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GENERAL ASSESSMENT ENDPOINTS FOR ECOLOGICAL RISK ASSESSMENT AT THE LOS ALAMOS NATIONAL LABORATORY

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EXECUTIVE SUMMARY

A critical component of any ecological risk assessment is the specification of the assessment endpoints. However, selecting assessment endpoints for risk assessment is often a formidable task. The Guidelines for Ecological Risk Assessment (EPA 1998, ER ID 62809) recognizes this, stating:

> All ecosystems are diverse, with many levels of ecological organization (e.g., individuals, populations, communities, ecosystems, and landscapes) and multiple ecosystem processes. It is rarely clear which of these characteristics are most critical to ecosystem function, nor do professionals or the public always agree on which are most valuable. As a result, it is often a challenge to consider the array of possibilities and choose which ecological characteristics to protect to meet management goals.

There are approximately 500 plant species on or near the Los Alamos National Laboratory (the Laboratory) property, 29 mammal species, 200 bird species, 19 reptile species, 8 amphibian species, and many thousands of invertebrate species. These species inhabit a variety of community types including mixed conifer forest, piñon-juniper woodland, grassland, riparian woodland and aquatic communities. The "array of possibilities" for selecting assessment endpoints is very large, indeed. A structured process is needed in selecting assessment endpoints, and to provide documentation as to why particular resources were selected and others were not. The General Assessment Endpoint (GAE) process provides a comprehensive, systematic and defensible basis for reaching consensus with regulators and other stakeholders on just what the "array of possibilities" should be when selecting assessment endpoints for ecological risk assessments. Douglas Reagan of URS Greiner Woodward Clyde and others (Parametrix 1995, ER ID 63307) developed the GAE process. The GAE approach has been successfully used for the ecological risk assessment at the Lavaca Bay Superfund Site and is currently being implemented at CERCLA and RCRA sites in the United States and for risk assessments at overseas locations.

This report provides an overview of the GAE process for the Pajarito Plateau ecosystem, the ecosystem potentially affected by Laboratory historical contamination. This report incorporates input from representatives of the New Mexico Environment Department (NMED), New Mexico Game and Fish, U.S. Fish and Wildlife, the Department of Energy (DOE) and the Laboratory's Environmental Restoration (ER) Project (including representatives from the Ecology Group) to develop GAEs for ecological risk assessments. Although this document reflects the consensus opinions of the NMED, NM Game and Fish, U.S. Fish and Wildlife, DOE and ER Project representatives, it does not reflect an official position of the organizations represented.

Section 1, the Introduction, provides the motivation and purpose for developing the GAEs. Section 2 gives an overview of the GAE process. The process of identifying GAEs occurs in two parts. First, ecologically relevant values are identified for the ecosystem under consideration and the associated GAEs are specified (described for the Pajarito Plateau ecosystem in Section 3). Second, human values associated with the ecological resources under evaluation and the associated GAEs are identified (described in Section 4). Section 5 presents some guidelines for developing site-specific assessment endpoints, using the GAE framework to ensure comprehensive, consistent, and defensible endpoints for ecological risk assessments conducted by the ER Project.

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1.0 INTRODUCTION

An ecological risk assessment must specify assessment endpoints in order for there to be a risk-based decision framework. The EPA, in both the Ecological Risk Assessment Guidance for Superfund (EPA 1997, ER ID 59370) and the Guidelines for Ecological Risk Assessment (the Guidelines) (EPA 1998, ER ID 62809), defines an assessment endpoint as "an explicit expression of the environmental values that are to be protected". The Guidelines also say that assessment endpoints are "operationally defined by an ecological entity and its attributes". By limiting the assessment endpoints to those that are to be protected, a policy call must be made, thus, a risk management decision is implicit in the specification of assessment endpoints.

Selecting assessment endpoints for risk assessment is often a formidable task. The Guidelines recognize this, stating:

> All ecosystems are diverse, with many levels of ecological organization (e.g., individuals, populations, communities, ecosystems, and landscapes) and multiple ecosystem processes. It is rarely clear which of these characteristics are most critical to ecosystem function, nor do professionals or the public always agree on which are most valuable. As a result, it is often a challenge to consider the array of possibilities and choose which ecological characteristics to protect to meet management goals.

The scope of the task for the Los Alamos National Laboratory (LANL or Laboratory) Environmental Restoration (ER) Project ecological risk assessors is made clear when considering the species list for the Laboratory, shown in Appendix I. There are approximately 500 plant species on or near the Laboratory property, 29 mammal species, 200 bird species, 19 reptile species, 8 amphibian species, and many thousands of invertebrate species. The "array of possibilities" for selecting assessment endpoints is very large indeed. A structured process for reaching consensus on the array specification is needed to ensure that all relevant valued resources are considered in selecting assessment endpoints, and to provide documentation as to why these resources were selected and others were not. The General Assessment Endpoint (GAE) process provides a comprehensive, systematic and defensible basis for reaching consensus with regulators and other stakeholders on just what the "array of possibilities" should be when selecting assessment endpoints for ecological risk assessments.

GAEs are intended to reflect ecological values of broad significance to risk managers and other stakeholders. GAEs encompass ecological and human use values at all levels of ecological organization (ecosystems, communities, and individual species). The development of GAEs, with direct involvement of the risk managers and other stakeholders, should provide essential input on the values of concern to risk managers that will be considered when selecting the actual assessment endpoints to be used in conducting ecological risk assessments at LANL.

This report provides an introduction to the GAE process (Section 2), describes the GAEs developed for LANL with input from stakeholders (Sections 3 and 4), and provides some preliminary guidelines for identifying assessment endpoints in the context of the GAE framework (Section 5).

The GAE process is applied to the Pajarito Plateau ecosystem, the ecosystem potentially affected by Laboratory historical contamination. Those participating in this first attempt at applying the process at the Laboratory were members of the New Mexico Environment Department (NMED), New Mexico Game and Fish, U.S. Fish and Wildlife, DOE, and the Laboratory's ER Project (including representatives from the Ecology Group). The identification of GAEs is an ongoing process that will incorporate the values of other stakeholders (e.g., Pueblos) as the ecological risk assessment process proceeds.

2.0 OVERVIEW OF GAE PROCESS

The process of identifying GAEs occurs in two parts. First, ecologically relevant values are identified for the system under consideration, and second, human values associated with the ecological resources under evaluation are identified. The GAE process is based on the assumption that the ultimate ecological value under consideration is a healthy, sustainable ecosystem. Ecological relevance, therefore, refers to the properties necessary for unimpaired ecosystem function.

The ecological evaluation begins with the identification of characteristics and processes integrally important, yet common to all ecosystems. This evaluation progresses to a consideration of the particular ecosystem present at the specific location under investigation (e.g., the Pajarito Plateau). This progression provides a hierarchical and objective means of determining which components of the ecosystem are potentially relevant to the assessment of ecological risk. This process consists of five steps.

1 Ecological values, common to all ecosystems, are identified (Section 3.1).
2 Functional components of the specific ecosystem (e.g., Pajarito Plateau) are identified (Section 3.2.1).
3 A functional food web of the ecosystem is developed (often done concomitantly with step 2) (Section 3.2.1).
4 Attributes of the functional components of the ecosystem are determined (e.g. ecological values common to the Pajarito Plateau) (Section 3.2.2).
5 Ecologically relevant GAEs are described (Section 3.2.3).

Once ecologically relevant GAEs have been determined, ecological values relevant to societal values and/or management goals are identified to supplement GAEs that were based directly on ecological relevance (Section 4.0).

In the following sections, the details of the process are presented in the context of the Pajarito Plateau ecosystem. Section 3.1 describes ecological values that are relevant to all ecosystems, including the Pajarito Plateau. The content of this section reflects the consensus opinion of the NMED, NM Game and Fish, U.S. Fish and Wildlife, and ER Project representatives. However, this consensus opinion does not reflect an official position of the organizations represented, it merely reflects the ideas of the representatives involved in the development of this document.

3.0 GAEs FOR THE PAJARITO PLATEAU BASED ON ECOLOGICAL RELEVANCE

The Pajarito Plateau ecosystem is defined as the habitats, both aquatic and terrestrial, of the Pajarito Plateau on and adjacent to the Laboratory. The plateau is situated on the eastern slopes of the Jemez Mountains in northern New Mexico. Descriptions of the habitats and biota of this ecosystem are found in numerous documents, including the Installation Work Plan (IWP) (LANL 1998, ER ID 58605).

Sustaining a healthy Pajarito Plateau ecosystem is the ultimate ecological value to protect; however, to achieve this goal, a variety of ecological values must be considered and protected. The process of identifying these values, beginning at the ecosystem level and progressing to lower levels of ecological organization is described in the following sections.

3.1 VALUES COMMON TO ALL ECOSYSTEMS

Recognizing that assessment endpoints are defined as values to be protected (EPA 1997, ER ID 59370; EPA 1998, ER ID 62809), the approach to developing GAEs starts by identifying values common to all ecosystems at the highest level possible: the value of preserving a healthy and sustainable ecosystem. De Leo and Levin (1997, ER ID 62897) prefer the notion of ecological integrity rather than ecological health, as they feel that integrity includes the concept of valuations that are based on human use, which they believe is the appropriate value structure for environmental management decisions. Recognizing that ecological values are ultimately human values (Harwell et al. 1994, ER ID 63308), we use the terms ecological health and integrity or intactness interchangeably. For the purposes of this project, a healthy ecosystem is defined to be one that contains all essential functional components and interactions, which operate at levels typical of that type of ecosystem.

There are a number of characteristics that one may identify that are seminal to the healthy state and function of an ecosystem. Following the GAE approach, characteristics were organized into three separate, but interrelated, attributes common to all ecosystems: biological diversity, functional integrity, and nutrient and energy dynamics. While these attributes can be considered in various combinations (e.g., functional integrity can be defined to encompass both biodiversity and process dynamics), this division allows one to look at the components, patterns of organization, and process rates somewhat independently.

In the sections that follow, the attributes common to all ecosystems are defined and discussed in the context of why they are valued and how they are related to the goal of preserving a healthy and sustainable ecosystem.

3.1.1 Biological Diversity (Biodiversity)

A simple definition of biological diversity is "the number of species in a community". The more species, the greater the biological diversity. However, biological diversity described in this way misses much that is relevant to why biodiversity is valued (De Leo and Levin 1997, ER ID 62897), and hence why the maintenance of biological diversity is a foundational GAE.

Biological diversity is valued from a human perspective for multiple reasons. These include the value of extractable resources (fisheries, and forests), the aesthetic value, the value of rarity, the value of undiscovered natural products of potential benefit to human health, and the indirect value of the processes performed by diverse assemblages of species (e.g., nutrient cycling, erosion control, cleansing of water and air).

Moreover, biologically diverse systems in temperate regions of the world may be generally more resilient to natural and anthropogenic perturbations and changes than less diverse systems (De Leo and Levin, 1997, ER ID 62897). Maintaining diversity can be important for maintaining the structure and function of the system. In biologically diverse systems we often find multiple species within a particular functional group, or guild. To the extent that these species perform the same ecological function, they provide functional redundancy. Functional redundancy has been shown to play an important role in maintaining an ecosystem's ability to respond to change (De Leo and Levin, 1997, ER ID 62897). The maintenance of biological diversity is recognized as an important factor that keeps the Pajarito Plateau habitable and functional for indigenous biota, as well as humans.

When attempting to measure biological diversity, it is important to carefully delineate the geographical and temporal domain prior to taking any measurements, and then accurately identify species and the variation within species that are present within these bounds. There are several broad approaches to defining biological diversity, including assemblage diversity, genetic diversity, and phenotypic diversity, as outlined below.

Assemblage diversity. Biodiversity is most often defined in terms of species richness (number of species) and evenness (relative abundance of species) in a given area at a given time. In order to evade confusion over the breadth of definitions for biological diversity, we refer to this form of diversity as *assemblage diversity*. This definition has led to many attempts at the quantification and indexing of biological diversity, all of which have evident shortcomings (Magurran 1988, ER ID 62877). However, the simplest and most constructive way to consider and quantify assemblage diversity, is to simply count the number of species (species richness) in a geographically and temporally defined space (or alternately, at several scales of interest), while simultaneously measuring the relative abundance of each species (species evenness). These are perhaps the simplest measures of "biological diversity" and are applicable in many managerial practices. Assemblage diversity will form the basis for measuring biological diversity in the common practice of defining assessment endpoints for ecological risk assessment as practiced for the Laboratory.

Assemblage diversity changes through time and across geography. There have been many attempts to characterize assemblage diversity on landscape levels (i.e. across geographic expanses that exceed the range of one or more species in an assemblage). Most of the landscape-level measures of assemblage diversity are characterized with respect to the functional relationships (roles, niche space, and trophic position) of organisms in and among biotic communities. These measures include the assemblage diversity and the particular species that comprise the assemblage. Such measures are often useful when considering expectation for the presence or absence of particular species in a community, the replacement of species by others that provide the same function across communities, and the relative abundance of these species, given the constraints of the community dynamics. This form of assemblage diversity (often coined gamma diversity) can be used as a measure of functional redundancy between communities or ecosystems. For example, a community in one geographic locale may have an equivalent assemblage diversity and functional redundancy within guilds, to another, very different community in a geographically distinct place. The geographic realms of this type of diversity are arbitrary; e.g. north-facing slopes vs. south-facing slopes in montane environment, or deciduous forests of the Rio Grande Valley vs. deciduous forests of the New River, West Virginia. This measure may be useful for assessing the biodiversity of communities on the Pajarito Plateau with respect to "reference communities" (communities that serve as a benchmark for measurement).

Communities that are more diverse are not necessarily more relevant to GAE development than less diverse communities. Communities in disturbed ecosystems may be more or less diverse than those in comparable but undisturbed ecosystems; this includes communities comprised of non-indigenous members. Although many different assemblage diversity indices have been developed and used, ecologists recognize a variety of measures are needed to capture the essence of assemblage diversity (Magurran 1988, ER ID 62877).

Genetic diversity is most often measured in terms of diversity of "type" or, more precisely, "genotype" of a given organism in geographically and temporally bounded environs. This is a rather precise and complex measure, and is not usually considered in ecological risk assessment, unless there is a special case, e.g. an endangered species at stake or a unique population at risk. However, the maintenance of genetic diversity may be at the crux of an ecosystem's ability to sustain perturbation (e.g. influx of contamination). Often, a species or population can sustain the impact of strong selection (a strong perturbation) in the near-term only because of the genetic basis for resistance to the selective force (perturbation). If more than one perturbation impacts a population under conditions of reduced genetic basis for population resilience, then a population may not be able to recover. For example, Clements and co-researchers (NIEHS/EPA 1999, ER ID 62896) have found that communities of benthic insects in Colorado streams are no less diverse, in terms of species composition, in streams polluted by heavy metals, than in similar streams that are relatively unimpacted. These researchers have also found that the genetic diversity of the insect populations studied was far less in polluted vs. unpolluted streams. The reduced genetic diversity, observed by Clements, may put these populations at a much greater risk to extirpation due to natural perturbation (e.g. drought, disease) than the more genetically diverse populations. Therefore, in order to minimize the implicit impact to biotic populations from anthropogenic disturbance, it is important to minimize disturbances that reduce genetic diversity, and attempt to maintain genetically diverse populations.

Phenotypic diversity, i.e. variation of ecological type, morph, or form, is often recognized as a morphological expression of a genetic basis of diversity within species, and hence can be viewed as an expression of the genetic diversity, discussed above. Phenotypic diversity is dependent on many factors, but is relevant to a species only with respect to traits that are adaptive, and therefore confer selective advantage to individuals under the biotic and abiotic conditions in which the organisms carry out phenologic (life history) events. Phenotypic diversity may be a useful surrogate for the measurement of genetic diversity. Therefore, in order to minimize the implicit impact to biotic populations from anthropogenic disturbance, it is important to minimize disturbances that reduce phenotypic diversity.

3.1.2 Functional Integrity

Ecosystem integrity was defined by Karr and Dudley (1981, as quoted by DeLeo and Levin 1997, ER ID 62897) as "the capability of supporting and maintaining a balanced, integrated, adaptive, community of organisms having species composition, diversity and functional organization comparable to that of natural habitats in the region." For the purpose of defining assessment endpoints, it is convenient to define functional integrity more narrowly as the pattern of interactions among components of the ecosystem. This allows us to discriminate between species composition in the ecosystem (e.g., biodiversity) and the functional interactions among components. Thus we can distinguish patterns such as trophic structure or habitat relationships among specific species or functional guilds in addition to evaluating biological diversity. In practice, to assess functional integrity, factors such as food chain length, connectivity, degree of omnivory, extent of reciprocal predation (food loops), and subweb organization can be evaluated. (Pimm 1982, ER ID 63305; Reagan et al. 1996, ER ID 62914; Schindler et al. 1985, ER ID 62916; Waide 1991, ER ID 63306).

Functional integrity is a valued attribute because it connotes an intact system — one in which there is no missing link that would result in structural or functional imbalances that render the entire system more vulnerable (less resilient) to perturbation. Understanding changes in trophic structures can also elucidate the mechanism for changes in process rates. For example, the loss of functional integrity might appear as the accumulation of detritus, shifts in the relative abundance (evenness) of species (e.g. eutrophication of lentic and lotic systems) or the disappearance or replacement of species in an assemblage. Newman and co-researchers (*in* Clements 1997, ER ID 62917) reported that reduced litter processing in streams dosed with chlorine resulted primarily from the elimination of shredders (a functional group of aquatic invertebrates).

Measures of interaction among species, according to principles of organization applicable to that system, may be more subtle than the measures for assessing functional integrity, mentioned above, but may be equally important for recognizing shifts in the functional integrity of the system. For example, sublethal doses of contaminants can alter key ecological processes (predator prey relationships, competition, ability to take up nutrients, organismal behavior, etc.), but may go unnoticed due to the coarseness of measurement. These measures vary with scales of biotic relevance, geography and time.

3.1.3 Energy and Nutrient Dynamics

The flow rates and patterns of nutrient and energy processing in a given ecosystem are critical for maintaining populations of indigenous species at levels characteristic of that ecosystem. Disruption of nutrient and energy flow rates (e.g. by nutrient enrichment or chemical contamination) can lead to accumulation of detritus, reduction of primary productivity, or loss of top predators (NcNaugton 1978, ER ID 63309). Each of these changes could affect ecosystem structure, function, and overall health. Just as GAEs provide a framework for the organization of assessment endpoints, the qualities of biodiversity, functional integrity, and nutrient and energy dynamics are essential ecological values across all ecosystems. These properties offer a structure for considering the intact nature of an ecosystem, at all scales of ecological organization. The values (GAEs) identified in the following sections are founded on the vision of an intact ecosystem.

3.2 VALUES COMMON TO THE PAJARITO PLATEAU ECOSYSTEM

In the GAE process, ecological values common to the regional ecosystem are identified next. These values are identified through a systematic process that includes first identifying the principal functional components of the regional ecosystem. Functional components are identified using food webs based on feeding guilds. A table associating attributes with the functional components is then developed. The attribute table provides the ecological values common to the regional ecosystem and is the basis for identifying the regional GAEs.

3.2.1 Functional Components of the Pajarito Plateau Ecosystem

Because food webs provide essential structural organization of producer-consumer relationships in ecosystems (Gallopin 1972, ER ID 63340) and because all organisms in an ecosystem are part of the food web, food webs are used to identify basic functional components of the Pajanto Plateau ecosystem.

Food webs are typically comprised of three basic trophic categories. These categories are producers, consumers, and decomposers (which are a special category of consumer). The following definitons aptly fit these broad categories.

- Producers are organisms that manufacture their own food from inorganic compounds by photosynthesis or chemosynthesis (e.g., green plants). These organisms are often referred to as "autotrophs".
- Consumers are organisms that ingest other organisms (e.g., animals that consume plants or other animals).
- Decomposers are organisms that derive their nourishment from dead organic matter (e.g., fungi and bacteria).

These categories are based on the broad interrelationships among groups of organisms but do not describe the many ways in which these interactions may occur. Organisms that obtain their food in a functionally similar way constitute a "feeding guild". Food webs based on feeding guilds facilitate the identification of critical ecosystem functions above the guild level, and aid in the identification of interrelationships among guilds, which may affect other ecosystem properties. As we consider the many forms of food webs for the Pajarito Plateau, we will focus on the feeding guild approach, or "functional food web".

While exotic (non-indigenous) plant and animal species are components of most ecosystems, they are frequently considered stressors for indigenous species. For the purpose of developing GAEs for the Pajarito Plateau, exotic organisms are not considered valued components of the ecosystem. All functional groups identified herein include only native species.

Below, we will first consider terrestrial and aquatic functional food webs combined, then these food webs will be considered independently for the sake of clarity.

Integrated Food Web

The aquatic and terrestrial ecosystems of the Pajarito Plateau can be considered as a single integrated ecosystem due to the close association of aquatic and terrestrial biota in this semi-arid environment. Water availability in this region can be limiting for the range, foraging and migratory patterns of many organisms in the region. Additionally, aquatic and terrestrial environs are closely linked in terms of energy and nutrient flows.

Figure 3.1 illustrates a current understanding of an integrated functional food web for the Pajarito Plateau. Table 3.1 provides a non-exhaustive list of representative organisms for each of the functional components illustrated in Figure 3.1. The species list in Appendix I provides the detailed list of organisms at the Laboratory and their associated functional components. The Ecology Group, ESH-20, has provided this list and continues to work on it. A final list will be issued as a LA-MS report this year.

Figure 3.1: Integrated Food Web for the Los Alamos National Laboratory

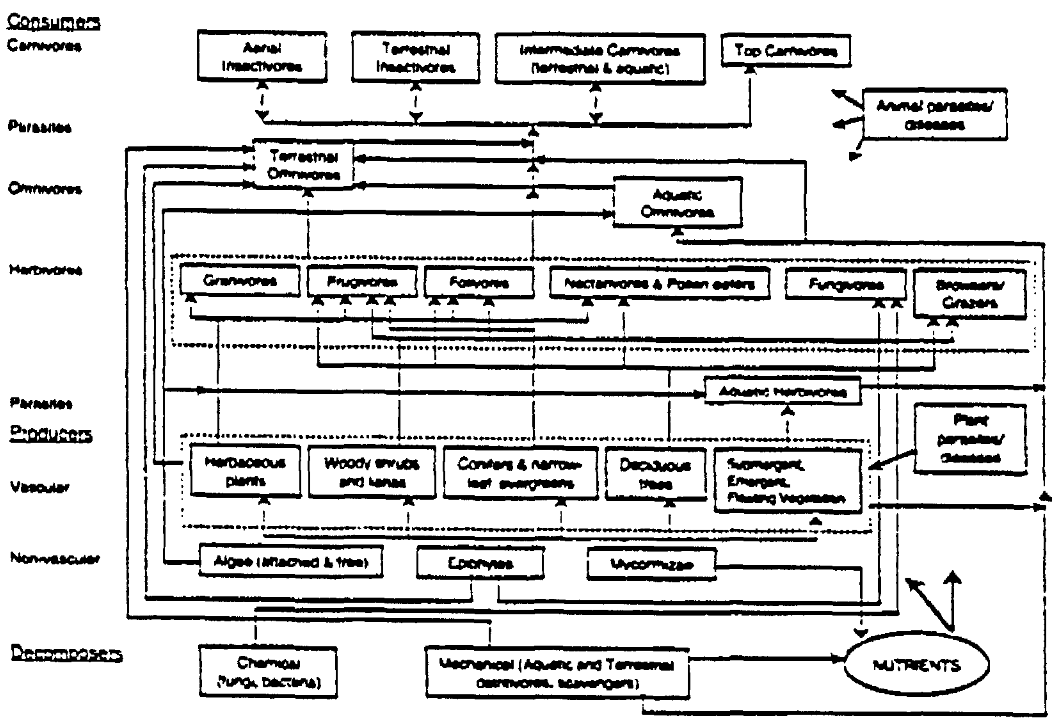


Table 3.1. A list of representative organisms for each of the functional guilds of the Pajarito Plateau

FUNCTIONAL COMPONENTS	REPRESENTATIVE ORGANISMS
Producers	Autotrophic organisms
Herbaceous Plants	grasses, forbs, annuals, perennials
Woody Shrubs	chamisa, willow, gambel oak
Conifers	Douglas fir, piñon, spruce, ponderosa pine
Deciduous Trees	aspen, cottonwood, box elder
Submergent, Emergent, and Floating Vascular Plants	cattails, duckweed, watercress
Algae	green filamentous algae, diatoms
Epiphytes	lichens, mosses
Mycorrhizae	mycorrhizal fungi
Consumers	Flesh and plant eaters
Granivores/Frugivores (seed and fruit eaters)	insects (e.g. some ants), rodents, birds
Folivores (leaf eaters)	insects (e.g. grasshoppers), mammals (e.g. elk)
Browsers	mammals (e.g. deer, rabbits and hares)
Necatarivores (nectar and pollen feeders)	insects (e.g. bees) , birds (e.g. hummingbirds), mammals (e.g. some bats)
Fungivores	insects (e.g. some beetles, flies), mammals (e.g. squirrels and mice [incidental])
Aquatic Herbivores (plant eaters)	invertebrates (e.g. snails, insects), tadpoles
Parasites	invertebrates (e.g. ticks, lice, worms)
Terrestrial Omnivores	mammals (e.g. skunk, fox), birds (e.g. robin, raven)
Aquatic Omnivores	invertebrates (e.g. isopods, mollusks)
Aerial Insectivores	mammals (e.g. bats), birds (e.g. flycatchers)
Terrestrial Insectivores	invertebrates (e.g. spiders), mammals (e.g. shrews), reptiles (e.g. lizards)
Intermediate Carnivores	reptiles (e.g. snakes), birds (e.g. kestrel [in part])
Top Carnivores	mammals (e.g. mountain lion), birds (e.g. red-tailed hawk)
Decomposers	Consumers of dead organic material
Mechanical Decomposers	invertebrates (e.g. earthworms, stoneflies), detritivores (e.g. amphipods), filter feeders (e.g. caddisflies), scavengers (e.g. turkey vultures), shredders (e.g. stoneflies)
Chemical Decomposers	fungi, bacteria

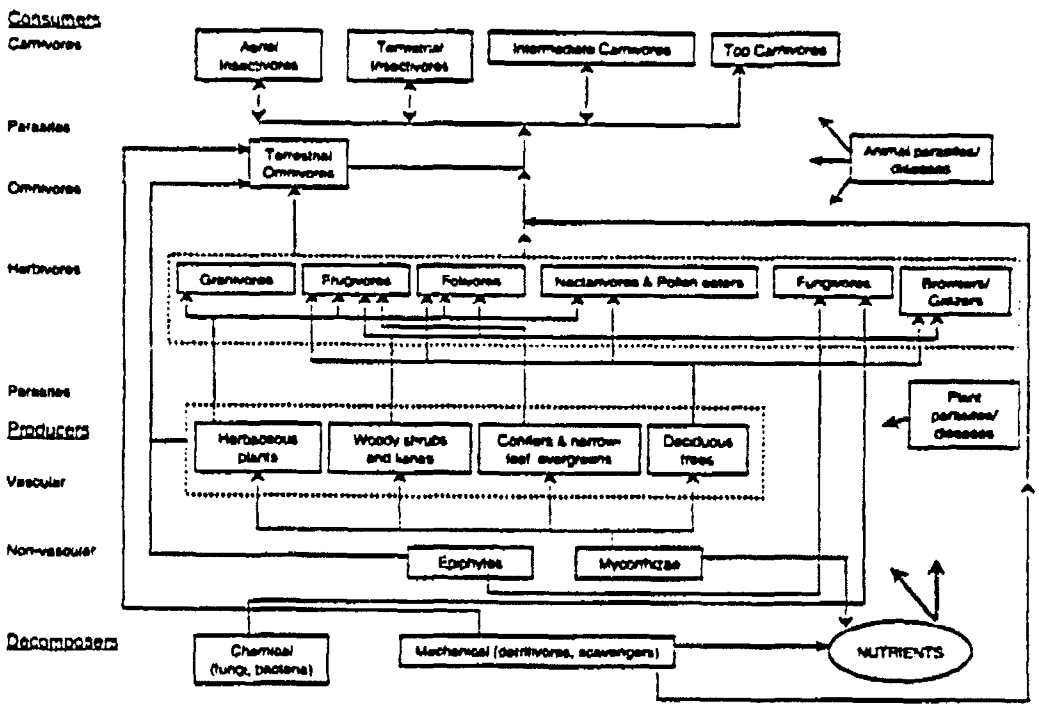
Terrestrial Food Web

Terrestrial habitats of the Pajarito Plateau ecosystem include grassland, juniper savanna, piñon-juniper woodland, ponderosa pine forest, mixed conifer forest, and aspen forest. While some species of plants and animals are limited to one or two of these habitats (e.g. the Mexican spotted owl in mixed conifer forest), others such as deer mice (*Peromyscus maniculatus*) occur in nearly all terrestrial habitats. Large herbivores, such as mule deer and elk, range over the entire Pajarito Plateau, using various combinations of habitats during different seasons. Top carnivores such as mountain lion, eagles, and hawks also range widely over the various habitats of the Pajarito Plateau. A functional food web of terrestrial biota is presented in Figure 3.2.

Aquatic Food Web

Aquatic ecosystems of the Pajarito Plateau consist of springs, perennial streams and associated wetlands, ponds, and ephemeral streams and pools. A variety of invertebrates inhabit these

Figure 3.2: Terrestrial Food Web



ecosystems including mollusks, various worms, crustaceans, and many species of insects. Several species of frogs and the tiger salamander (*Ambystoma tigrinum*) inhabit aquatic systems for all or a portion of their lifecycles. No fish are known to naturally inhabit the streams that traverse the Laboratory, although some non-native fisheries have been established in some limited areas (for example, Los Alamos Reservoir). A functional food web of aquatic biota is presented in Figure 3.3.

Aquatic resources are important to many terrestrial species, particularly because of the generally arid conditions throughout the region. Some terrestrial species (e.g., garter snakes, raccoon) also forage on aquatic species. Waterfowl and shorebirds seasonally inhabit wetlands and forage on aquatic plants and animals.

3.2.2 Attributes of the Functional Components

The functional components of the Pajarito Plateau are defined on the basis of their role in the food web, however, each of these components possess additional ecologically important attributes. For example, while trees may supply leaves and seeds for food, they also provide important structural habitat for nesting birds and squirrels. Nectar and pollen-feeding animals may be relatively unimportant in terms of nutrient and energy transfer through the food web, but critically important as plant pollinators. Relevant attributes of the ecological components of the Pajarito Plateau ecosystem are defined below (Table 3-2).

Figure 3.3: Aquatic Food Web

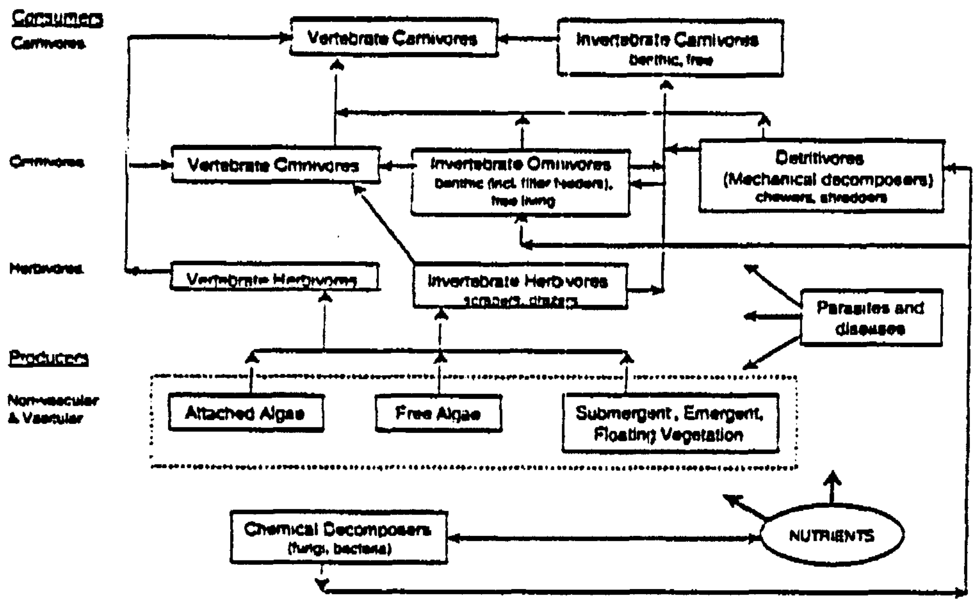


Table 3-2. Attributes of the Pajarito Plateau Ecosystem

ATTRIBUTE	DEFINITION
Food	Source(s) of energy and nutrients for organisms
Habitat	The biotic and abiotic structural environment in which organisms carry out their life functions.
Energy and Nutrient Fixation	The processes by which inorganic chemicals are yielded useful to living organisms.
Decomposition	The breakdown of dead organic matter by mechanical or chemical processes (both biotic and abiotic).
Propagule Dispersal	The distribution of reproductive propagules (e.g. seeds, spores, or vegetative bodies) from a parent organism into the environment.
Pollination	The sexual reproductive mechanism of flowering and seed-bearing plant species. For many plants, this process is mediated solely by symbionts (e.g. bees).
Control	The processes by which the abundance and distribution of organisms are affected by predation, herbivory and parasitism.

Attributes of each functional component of the ecosystem are presented in Table 3-3. Each functional component has at least one attribute. While some attributes could be considered more important than others, the table summarizes ecological values useful for identifying GAEs. One may read GAEs from the table in sentence form; for example, "top carnivores and intermediate carnivores are valued components of the Pajarito Plateau ecosystem because of their role in control".

Table 3-3. Critical ecological attributes of functional subgroups at the Los Alamos National Laboratory.

Functional Subgroups	Significant Ecological Attribute: Food Source	Habitat	Energy and Nutrient Fixation	Decomposition	Propagule Dispersal	Pollination	Control
Top Carnivores (e.g. raptors, native cats)							●
Intermediate Carnivores (e.g. snakes, birds, invertebrates)							●
Terrestrial Insectivores (e.g. rodents, lizards, arachnids)	●						●
Aerial Insectivores (e.g. birds, bats)							●
Terrestrial Omnivores (e.g. birds, mammals)	●			●			
Aquatic Omnivores (e.g. mollusks, freshwater crustaceans, caddisflies)	●			●			
Granivores/ Frugivores (e.g. insects, rodents, birds)	●				●		
Folivores (e.g. insects, ungulates)	●						
Browsers (e.g. ungulates, lagomorphs)	●						
Nectarivores/pollen eaters (e.g. insects, other invertebrates, birds)	●					●	
Fungivores (e.g. insects, mammals)					●		
Aquatic Herbivores (e.g. fish, benthic scrapers, tadpoles)	●						
Parasites (e.g. insects, worms)							●
Native Herbaceous Plants (e.g. grasses, forbs)	●	●	●				
Native Woody Shrubs (e.g. chamisa, Gambel oak)	●	●	●				
Native Conifers (e.g. douglas fir, piñon)	●	●	●				
Native Deciduous Trees (e.g. aspen, cottonwood)	●	●	●				
Native Submergent, Emergent and Floating Plants (e.g. duckweed, watercress)	●	●	●				
Submergent Aquatic Plants (e.g. algae)	●	●	●				
Epiphytes (e.g. lichens, moss)	●	●	●				
Mycorrhizae (nitrogen fixing symbiotic fungi, associated with plant roots)			●				
Mechanical Decomposers (e.g. earthworms, detritivores, scavengers, shredders)	●			●			
Chemical Decomposers (e.g. fungi, bacteria)	●			●			

3.3 GAEs BASED ON ECOLOGICAL RELEVANCE

3.3.1 Globally Relevant Endpoints

The following GAEs are based on ecological values characteristic of all ecosystems:

- Biodiversity is a valued ecological attribute because of its importance to human use, contribution to resilience, and importance for maintaining structure and function.
- Functional integrity is a valued attribute because it connotes an intact system — one in which there is no missing link that would result in structural or functional imbalances that render the entire system more vulnerable (less resilient) to perturbation.
- Energy and nutrient dynamics is a valued attribute because flow rates and patterns of nutrient and energy processing are critical for maintaining populations of indigenous species at levels characteristic of the ecosystem.

3.3.2 Regionally Relevant Endpoints

The following regional GAEs are based on the definitions provided in Table 3.2 and the attribute table (Table 3.3).

- Top carnivores and intermediate carnivores are valued components of the Pajarito Plateau ecosystem because of their role in control.
- Terrestrial insectivores are a valued component of the Pajarito Plateau ecosystem because of their importance both in control and as a food source to higher level carnivores.
- Aerial insectivores are a valued component of the Pajarito Plateau ecosystem because of their importance in processes of control.
- Terrestrial and aquatic omnivores are valued components of the Pajarito Plateau terrestrial and aquatic ecosystems because of their roles in decomposition and as a food source to higher level carnivores.
- Granivores and frugivores are valued components of the Pajarito Plateau ecosystem because of their importance as a food source to higher level carnivores and their role as propogule dispersers.
- Folivores and browsers are a valued component of the Pajarito Plateau ecosystem because of their importance as a food source to higher level carnivores and their role as non-food chain based propogule dispersers (e.g., seeds cling to their coat).
- Nectarivores and pollen eaters are valued components of the Pajarito Plateau ecosystem because of their importance in pollination and value as a food source.
- Fungivores are a valued component of the Pajarito Plateau ecosystem because of their importance in fungal species propogule dispersal.
- Aquatic herbivores are a valued component of the Pajarito Plateau ecosystem because of their importance as a food sources and role in aquatic decomposition.
- Plant and animal parasites are valued components of the Pajarito Plateau ecosystem because of their influence on population dynamics.
- All native herbaceous and woody plants and shrubs, conifers, deciduous trees, emergent plants, epiphytes, and lianas are valued components of the Pajarito Plateau ecosystem because of their importance as food sources and habitat, as well as their role in nutrient cycling.
- Aquatic plants are a valued component of the Pajarito Plateau ecosystem because of their importance as food sources and habitat and their role in nutrient cycling.
- Mycrrohizae are a valued component of the Pajarito Plateau ecosystem because of their importance in nutrient recycling and regeneration of soils.

- Mechanical and chemical decomposers are a valued component of the Pajarito Plateau ecosystem because of their importance in decomposition, nutrient recycling and as a food source.

4.0 VALUES AND GAEs FOR THE PAJARIO PLATEAU BASED ON SOCIETAL RELEVANCE

Ecological risk assessments should be conducted to reveal or predict adverse impacts of environmental stressors. Ultimately, however, the effectiveness of an ecological risk assessment depends on how it improves the quality of management decisions. Risk managers are more willing to use a risk assessment as the basis for making remedial decisions if the risk assessment considers ecological values that people care about (EPA 1998, ER ID 62809). Therefore, an ecological risk assessment must consider both ecological and societal values to be effective.

4.1 Criteria

Management goals are inextricably tied to the societal values of ecological resources. As LANL develops management goals for LANL habitats, they will be reflected in the GAEs. Values include formally recognized and protected ecological resources such as threatened and endangered species, as well as recreationally important species (e.g. game and non-game wildlife). Identification of societal values should involve input from risk managers, risk assessors, ecologists, appropriate regulatory authorities (e.g., State Department of Game and Fish, U. S. Fish and Wildlife Service), other experts (e.g. anthropologists) tribal representatives and municipalities, and the general public.

The Habitat Management Plan for Los Alamos National (LANL 1999, ER ID 62887) reflects the sentiments of parties interested in the ecological resources of the Pajarito Plateau. This plan provides an outlook on the management of regional ecological resources, and lists plant and animal species regulated in various categories of protection by federal, state, and local authorities. (Categories include federally threatened and endangered, state threatened and endangered, and both federal and state species of special concern). Recreationally important wildlife species identified in the plan include mule deer, elk, squirrels, wild turkey, and upland game. The federally listed species include the southwestern willow flycatcher, American peregrine falcon, arctic peregrine falcon, whooping crane, bald eagle, black-footed ferret, and Mexican spotted owl. Occupancy has been confirmed for only two federally listed species—the bald eagle and Mexican spotted owl (LANL 1999, ER ID 62887). The American peregrine falcon has had longstanding aeries immediately adjacent to the Laboratory and forages on Laboratory lands. State-listed species include the Great Plains ladies tresses, Jemez Mountains salamander, gray vireo, spotted bat, and New Mexican jumping mouse. More detailed information on T&E species may be found in LANL (1999, ER ID 62887) and Loftin and Haarmann (1998, ER ID 62881).

Other societal values for the ecosystem may be identified based on a review of the management goals and plans for areas potentially affected by Laboratory activities. For example, a given area may be under simultaneous management for production of forest products, protection of specific habitat, erosion control, fire suppression or protection of archeological sites.

Societal values recognized for the development of GAEs should incorporate concerns for clean water and watershed protection, both of which may fall under the scrutiny of regulatory compliance. GAEs should also be developed with an eye on neighboring systems of land use and control, as these may impact operations on the area of consideration.

4.2 GAEs Based on Societal Relevance

The specification of assessment endpoints with societal relevance is the last step in the process of identifying a comprehensive list of GAEs. For this last step, the involvement of stakeholders and the Natural Resource Trustees is critical. The following GAEs were identified for the Pajarito Plateau ecosystem, and are proposed for consideration by the Trustees and other stakeholders.

- Recreationally and commercially important species are valued components of the ecosystem and are to be protected because of their importance for consumptive uses such as hunting and fishing, and for non-consumptive uses, such as bird watching.
- Threatened and endangered species, their habitats, and migratory bird nesting, roosting and lighting sites are valued components of the ecosystem to be protected because of their regulatory stature.
- The quality and quantity of water within each watershed are valued components of the ecosystem and require management of point and non-point sources of contaminants, consumptive water usage or diversion, erosion and total suspended materials to meet regulatory limits and Total Maximum Daily Loads (TMDLs)
- Certain indigenous plants and animals are valued components of the ecosystem and are to be protected because of their ethnological and other consumptive and non-consumptive uses.
- The esthetic quality of the landscape is a valued component of the ecosystem because of its value to society.
- Wetlands within each watershed are valued due to their unique protection by the CWA, as well as their important ecological functions.

5.0 APPLICATION OF GENERAL ASSESSMENT ENDPOINTS IN THE ECOLOGICAL RISK ASSESSMENT PROCESS

GAEs are developed using a process based on ecological principles and knowledge of the ecological components and characteristics of an ecosystem. Additionally, GAEs reflect societal values and regulatory requirements. Development of GAEs involves regulators, trustees, and other stakeholders. Thus the GAE process delineates the "array of possibilities" from which the specific assessment endpoints are derived.

GAEs have been developed to ensure that values at all levels of ecological organization will be considered in the subsequent identification of site-specific assessment endpoints. The GAE process provides a framework for systematically considering how effects on particular species or other taxonomic groupings could affect functional components as well as higher levels of ecological organization (e.g., biological diversity, functional integrity or nutrient and energy cycling). Having stated the GAEs in Sections 3 and 4, it is now appropriate to apply the third major criterion for selecting assessment endpoints, i.e. susceptibility of receptors to known or potential environmental stressors.

Characterizing the species and habitats at a site and identifying which of these are sensitive to site contaminants are necessary first steps in the identification of site-specific assessment endpoints. Knowledge of receptor susceptibility may be used to identify site-specific assessment endpoints. The following questions should be answered in order to determine which GAEs are potentially affected by site-related contaminants:

- Which potential receptors (species representative of each functional group) and habitats are present in the area of concern?
- Which potential receptors are sensitive to which contaminants in the area of concern?

- What exposure pathways exist between contaminant sources and sensitive species (e.g., direct exposure, food chain transfer, etc.)?

Not all contaminants need to be considered simultaneously when identifying assessment endpoints. Details of the specific area under study such as contaminants, contaminant properties (e.g., bioavailability, bioaccumulation potential), ecological receptors present, sensitivity of receptors to contaminants, and exposure pathways, are evaluated by constructing conceptual site models and conducting a toxicity-based assessment. Multiple contaminants present at a site may act on various receptors through different exposure pathways, thus assessment endpoints may differ for each contaminant.

There are a number of ways that the GAE process is used to develop site-specific assessment endpoints. For instance, where aquatic crustaceans may be adversely affected, crustaceans would be an obvious value to be protected. It follows that the biodiversity of aquatic macroinvertebrates, including crustaceans, could also be considered as an appropriate assessment endpoint. However, it is less obvious that because the "detritivore" functional component of the aquatic ecosystem is comprised partially of crustaceans, decomposition rates for the aquatic system could be diminished as a result of contaminant effects on the detritvores.

Variability in ecological, time, and geographic scale is important in deciding how to apply GAEs to the selection of assessment endpoints. For example, contaminated sediments in a spring may have undetectable effects on the total biodiversity of the entire Pajarito Plateau ecosystem but may adversely affect the benthic biodiversity of the spring. It is important to consider geographic scale of effect (e.g. local, watershed, regional) when considering a specific assessment endpoint. It is also important to distinguish between effects on variable time scales, as this may, in turn, effect the selection of assessment endpoints. Time-dependent scales of effect may include processes that are population based (e.g. population viability measures) or community based (e.g. species exclusion based on competitive inhibition/release due to contaminant effects). For example, population-based effects from contamination may be more readily observed in short-lived organisms (e.g. rabbits) than in long-lived organisms (e.g. elk).

Once spite-specific assessment endpoints have been identified, at least one measure of effect or exposure must be selected to evaluate the potential risk posed to each assessment endpoint. (It is beyond the scope of this document to treat the development of appropriate measures in detail. The purpose of this discussion is to show how the GAE process can be of assistance during the scoping process, when site-specific assessment and measurement endpoints are developed.) A measurement endpoint is a measurable characteristic that is related to the valued characteristic chosen as the assessment endpoint (EPA 1997, ER ID 59370). EPA (1998, ERID 62809) narrowly defines measurement endpoint as a measure of effect but recognizes that other measures may be needed or appropriate. When selecting appropriate measures, it is important to consider the way in which the results will be used to contribute to the risk assessment. Typically a weight of evidence approach is used, combining multiples lines of evidence together in a qualitative or quantitative fashion. Thinking ahead about which lines of evidence will be supportive during the risk characterization phase will ensure that useful measures are selected.

Most assessment endpoints are addressed by measures that include one or more of the following:

- Media-specific contaminant measurements.
- Tissue analysis of plants and lower trophic-level animals.
- Food chain modeling to higher trophic-level organisms.
- Biological toxicity testing and bioaccumulation studies conducted under controlled conditions.
- Field measurements of biodiversity and various aspects of ecosystem function and health.

In some instances biomarkers (metabolic byproducts of specific contaminants) are also useful measures, since they can be used to determine more directly whether a receptor has actually been exposed to the stressor of concern.

Table 5-1 provides an example of a tool that can be used for moving from GAEs to the information necessary to conduct site specific ecological risk assessments. Site specific ecological risk assessments require identification of specific assessment endpoints, risk questions, and measures of effect or exposure. This summary table provides a format for capturing site specific information in the GAE context. Specifically, one row of the table should be completed for each GAE functional group, with supporting rationale for why and how each group is, or is not, important in the context of the ERA. By using this table, risk assessors can ensure that each of the GAEs are considered, and addressed by a site-specific assessment endpoint, or that an explanation is documented for why no site-specific assessment endpoint is necessary. For example, a site-specific assessment endpoint is not required if a GAE is not pertinent to an assessment, e.g. due to an incomplete exposure pathway or lack of toxic effects. Table 5-1 provides a checklist for problem formulation of an ecological risk assessment. Inputs to Table 5-1 must be consistent with the conceptual site model and food web for the specific area under study.

Table 5-1. Summary of GAEs, Site Specific Assessment Endpoints (AEs), Risk Questions and Appropriate Measures.

General Assessment Endpoint	Site Specific AEs Representatives of GAE	Risk Questions	Surrogate Species or Community	Appropriate Measures	Uncertainties	Rationale for Addressing or Not Addressing GAE
State each of the GAEs identified in this document, including system level GAEs such as biodiversity, and societally important GAEs such as protection of T&E species.	State specific value to be protected relative to the functional group. For example: - Survival and reproduction - Maintaining similar diversity within this functional group as at a reference site - Maintain rates of energy and nutrient cycling similar to a reference site, or characteristic of the tropic status of the system.	State the specific question(s) that relate to the AEs. For example: - Are concentrations of LANL related contaminants present at levels known to have chronic or acute toxicity to important species in this functional group? - Are concentrations of LANL related contaminants high enough to cause adverse impacts to the biodiversity of species comprising this functional group? - Are concentrations of LANL related constituents high enough to affect rates of energy production, or nutrient cycling?	State the specie(s) that are good candidates for use in evaluating site specific impacts: For example, a specific species present at the site within the functional group, or a surrogate for this species that could be used in biotoxicity tests. Alternately the whole community representative of the functional group could be stated here.	List the specific measures related to the species, and risk questions, that are in turn related to the assessment endpoint of interest. For example: - Laboratory biotoxicity test. - A specific biodiversity index measured for the site and for a reference area. - Specific measure of energy flow, such as primary productivity to be measured at the site and a reference area.	Discuss the types of uncertainties that will, at a minimum, be considered in evaluating the measures. For example: - Laboratory test may not reflect field conditions, or surrogate may not respond same as species present in field - Representativeness of selected reference site. - Potential confounding factors for interpreting biotoxicity tests - Inability to adequately represent species diversity in timeframe available for assessment	State the rationale for including or not including the assessment endpoints and appropriate measures. Explain strength of the particular line(s) of evidence, relative sensitivity, practicality, etc.

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APPENDIX I : Partial* Species List

*reflects current knowledge

Mammals

Family	Genus/Species	Common Name	Functional Group[1]	Functional Subgroup[2]
CANIDAE	Canis latrans	Coyote	O	TO
	Vulpes vulpes	Red fox	C	TC
	Urocyon cinereoargenteus	Gray fox	C	TC
CERVIDAE	Cervus elaphus subsp. nelsoni	Elk	H	BG
	Odocoileus hemionus	Mule deer	H	BG
EQUIDAE	Equus asinus	Feral ass	H	BG
ERETHIZONTIDAE	Erethizon dorsatum	Porcupine	H	BG
FELIDAE	Lynx rufus	Bobcat	C	TC
	Felis concolor	Mountain lion	C	TC
GEOMYIDAE	Thomomys bottae	Bottae's pocket gopher	H	BG
HETEROMYIDAE	Perognathus flavus	Silky pocket mouse	H	BG
HETEROMYIDAE	P. flavescens	Plains pocket mouse	O	TO
	P. intermedius	Rock pocket mouse	O	TO
LEPORIDAE	Sylvilagus audubonii	Desert cottontail	H	BG
	S. nuttallii	Nuttall's cottontail	H	BG
MOLOSSIDAE	Nyctinomops macrotis	Big free-tailed bat	C	IC
	Tadarida brasiliensis	Brazilian free-tailed bat	C	IC
MURIDAE	Clethrionomys gapperi	Southern red-backed vole	O	TO
	Microtus longicaudus	Long-tailed vole	H	BG
	M. montanus	Montane vole	O	BG
	Neotoma albigula	White-throated woodrat	H	BG
	N. cinerea	Bushy-tailed woodrat	H	BG
	N. mexicana	Mexican woodrat	H	BG
	Peromyscus boylii	Brush mouse	O	TO
	P. leucopus	White-footed mouse	O	TO
	P. maniculatus	Deer mouse	O	TO
	P. nasutus	Rock mouse	O	TO
	P. truei	Piñon mouse	O	TO
	Reithrodontomys megalotis	Western harvest mouse	O	TO
	Sigmodon hispidus	Cotton rat	H	BG
MUSTELIDAE	Mustela erminea	Ermine weasel	C	IC
	M. frenata	Long-tailed weasel	C	IC
	Taxidea taxus	Badger	C	TC
MUSTELIDAE	Mephitis mephitis	Striped skunk	O	TO
OCHOTONIDAE	Ochotona princeps nigrescens	Goat Peak pika	H	BG
PROCYONIDAE	Bassariscus astutus	Ringtail cat	O	TO
	Procyon lotor	Raccoon	O	TO
SCIURIDAE	Cynomys gunnisonni	Gunnison's prairie dog	H	BG
	Eutamias minimus	Least chipmunk	O	TO
	Eutamias quadrivittatus	Colorado chipmunk	O	TO

Family	Genus/Species	Common Name	Functional Group[1]	Functional Subgroup[2]
	Sciurus aberti	Abert's squirrel	H	BG
	S. spilosoma	Spotted ground squirrel	O	TO
	Spermophilus lateralis	Golden-Mantled ground squirrel	H	BG
	S. variegatus	Rock squirrel	O	TO
	Tamiasciurus hudsonicus	Red squirrel	H	BG
SORICIDAE	Sorex vagrans	Vagrant shrew	O	TO
	S. nanus	Dwarf shrew	O	TO
	S. palustris	Northern water shrew	O	TO
URSIDAE	Ursus americanus	Black bear	O	TO
VERSPER-TILIONIDAE	Antrozous pallidus	Pallid bat	C/I	IC
	Eptesicus fuscus	Big brown bat	C/I	IC
	Euderma maculatum	Spotted bat	C/I	IC
	Lasionycteris noctivagans	Silver-haired bat	C/I	IC
	Lasiurus cinereus	Hoary bat	C/I	IC
	Myotis californicus	California myotis	C/I	IC
	M. ciliolabrun	Western small-footed myotis	C/I	IC
	M. evotis	Long-eared myotis	C/I	IC
	M. leibii	Small-footed myotis	C/I	IC
	M. thysanodes	Fringed myotis	C/I	IC
	M. yumanensis	Yuma myotis	C/I	IC
	M. volans	Long-legged myotis	C/I	IC
	Plecotus townsendii	Townsend's big-eared bat	C/I	AI
	Pipistrellus hesperus	Western pipistrelle	C/I	AI

[1,2] Functional groups and subgroups are a Laboratory standard and do not reflect those of Figures 3.1, 3.2 or 3.3.

Birds

Family	Genus/Species	Common Name	Functional Group[1]	Functional Subgroup[2]
GAVIIDAE	Gavia immer	Common loon	C	IC
	G. stellata	Red-throated loon	C	IC
ARDEIDAE	Ardea herodias	Great blue heron	C	I, IC
CATHARTIDAE	Cathartes aura	Turkey vulture	C	TC
ANATIDAE	Chen caerulescens	Snow goose	H	Gr, B/G
	Anas platyrhynchos	Mallard	O	I, Gr
	Mergus merganser	Common merganser	C	I
ACCIPITRIDAE	Accipiter cooperii	Cooper's hawk	C	TC
	A. gentilis	Northern goshawk	C	TC
	A. striatus	Sharp-shinned hawk	C	TC, I
	Aquila chrysaetos	Golden eagle	C	TC
	Buteo jamaicensis	Red-tailed hawk	C	TC
	B. albonotatus	Zone-tailed hawk	C	TC
	Circus cyaneus	Northern harrier	C	TC
	Haliaeetus luecocephalus	Bald eagle	C	TC
FALCONIDAE	Falco sparverius	American kestrel	O	TC, I
	F. mexicanus	Prairie falcon	C	TC
	F. peregrinus	Peregrine falcon	C	TC
PHASIANIDAE	Callipepla gambelii	Gambel's quail	H	Gr, Fo
	Dendragapus obscurus	Blue grouse	H	Gr, Fo
	Meleagris gallopavo	Wild turkey	O	Gr, Fo, I
RALLIDAE	Fulica americana	American coot	O	Gr, Fo, I
	Rallus limicola	Virginia rail	O	BG, I
GRUIDAE	Grus americana	Whooping crane	O	BG, I
	G. canadensis	Sandhill crane	O	BG, I
SCOLOPACIDAE	Actitis macularia	Spotted sandpiper	C	I
COLUMBIDAE	Columba fasciata	Band-tailed pigeon	H	Gr, Fo
	C. livia	Rock dove	H	Fr, Fo
	Zenaida macroura	Mourning dove	H	Gr
CUCULIDAE	Geococcyx californianus	Greater roadrunner	C	I, IC
STRIGIDAE	Glaucidium gnoma	Northern pygmy-owl	C	I, TC
	Aegolius acadicus	Northern saw-whet owl	C	TC
	Bubo virginianus	Great horned owl	C	TC
	Otus flammeolus	Flammulated owl	C	I, TC
	O. kennicottii	Western screech owl	C	TC
	Strix occidentalis lucida	Mexican spotted owl	C	I, TC
CAPRIMULGIDAE	Caprimulgus vociferus	Whip-poor-will	C	I
	Chordeiles minor	Common nighthawk	C	I
	Phalaenoptilus nuttallii	Common poorwill	C	I
APODIDAE	Aeronautes saxatalis	White-throated swift	C	I
TROCHILIDAE	Selasphorus	Broad-tailed hummingbird	O	NP, I

	platycercus			
	Archilochus alexandri	Black-chinned hummingbird	O	NP, I
PICIDAE	Colaptes auritus	Northern flicker	O	I, Gr
	Melanerpes lewis	Lewis' woodpecker	O	I, Gr
	M. formicivorus	Acorn woodpecker	H	Gr
PICIDAE	Picoides pubescens	Downy woodpecker	O	I, Gr
	P. villosus	Hairy woodpecker	O	I, Gr
	P. tridactylus	Three-toed woodpecker	C	I, Gr
	P. scalaris	Ladder-backed woodpecker	C	I
	Sphyrapicus nuchalis	Red-naped sapsucker	C	I
	S. thyroideus	Williamson's sapsucker	C	I
	S. varius	Yellow-bellied sapsucker	O	I, Gr
TYRANNIDAE	Contopus borealis	Olive-sided flycatcher	C	I
	C. sordidulus	Western wood-pewee	C	I
	Empidonax hammondii	Hammond's flycatcher	C	I
	E. oberholseri	Dusky flycatcher	C	I
	E. occidentalis	Cordilleran flycatcher	C	I
	E. traillii extimus	Southwestern willow flycatcher	C	I
	E. wrightii	Gray flycatcher	C	I
	Myiarchus cinerascens	Ash-throated flycatcher	C	I
	Tyrannus vociferans	Cassin's kingbird	C	I
	Sayornis saya	Say's phoebe	C	I
	S. nigricans	Black phoebe	C	I
HIRUNDINIDAE	Tachycineta thalassina	Violet-green swallow	C	I
	Hirundo pyrrhonota	Cliff swallow	C	I
CORVIDAE	Aphelocoma coerulescens	Scrub jay	O	I, Gr
	Cyanocitta stelleri	Steller's jay	O	I, Gr
	Gymnorhinus cyanocephalus	Piñon jay	O	I, Gr
	Corvus brachyrynchos	American crow	O	I, Gr, TC
	Corvus corax	Common raven	O	I, Gr, TC
	Corvus cryptoleucus	Chihuahuan raven	O	I, Gr, TC
	Nucifraga columbiana	Clark's nutcracker	O	I, Gr, IC
	Perisoreus canadensis	Gray jay	O	I, Gr, IC
	Pica pica	Black-billed magpie	O	I, Gr, IC
PARIDAE	Parus gambeli	Mountain chickadee	O	I, Gr
	P. inornatus	Juniper titmouse	O	I, Gr
AEGITHALIDAE	Psaltriparus minimus	Bushtit	O	I, Gr
SITTIDAE	Sitta canadensis	Red-breasted nuthatch	O	I, Gr
	S. carolinensis	White-breasted nuthatch	O	I, Gr
	S. pygmaea	Pygmy nuthatch	O	I, Gr

CERTHIIDAE	Certhia americana	Brown creeper	O	I, Gr
TROGLODYTIDAE	Troglodytes aedon	House wren	C	I
	T. troglodytes	Winter wren	C	I
	Catherpes mexicanus	Canyon wren	C	I
	Salpinctes obsoletus	Rock wren	C	I
	Thryomanes bewickii	Bewick's wren	O	I, Gr
CINCLIDAE	Cinclus mexicanus	American dipper	C	I
MUSCICAPIDAE	Catharus guttatus	Hermit thrush	O	I, Gr
	Myadestes townsendi	Townsend's solitaire	O	I, Gr
	Polioptila caerulea	Blue-grey gnatcatchor	C	I
MUSCICAPIDAE	Regulus calendula	Ruby-crowned kinglet	C	I
	R. satrapa	Golden-crowned kinglet	C	I
	Sialia currucoides	Mountain bluebird	C	I
	S. mexicana	Western bluebird	C	I
	Turdus migratorius	American robin - Screening Receptor	O	I, Gr
MIMIDAE	Mimus polyglottos	Northern mockingbird	O	I, Gr
STURNIDAE	Sturnus vulgaris	European starling	O	I, Gr
VIREONIDAE	Vireo gilvus	Warbling vireo	C	I
	V. solitarius	Solitary vireo	C	I
EMBERIZIDAE	Vermivora celata	Orange-crowned warbler	C	I
	V. virginiae	Virginia's warbler	C	I
	Dendroica petechia	Yellow warbler	C	I
	D. caerulescens	Black-throated blue warbler	C	I
	D. coronata	Yellow-rumped warbler	C	I
	D. nigrescens	Black-throated grey warbler	C	I
	D. graciae	Grace's warbler	C	I
	Oporornis tolmiei	MacGillivray's warbler	C	I
	Wilsonia pusilla	Wilson's warbler	C	I
	Piranga flava	Hepatic tanager	O	I, Gr
	P. ludoviciana	Western tanager	O	I, Gr
	P. rubra	Summer tanager	O	I, Gr
	Guiraca caerulea	Blue grosbeak	O	I, Gr
	Pheucticus melanocephalus	Black-headed grosbeak	C	I
	Passerina amoena	Lazuli bunting	C	I, Gr
	P. cyanea	Indigo bunting	O	I, Gr
	Pipilo chlorurus	Green-tailed towhee	O	I, Gr
	Psaltriparus fuscus	Canyon towhee	O	I, Gr
	P. maculatus	Spotted towhee	O	I, Gr
	Aimophila ruficeps	Rufous-crowned sparrow	O	I, Gr
	Melospiza lincolnii	Lincoln's sparrow	O	I, Gr
	M. melodia	Song sparrow	O	I, Gr
	Pooecetes gramineus	Vesper sparrow	O	I, Gr
	Spizella passerina	Chipping sparrow	C	I
	S. atrogularis	Black-chinned sparrow	O	I, Gr
	Junco hyemalis	Dark-eyed junco	C	I
	Sturnella neglecta	Western meadowlark	O	I, Gr
	Agelaius phoeniceus	Red-winged blackbird	O	I, Gr

	Euphagus cyanocephalus	Brewer's blackbird	O	I, Gr
	Molothrus ater	Brown-headed cowbird	O	I, Gr
	Chondestes grammacus	Lark sparrow	O	I, Gr
	Icterus bullockii	Bulluck's oriole	O	I, Gr
	I. parisorum	Scott's oriole	O	I, Gr
	Zonotrichia leucophrys	White-crowned sparrow	O	I, Gr
FRINGILLIDAE	Carduelis pinus	Pine siskin	O	I, Gr
	C. psaltria	Lesser goldfinch	H	Gr, Fo
	Carpodacus cassinii	Cassin's finch	O	I, Gr
	Catherpes mexicanus	House finch	O	I,Gr
	Coccothraustes vespertinus	Evening grosbeak	O	I, Gr
	Loxia curvirostra	Red crossbill	H	Gr
PASSERIDAE	Passer domesticus	House sparrow	O	I, Gr

[1,2] Functional groups and subgroups are a Laboratory standard and do not reflect those of Figures 3.1, 3.2 or 3.3.

Reptiles

Family	Genus/Species	Common Name	Functional Group[1]	Functional Subgroup[2]
COLUBRIDAE	Diadophis punctatus	Ringneck snake	C	IC
	Elphae guttata	Corn snake	C	IC
	Hypsiglena torguata	Night snake	C	IC
	Masticophis taeniatus	Striped whipsnake	C	IC
	M. flagollum	Coachwhip snake	C	IC
	Pituophis melanoleucus	Gopher snake	C	IC
	Salvadora grahamiae	Mountain patch-nosed snake	C	IC
	Thamnophis cyrtopsis	Black-headed garter snake	C	IC
	Thamnophis elegans	Western terrestrial garter snake	C	IC
	Opheodrys vernalis	Smooth green snake	C	IC
	Pituophis melaonleucus sayi	Bull snake	C	IC
VIPERIDAE	Crotalus atrox	Western diamondback rattlesnake	C	IC
	Crotalus viridis sub. viridis	Prairie rattlesnake	C	IC
IGUANIDAE	Crotophytus collaris	Collared lizard	C	TI
	Phrynosoma douglassi	Short-horned lizard	C	TI
	Sceloporus undulatus	Eastern fence lizard	C	TI
	Scelophorus undulatus tristichus	Southern plateau lizard	C	TI
	Urosaurus ornatus	Tree lizard	C	TI
SCINCIDAE	Eumeces multivirgatus	Many-lined skink	C	TI
	Eumeces obsoletus	Great Plains skink	C	TI
TEIIDAE	Cnemidophorus exanguis	Chihuahuan spotted whiptail	C	TI
	C. inoranatus	Little striped whiptail	C	TI
	C. neomexicanus	New Mexico whiptail	C	TI
	Cnemidophorus velox	Plateau striped whiptail	C	TI

[1,2] Functional groups and subgroups are a Laboratory standard and do not reflect those of Figures 3.1, 3.2 or 3.3.

Amphibians

Family	Genus/Species	Common Name	Functional Group[1]	Functional Subgroup[2]
AMBYSTOMATIDAE	Ambystoma tigrinum	Tiger salamander	C	TI
	Plethodon neomexicanus	Jemez Mountains salamander	C	TI
BUFONIDAE	Bufo woodhousei	Woodhouse's toad	C	TI
	Bufo punctatus	Red spotted toad	C	TI
HYLIDAE	Pseudacris triseriata	Western chorus frog	C	TI
	Hyla arenicolor	Canyon tree frog	C	TI
PELOBATIDAE	Scaphiopus couchi	Couch's spadefoot toad	C	TI
	S. multiplicatus	New Mexican spadefoot toad	C	TI

[1,2] Functional groups and subgroups are a Laboratory standard and do not reflect those of Figures 3.1, 3.2 or 3.3.

Insects [†]

Order	Scientific Name	Common Name	Functional Group	Functional Subgroup
Coleoptera	MANY SPECIES	Beetles	MANY	MANY
Collembola	FEW SPECIES	Springtails	FEW	FEW
Dermaptera (Earwigs)	FEW SPECIES	Earwigs	FEW	FEW
Diptera	MANY SPECIES	True flies	MANY	MANY
Ephemeroptera	MANY SPECIES	Mayflies	FEW	FEW
Hemiptera	MANY SPECIES	True bugs	MANY	MANY
Homoptera	MANY SPECIES	Cicadas, aphids and kin	FEW	FEW
Hymenoptera	MANY SPECIES	Bees, ants, wasps	MANY	MANY
Lepidoptera	MANY SPECIES	Butterflies and moths	FEW	FEW
Neuroptera	MANY SPECIES	Net-veined insects	FEW	FEW
Odonata	MANY SPECIES	Dragonflies and damselflies	FEW	FEW
Orthoptera	MANY SPECIES	Grasshoppers and crickets	FEW	FEW
Phasmida	FEW SPECIES	Walkingsticks	FEW	FEW
Plecoptera	MANY SPECIES	Stoneflies	FEW	FEW
Thysanoptera	MANY SPECIES	Thrips	FEW	FEW
Thysanura	FEW SPECIES	Bristletails and silverfish	FEW	FEW
Tricoptera	MANY SPECIES	Caddisflies	MANY	MANY

[†] The current species list of insects is very incomplete, therefore only known orders are listed.

Legend

Category	Legend	Definition
Functional feeding group	He	
Functional feeding subgroup	AI	Aerial insectivore
	AG	Annual Grass
Functional feeding subgroup	AqI	Aquatic Insectivore
	A	Aspen forest
Modes of existence	Bu	Browser
	BG	Browsers/Grazers
	Ca	Cacti
Functional feeding group	C	Camivore
	C/I	Camivore/Insectivore
	CD	Chemical Decomposer
Modes of existence	Cb	Climber
Modes of existence	Cl	Climber
Functional feeding group	Cf	Collector/Filterers
Functional feeding group	CG	Collector/Gatherers
	CE	Conifers & narrow leaf evergreens
	DT	Deciduous trees
	D	Decomposer
Modes of existence	Dv	Diver
	Ep	Epiphytes
	FE	Federal endangered
	FT	Federal Threatened
	Fo	Folivores
	Fr	Frugivores
HEADINGS	FG	Functional Group
	FS	Functional Subgroup
	Fu	Fungivores
	Gr	Granivores
	G	Grasslands
	HP	Herbaceous plants
Functional feeding group	H	Herbivores
	IC	Intermediate Carnivore
	JS	Juniper Savanna
	MD	Mechanical Decomposer
	MC	Mixed Conifer
	My	Mycorrhizae
	NP	Nectivores & Pollen eaters
	N	Non-vascular
	O	Omnivore
	P	Parasite
	PG	Perennial Grass
	PW	Pinon Woodlands
	PP	Ponderosa Pine
Functional feeding group	Pr	Predators
	PRA	Preliminary Risk Assessment
	SF	Sap Feeder
Functional feeding group	Sc	Scrapers

Functional feeding group	Sh	Shredders
Modes of existence	Sk	Skater
	SOC	Species of Concern
Modes of existence	Sp	Sprawler
	SL	State Listed
Modes of existence	Sw	Swimmer
	TI	Terrestrial Insectivore
	TO	Terrestrial Omnivore
	TC	Top Carnivores
	VP	Vasular Plant
	WS	Woody shrubs & lianas