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Selection of Assessment and Measurement Endpoints for Ecological Risk Assessment

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14. ABSTRACT
This document provides general recommendations for selecting appropriate assessment and measurement endpoints for ecological risk assessments at military installations. Decision makers, stakeholders, risk assessors, installation natural resource managers, ecologists, biologists and soil scientist should be consulted when choosing Measurement Endpoints. This guidance provides some background and the logic that should be used to determine appropriate endpoints.

15. SUBJECT TERMS
Ecological Risk Assessment(ERA); Installation Restoration Program (IRP); Base Realignment and Closure (BRAC); Formerly Used Defense Sites (FUDS); Assessment and Measurement Endpoints

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DEPARTMENT OF THE ARMY
U.S. ARMY BIOLOGICAL TECHNICAL ASSISTANCE GROUP

TECHNICAL DOCUMENT FOR ECOLOGICAL RISK ASSESSMENT

Selection of Assessment and Measurement Endpoints for Ecological Risk Assessments

February 2002

1. PURPOSE

The purpose of this document is to provide general recommendations in regard to selecting appropriate assessment and measurement endpoints for ecological risk assessments at military installations. This includes Installation Restoration Programs (IRP), Base Realignment and Closure (BRAC) and Formerly Used Defense Sites (FUDS). Since the Assessment and Measurement Endpoints[1] are integral to the focus of the Ecological Risk Assessment (ERA), it is important that they are selected involving decision makers, their stakeholders, risk assessors, installation natural resource managers and other supporting ecologists, biologists, and soil scientists. However, it is recognized that it is difficult to get consensus on the proper valued resources at any particular site or installation. This guidance provides some background and the logic that should be used to address the proper selection of these endpoints.

2. BACKGROUND

The concept of Assessment and Measurement Endpoints was initially described by Suter (1989, 1990) and first appeared in USEPA Guidance in the Framework for Ecological Risk Assessment (1992). The Guidelines for Ecological Risk Assessment expands on these definitions and use (USEPA 1998). These are defined as:

ASSESSMENT ENDPOINT – "Explicit expression of the actual environmental values that are to be protected"(USEPA 1992, 1997, 1998). As "values", the relevance of such endpoints ultimately depends upon how society or the public at large views specific species of animals and plants. Although important to ecosystem function, the public generally does not currently accept fungi, bacteria, and species of invertebrates as appropriate assessment endpoints. Species of soil invertebrates generally should not be selected as assessment endpoints unless there is clear consensus among stakeholders. These should also be consistent with the management goals of the installation Natural Resource Management Plan. It is suggested that these species be considered as attributes of the ecosystem so they may be measured, and used to address specific assessment endpoints. Thus the assessed impact of these species may be used to communicate the ecological importance of these species to and among the more publicly valued species (e.g., birds and mammals).

Site management goals and objectives will guide and influence Assessment Endpoints, and need to be identified or developed prior to the selection of Assessment Endpoints. Factors that are considered in management objectives are the current and future site land use and identified valuable biological resources.

[1] The term "Measurement Endpoint" has been redefined to "Measures of Effect", noting that the latter term is more specific and less confusing (USEPA 1998). However, since the Ecological Risk Assessment Guidance for Superfund (USEPA 1997) uses the term Measurement Endpoint, this paper is meant to be consistent with that use, and therefore include the use of media-specific chemical concentration data for use in risk assessments.

If an IRP or BRAC installation has an Installation Natural Resource Management Plan, goals and information contained therein are also considered. U.S. Army BTAG guidance on the development of site-specific management objectives is being developed.

Assessment Endpoints can be identified at the individual, population, or community level of biological organization (USEPA 1996). Examples of these may include.

Individual Level –

These include individual-specific parameters and are important particularly where health consequences of individuals may have or be suspected of having profound ecological influences. Examples include:

- Threatened or Endangered (T&E) species
- Changes in top predator activity

Population Level -

These include factors that influence the abundance or densities of a single species existing within a specific area.[2] Examples include:

- Survival and reproduction of native Brook trout
- Survival and reproduction of Eastern Bluebirds
- Survival and reproduction of meadow voles (prey base)

Community Level -

This includes factors that affect the number of species (or composition) within a habitat. Other measures may include how these species interact together. Examples include:

- Longleaf pine communities
- Estuarine communities
- Wetland plant communities
- Grassland communities
- Communities of naturally occurring winter annuals
- Old Growth Forests
- Sensitive habitat communities:
  - Northern Coastal Scrub
  - Coastal Prairie
  - Coastal Strand
  - Coastal Riparian Woodland
  - Mixed Evergreen Forest

It is important that knowledge of the ecosystem be understood as well as possible, with regard to how exposure to contamination may influence these biological levels of organization and their ecological components. Factors that may be important to the extrapolation of site-specific data to the assessment endpoints may include: knowledge of the factors important in site-specific population regulation (e.g., predation rates, food abundance, habitat availability, dispersal, climate, weather, population dynamics, life-cycles, etc.), factors important in maintaining habitat quality (e.g., fire succession, moisture regime, microclimate, and seasonal variation, etc.), and other factors that may affect exposure. Natural resource

[2] Although measured at the individual level, these factors are important in toxicological dose/response relationships and in maintaining local populations.

personnel (when present) at Army installations often best know the areas in question and can be excellent sources of site-specific information.

Importance of Selecting Assessment Endpoints:

> Specific or clearly defined assessment endpoints provide the risk assessors and risk managers with sufficient direction and detail for determining the answers for specific questions, whereas, broad assessment endpoints do not. Specific Assessment Endpoints provide risk assessors and risk managers with more information for the development of Measurement Endpoints (USEPA 1998). Keep in mind that attributes of the Assessment Endpoints are often not measured, it is the attributes of the Measurement Endpoints that are.

MEASUREMENT ENDPOINT– "Measurable responses to a stressor that are related to the valued characteristic chosen as the Assessment Endpoints" (Suter 1989, 1990, USEPA 1992). Properly selected measurement endpoints are used to infer a measure of protection or evaluate risk to the assessment endpoints. This can include specific measurements of receptor health, population indices, measurements of exposure, or direct measures of ecotoxicological effects. More specific sub-definitions are provided below (USEPA 1998).

> **Measures of Exposure –** "Measures of stressor existence and movement in the environment and their contact or co-occurence with the Assessment Endpoint or its surrogate."
>
> **Measures of Effect –** "Measurable changes in an attribute of an Assessment Endpoint or its surrogate in response to a stressor to which it is exposed".
>
> **Measures of ecosystem and receptor characteristics –** "Measures of ecosystem characteristics that influence the behavior, life history, and distribution of populations or individuals in a community that may be adversely affected by contaminant exposure."

Measures of Exposure are chemical-specific values used to determine exposure. Examples include soil, surface water, sediment, and food concentrations of specific chemicals that either can be modeled or empirically determined to evaluate the amount of chemical(s) receptors are exposed to. They are usually media specific (in units of mg substance/kg media) or based on food intake (in units of mg substance/kg body weight of the receptor).

Measures of Effect are primarily quantitative observations (e.g., population diversity measurements, abundance measurements, measures of direct toxicity, etc.) and are made at both reference and study sites for statistical comparison purposes. Most often they are measured media concentrations of substances, which are used to estimate exposure to the species of concern or its surrogate. Those measured (or modeled) estimates of exposure are then compared to a toxicity benchmark to characetrize the potential for risk. Others may use site-specific media and perform toxicity tests under controlled laboratory conditions to address likelihood of adverse effects. The most appropriate Measures of Effect for an Assessment Endpoint depend on the number and types of lines of evidence that are needed to support risk-management decisions at the site in question, consistent with the management goals of the installation or site (USEPA 1997). Sometimes more than one line of evidence is necessary to adequately assess the hypotheses formulated for the Assessment Endpoints.

Measures of ecosystem and receptor characteristics include more relevant information that is specific to the site and the influence of the site on the populations, communities and ecosystem in contact with it. Population-relevant criteria (such as density, relative abundance, reproductive performance, etc.) can be evaluated to determine the risk of extirpation from exposure to the substance(s). Species diversity indices, measures of community function (e.g., changes in species composition over time), and ecosystem function can be measured (e.g., amount biomass, carbon cycling, energetics of the system, etc.).

SELECTING MEASUREMENT ENDPOINTS –
The purpose of the Measurement Endpoint is to represent the Assessment Endpoints selected for the site in question (USEPA 1997). Measurement Endpoints should:

- Be based on the exposure routes of concern
- Be based on susceptible receptors that are ecologically relevant to the site and the Assessment Endpoints
- Use criteria protective of the Assessment Endpoint for inferring risks
- Be representative of the Assessment Endpoint (i.e., inclusive of risks to all species, populations, communities, or groups included in the assessment endpoint that are not directly measured)
- **Not** be threatened or endangered species. Direct investigations of toxicological relevance on T&E species are almost always prohibited by law, and always require special permitting for toxicological investigations. However, T&E species should be considered as Assessment Endpoints if present onsite and potentially exposed. In this case, proper surrogates can be chosen as Measurement Endpoint representatives for inference (e.g., using the Red-tailed Hawk to represent Bald Eagles). T&Es are should not be Assessment Endpoints if their presence is due to dispersing individuals found in uncharacteristic habitats or outside their natural range. These individuals are most often vagrants not likely to contribute to the gene pool of the population (e.g., birds found outside their range during or post migration).

Common Problems in Selecting Assessment Endpoints (USEPA 1998):

Several problem areas should be avoided. Do not select…

- Assessment Endpoints as goals (e.g., maintaining unspecified endemic populations)
- Assessment Endpoints that are vague (e.g., stream integrity rather than predatory fish abundance)
- Assessment Endpoints that evaluate a specific ecological entity:
  - These are often better used as a measurement endpoint (e.g., emergence of midges can be used to evaluate an assessment endpoint for fish feeding behavior)
  - May not be as sensitive to the stressor(s) of concern (e.g., catfish versus salmon for sedimentation)
  - Are not exposed to the stressor (e.g., using insectivorous birds for avian risk to pesticide seed application)
  - Are irrelevant to the assessment (e.g., evaluating detrimental effects to exotic species, feral animals, etc.)
- The importance of a species or attributes of an ecosystem that will not be fully considered (e.g., mussel-fish connection)
- Attributes that are not sufficiently sensitive for detecting important effects (e.g., mortality vs. behavior changes that may in turn reduce survivorship and reproduction)

When are Assessment and Measurement Endpoints Selected and Who Selects Them?

Assessment Endpoints are most useful when considered early in the ERA process, however they should not be specified for the Baseline ERA until after the Screening-level ERA has been completed. Screening ERAs should focus on representative foraging guilds[3] of species potentially on site, not necessarily species *per se*. Of course each foraging guild should be represented by a specific species that is expected to have a high degree of exposure (e.g., meadow voles as a foraging guild representative for the small mammalian herbivore foraging guild; Table 1). Consideration should include species with small home ranges,

[3] Foraging guilds are defined here as species that feed on the same types of foods, having a similar gastrointestinal system and similar in size.

relatively small body size (thus relatively large surface/body weight ratio), and generalists in foraging habits. Selection of the Assessment and Measurement Endpoints are then finalized after the Screening ERA is completed, when the Contaminants of Concern (COCs) have been identified for investigation in a Baseline ERA .

TABLE 1. EXAMPLES OF POTENTIAL FORAGING GUILDS

Listed below are examples of foraging guilds and representative species for birds and mammals:

Mammals		
	Small herbivore	Voles (*Microtis spp.*) Rabbits (Family: Leporidae)
	Small omnivore	Mice (*Peromyscus spp.*) Wood rats
	Med.-Large omnivore	Coyote, Raccoon, Fox
	Small carnivore	Shrews (*Sorex, Blarina spp.*), weasels (*Mustela spp.*)
	Large carnivore	Wolf
Birds		
	Granivore	Mourning Dove, American Goldfinch, Carolina Chickadee
	Invertivore	American Woodcock, flycatchers, wood warblers (Family: Emberizidae)
	Omnivore	American Robin, Wood Thrush, Baltimore Oriole
	Carnivore (tertiary consumer)	Cooper's Hawk, Red-tailed Hawk, American Kestrel

Assessment Endpoints are first identified by risk managers and risk assessors, preferably in conjunction with Installation Natural Resource Management personnel. However, involvement in the selection process by all stakeholders is key to the success of an ERA, but only species with a clearly defined route of exposure should be included. Site-specific information on species, communities, functions, exposure scenarios, and response sensitivities of the receptors should be considered (USEPA 1996). Often this information is best elicited from Installation Natural Resource Management Personnel, and their participation is strongly encouraged.

Often trustee and natural resource personnel involvement in choosing Assessment Endpoints are not available (e.g., FUDS, BRAC sites). In such cases, assessment endpoints should be chosen that could represent all potentially valued species. In this case, it is useful to first describe the potential foraging guilds (usually the same used for the screening ERA) that represent populations of species that may be exposed. Assessment Endpoints can then be chosen to represent native species that best represent those foraging guilds or populations. Measurement endpoints can then be tailored to evaluate those representative species.

OTHER CONSIDERATIONS

Choosing a highly exposed receptor to represent a habitat may help avoid questions for wide-ranging receptors where many Areas of Concern (AOC) are relatively nearby. Since toxicity data are often limited (thus are often used for the entire class of animals; e.g., mammals), only the exposure criteria would differ to characterize risk to wide-ranging receptors (e.g., Red-tailed Hawk or white-tailed deer). If a conservative exposure model was initially chosen to characterize each AOC, it would be logical that wide ranging species would be exposed less than species with smaller home ranges within the same foraging guild.

Additional consideration should be given to short (acute) vs. long-term (chronic) exposure scenarios and outcomes. Exposures may be experienced by receptors in acute scenarios (e.g., animals exposed for short periods of time); however, these exposure conditions are often incorrectly compared to chronic toxicity data. The reverse can also occur. Therefore, the exposure conditions should be equivalent to the most appropriate scenarios and toxicity values (e.g., TRVs).

Do not assume that mortality, growth and reproduction are the only toxicological endpoints of concern. Population regulating mechanisms and life history factors that are important to the populations of species at your site should be considered. Examples of population regulating mechanisms include exposures that cause immunotoxic effects, behavioral changes that influence predation rates or loss of libido. Important life history characteristics include seasonal specific diet shifts (common in invertivorous migratory birds) and systemic increases in contaminant concentrations from the metabolism of fat in hibernating mammals. In addition, contaminant-related ecological effects may influence current or proposed wildlife management plans. If this is a possibility, then Assessment and Measurement Endpoints should be designed to consider these management goals (USEPA 1999). Examples are presented below.

3. EXAMPLES OF A MANAGEMENT GOAL, ASSESSMENT ENDPOINT, AND MEASUREMENT ENDPOINTS:

GOAL: Sustain small mammal populations

ASSESSMENT ENDPOINT:

- Survival and reproduction of small rodent species

MEASURES OF EFFECTS:

- Analysis of adverse heath effects to adult male Meadow voles and White-footed mice
- Reproductive success of female Meadow voles and White-footed mice
- Density of Meadow voles and White-footed mice in a specified area (e.g., population structure; males versus females and juveniles versus adults)
- Small rodent species community analysis

MEASURES OF ECOSYSTEM AND RECEPTOR CHARACTERISTICS

- Quality and extent of small rodent habitat (e.g., vegetative cover, preferred habitat structure)
- Abundance and distribution of juvenile and adult food sources
- Presence of burrows and runways in appropriate habitat
- Environmental conditions (e.g., temperature, rainfall)

MEASURES OF EXPOSURE

- Chemical concentrations in soil and food items

GOAL: Sustain Eastern Bluebird populations

ASSESSMENT ENDPOINT:

- Eastern Bluebird breeding success and site fidelity

MEASURES OF EFFECTS:

- Nest surveys (number of fledglings/female/year)
- Breeding density estimates (Nest box surveys)
- Seasonal point counts
- Gross physiological analyses (fat accumulation, body condition, ectoparasites, etc.)

MEASURES OF ECOSYSTEM AND RECEPTOR CHARACTERISTICS

- Analysis of age structure and return rates
- Evaluation of nest cavities and competition
- Feeding, resting, and breeding behavior
- Direct soil toxicity to prey (e.g., soil invertebrates)

MEASURES OF EXPOSURE

- Chemical concentrations in food (e.g., crop contents of nestlings)
- Egg chemical burdens (e.g., organochlorines)

GOAL: Viable, self-sustaining brook trout population that supports a sport fishery

ASSESSMENT ENDPOINT:

- Brook trout abundance, breeding success, fry survival, and adult return rates

MEASURES OF EFFECTS:

- Egg and fry response to low dissolved oxygen
- Spawning behavior and egg survival with changes in sedimentation
- Number of brook trout in selected stream segments (juveniles versus adults)

MEASURES OF ECOSYSTEM AND RECEPTOR CHARACTERISTICS

- Water temperature, pH, water velocity, physical habitat
- Substrate types (suitable types for spawning)
- Abundance and distribution of juvenile and adult food sources
- Feeding, resting, and breeding behavior
- Natural reproduction, growth, and mortality rates

MEASURES OF EXPOSURE

- Chemical concentrations in water, sediment, and fish tissue
- Riparian cover, habitat, sediment loading, and water temperature
- Nutrient and dissolved oxygen content in ambient waters
- Number physical barriers to fish passage (e.g., beaver dams, manmade dams, etc.)
- Number of nonindigenous species (e.g., rainbow trout, brown trout)

4. RECOMMENDATIONS

These are just a few examples of how Managements Goals, Assessment and Measurement Endpoints, and various ecosystem measures can be made consistent and mutually-reinforcing. Whenever possible, Management Goals and objectives should be directly applied within the context of selecting Assessment and Measurement Endpoints, within the ERA process. It is recommended that Assessment Endpoints be selected that are consistent with the Management Goals of the installation (and Natural Resource Management Plan, if applicable), and that Measurement Endpoints be selected that can be reliable in assessing the risk at the site and be used to base a remedial decision.

Choosing appropriate Assessment and Measurement Endpoints is an integral part of the ERA process and provides risk assessors and risk managers with direction. When selected in accordance with key parties (i.e., decision makers, risk assessors, stakeholders), the ERA objectives become apparent and the ERA process proceeds more efficiently. However, it is recognized that often the input of key parties is not easily obtained. Therefore, Assessment Endpoints must be chosen that represent all potentially valued species onsite, using specific Measurement Endpoints that are protective of these species. It is also recommended that these be selected understanding the resource management goals at the installation of concern, habitat onsite, and the potential for exposure.

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evaluation and risk analysis techniques. Four Army organizations currently comprise the BTAG – USAEC, the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), the U.S. Army Corps of Engineers (USACE) Hazardous, Toxic and Radioactive Waste Center of Expertise (HTRW CX), USACE Engineer Research and Development Center (ERDC), and the U.S. Army Edgewood Chemical Biological Center (USAECBC). Technical Chairperson of the BTAG is Dr. Mark Johnson, USACHPPM. The authors of this document are Dr. Ronald T. Checkai, USAECBC, Dr. Mark S. Johnson, USACHPPM, and Ms. Melanie S. Hawkins, USACHPPM. Technical reviewers are Mr. Matt McAtee, USACHPPM and Ms. Lia M. Gaizick, USACHPPM. This Technical Document for Ecological Risk Assessment is a product of the U.S. Army Biological Technical Assistance Group (BTAG).