinguished from communities and ecosystems, which may be valued in their own right, as discussed in Section A.3.) Ecological properties of special places (GEAE #15) can encompass attributes from all levels of biological organization. Special places are identified because of the extensive legal and other support for their protection or because of their ecological importance.

A.4.1. GEAEs #13 and #14. Area and Quality of Habitat for Threatened or Endangered Species

Laws, Regulations, and Precedents: Area and Quality of Critical Habitat

The obligation to protect endangered and threatened species under the ESA includes protection of the critical habitats on which they depend. Thus the legal and regulatory basis for protecting endangered species described under GEAE #3 generally also applies to this endpoint. For example, the Superfund NCP specifies that, "evaluations shall be performed to assess threats to the environment, especially sensitive habitats and *critical habitats of species protected under the Endangered Species Act*" (emphasis added) (U.S. EPA, 1989). EPA's regulations for State and Local Assistance (40 CFR, Part 35, Appendix A to Subpart H) require that project proposals determine whether there would be significant adverse effects on critical habitat of endangered species.

Practicality: Area and Quality of Critical Habitat

Designated critical habitat is readily identified, and it should be practical to determine whether it will be destroyed (reduced area) or adversely modified (reduced quality). Although critical habitat has not been officially designated for many endangered or threatened species, federal documents such as listing decisions and recovery plans typically discuss the distribution and ecological requirements of listed species. Toxic effects may be predicted if species or taxa that are components of critical habitat are identified and their response to pollutants can be evaluated.

A.4.2. GEAE #15. Ecological Properties of Special Places

Laws, Regulations, and Precedents: Special Places

The legislative acts establishing national parks and monuments, wildlife refuges, wilderness areas, wild and scenic rivers, recreation areas, marine sanctuaries, and other special places establish their status and indicate the properties for which the protected status was provided. Several statutes either give EPA a role in designating special places or direct EPA to consider environmental impacts to such places in administering Agency programs. The CWA directs EPA to administer the National Estuary Program and permits states to designate waterbodies as Outstanding National Resource Waters, which then receive increased protection in their water quality standards.

The CAA also has several provisions for special places. Section 160 of the CAA establishes that a purpose of the act is "to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value." Section 162 designates national (and international) parks, wilderness areas, and memorial parks of a certain size as "class I" areas, which merit the highest level of protection from air pollution. Other special places cited in both the CAA and the CWA include the Great Lakes, Chesapeake Bay, and Lake Champlain.

In the area of EPA regulations and guidance, the NCP cites special places such as national marine sanctuaries and estuarine research reserves as natural resources to be protected under CERCLA. Superfund removal process guidance (U.S. EPA, 1992b) recommends that the On-Scene Coordinator to undertake special considerations for actions that include wild and scenic rivers. EPA procedures for implementing NEPA (40 CFR §6.108) require an environmental impact statement to be prepared if "the proposed action may have significant adverse effects on parklands, preserves, or areas of recognized scenic, recreational, archeological, or historic value." "Guidelines for Specification of Disposal Sites for Dredged or Fill Material" (40 CFR, Part 230, Subpart E) recommend consideration of potential impacts on special aquatic sites, including sanctuaries and refuges. The protocol for screening-level ecological risk assessment for hazardous waste combustion facilities calls for special consideration of areas having legislatively conferred protection (U.S. EPA, 1999a).

Practicality: Special Places

Special places and their important ecological properties usually can be defined readily. Given the diverse set of ecological properties at different places, it is not possible to make overall statements about the practicality of this endpoint. Potentially, all of the surveying, testing, and modeling methods discussed in the previous sections could be applicable.

APPENDIX B. TYPES OF VALUES ASSOCIATED WITH ASSESSMENT ENDPOINTS

EPA's ecological risk assessment guidelines (U.S. EPA, 1998a) define an assessment endpoint as "an explicit expression of the *environmental value* that is to be protected, operationally defined by an ecological entity and its attributes" [emphasis added]. In the context of the guidelines, an *environmental value* refers to a component of the environment (or an ecological entity) that society values, with some examples being endangered species and commercially or recreationally important species. The literature on environmental valuation covers a wide range of ecological systems and components; for example, bays (Kahn, 1985), wetlands (Barbier, 1993), riparian corridors (Lant and Tobin, 1989), deserts (Richer, 1995), recreation areas (Adamowicz et al., 1994), and wilderness or "unspoiled" natural areas (Hanink, 1995; Kopp and Smith, 1993; Randall and Peterson, 1984). In many of these studies, ecosystems are conceptualized as having *assets* or structural components such as energy resources, minerals, or timber; *services* or natural functions benefitting society (e.g., groundwater recharge, flood control, the absorption or assimilation of pollutants) and/or other *attributes* provided by the whole ecosystem, such as biological diversity, cultural uniqueness, or natural heritage (Westman, 1977; Daily et al., 1997).

Table B-1 presents one way of organizing environmental values, drawing on Blomquist and Whitehead (1995), Daily (2000), Ehrlich and Ehrlich (1981), MacLean (1995), Primack (1993), and Freeman (1984, 1993). The table is not intended to represent a definitive or comprehensive list of environmental values, rather it is intended to illustrate the breadth of values that may be cited in support of a GEAE.

Each of the GEAEs presented in this document relate to one or more of these environmental values. For example, an "assessment population" and its attributes may be used to represent a commercially and recreationally valuable fish or wildlife population (consumptive and recreational values). Such an assessment population could also represent a species population that is valued as a learning tool (educational value) and protected for cultural and aesthetic reasons (preservation value). Table B-1 provides further examples of how each of the GEAEs may correspond with these values.

Table B-1. Some categories of environmental values

Value	Definition and examples of corresponding GEAEs
Consumptive	The value of commodities produced by the environment such as food, energy, timber, fiber, and pharmaceutical and industrial products. • Area of ecosystems: timber and fuel production by trees • Production of an assessment population: commercially valuable fisheries • Extirpation of an assessment population: commercially valuable furbearers
Informational	The value of natural structures, chemicals, or processes as models for anthropogenic structures, chemicals, or processes (e.g., pharmaceuticals, synthetic commodities, engineering designs). Also see Option value. • Extirpation of organisms: as sources of model adaptations to extreme environments • Taxa richness of communities: highly diverse communities may be valuable sources of bioactive chemicals as models for pharmaceuticals
Functional	The value of ecological functions benefitting public health and welfare, such as pollen and seed dispersal, water retention and purification, detoxification of wastes, and moderation of weather extremes. In some cases, ecosystems are re-established to make use of their functional value for remediation. • Ecosystem function: water retention and purification by wetlands • Abundance of an assessment community: water and soil retention by forests • Abundance of an assessment population: pollination by insects
Recreational	The value of recreational opportunities such as fishing, birding, boating, and hiking. In some cases, this is a passive use of a resource, but in others (e.g., tourism) it is an economic activity. • Physical structure of an ecosystem: boating, fishing • Survival, fecundity, and growth of organisms (migratory birds): birding, hunting • Properties of special places: camping, hiking, boating
Educational	The value of academic and nonacademic educational opportunities, including nature and scientific study. • Properties of special places: parks and refuges for nature study, research • Area of ecosystems: environmental education sites
Option	The value to future generations of preserving the option of using the environment at some future time. Option value also includes human welfare gains or net benefits associated with delaying a decision when there is uncertainty about the payoffs of certain alternatives, or when one of the choices involves an irreversible commitment of resources. • Area and function of ecosystems • Properties of special places • Abundance of assessment populations
Existence	Value ascribed to the existence of ecological systems independent of any direct services or functions. Aesthetic, moral, cultural, religious, or spiritual grounds may be cited in support of this type of nonuse value. • Area and quality of critical habitat for endangered species • Gross anomalies and kills of organisms • Properties of special places

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