Standard Guide for Estimating Wildlife Exposure Using Measures of Habitat Quality[1]

This standard is issued under the fixed designation E2385; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Ecological Risk Assessments (EcoRAs) typically focus on valued wildlife populations. Regulatory authority for conducting EcoRAs derives from various federal laws [for example, Comprehensive Environmental Response, Compensation and Liability Act 1981, (CERCLA), Resource Conservation Recovery Act (RCRA), and Federal Insecticide, Fungicide, and Rodenticide Act, (FIFRA)]. Certain procedures for conducting EcoRAs (**1-4**)[2] have been standardized [E1689-95(2003) Standard Guide for Developing Conceptual Site Models for Contaminated Sites; E1848-96(2003) Standard Guide for Selecting and Using Ecological Endpoints for Contaminated Sites; E2020-99a Standard Guide for Data and Information Options for Conducting an Ecological Risk Assessment at Contaminated Sites; E2205/E2205M-02 Standard Guide for Risk-Based Corrective Action for Protection of Ecological resources; E1739-95(2002) Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites]. Specialized cases for reporting data have also been standardized [E1849-96(2002) Standard Guide for Fish and Wildlife Incident Monitoring and Reporting] as have sampling procedures to characterize vegetation [E1923-97(2003) Standard Guide for Sampling Terrestrial and Wetlands Vegetation].

1.2 Most states have enacted laws modeled after the federal acts and follow similar procedures. Typically, estimates of likely exposure levels to constituents of potential concern (CoPC) are compared to toxicity benchmark values or concentration-response profiles to establish the magnitude of risk posed by the CoPC and to inform risk managers considering potential mitigation/remediation options. The likelihood of exposure is influenced greatly by the foraging behavior and residence time of the animals of interest in the areas containing significant concentrations of the CoPC. Foraging behavior and residence time of the animals are related to landscape features (vegetation and physiognomy) that comprise suitable habitat for the species. This guide presents a framework for incorporating habitat quality into the calculation of exposure levels for use in EcoRAs.

1.3 This guide is intended only as a framework for using measures of habitat quality in species specific habitat suitability models to assist with the calculation of exposure levels in EcoRA. Information from published Habitat Suitability Index (HSI) models (**5**) is used in this guide. The user should become familiar with the strengths and limitations of any particular HSI model used in order to characterize uncertainty in the exposure assessment (**5-7**). For species that do not have published habitat suitability models, the user may elect to develop broad categorical descriptions of habitat quality for use in estimating exposure.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E1689 Guide for Developing Conceptual Site Models for Contaminated Sites
E1739 Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites
E1848 Guide for Selecting and Using Ecological Endpoints for Contaminated Sites
E1849 Guide for Fish and Wildlife Incident Monitoring and Reporting
E1923 Guide for Sampling Terrestrial and Wetlands Vegetation (Withdrawn 2013)[4]
E2020 Guide for Data and Information Options for Conducting an Ecological Risk Assessment at Contaminated Sites
E2205/E2205M Guide for Risk-Based Corrective Action for Protection of Ecological Resources

3. Terminology

3.1 The words "must," "should," "may," "can," and "might" have specific meanings in this guide. "Must" is used to express

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[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.47 on Biological Effects and Environmental Fate.

Current edition approved Feb. 1, 2016. Published May 2016. Originally approved in 2004. Last previous edition approved in 2011 as E2385–11. DOI: 10.1520/E2385-11R16.

[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

an absolute requirement, that is, to state that the test ought to be designed to satisfy the specified condition, unless the purpose of the test requires a different design. "Should" is used to state that the specified condition is recommended and ought to be met if possible. Although violation of one "should" is rarely a serious matter, violation of several will often render the results questionable. "May" is used to mean "is (are) allowed to," "can" is used to mean "is (are) able to," and "might" is used to mean "could be possible." Thus, the distinction between "may" and "can" is preserved, and "might" is never used as a synonym for either "may" or "can."

3.2 Consistent use of terminology is essential for any vegetation sampling effort. below is a list of terms that are used in this guide, as well as others that may be encountered commonly in the wildlife habitat quality literature. this list is not exhaustive.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *abundance*—the number of individuals of one taxon in an area; equivalent to the term density as used in botanical literature.

3.3.2 *basal area (BA)*—the cross-sectional area of a tree trunk at 1.4 m (4.5 ft) above ground. (See *diameter at breast height*.)

3.3.3 *biomass*—the mass of vegetation per unit area.

3.3.4 *canopy*—the uppermost layer, consisting of branches and leaves of trees and shrubs, in a forest or woodland.

3.3.5 *carrying capacity*—the theoretical density of organisms that can be supported in a specified ecological system.

3.3.6 *cover*—the area of ground covered by plants of one or more taxa.

3.3.7 *density*—the number of organisms in a specified area.

3.3.8 *diameter at breast height (DBH)*—the widest point of a tree trunk measured 1.4 m (4.5 ft) above the ground.

3.3.9 *foraging-range*—the area typically explored by an animal while it is feeding. (See *home-range*.)

3.3.10 *forb*—a non-graminoid (that is, broadleaf) herbaceous plant.

3.3.11 *geographic information system (GIS)*—an integrated spatial data base and mapping system in which geographical information can be used to produce digital maps, manipulate spatial data, and model spatial information. It allows the overlay of layers of information, such as habitats or plant ranges.

3.3.12 *global positioning system (GPS)*—a survey system in which a GPS unit is used to receive signals from satellites. Signals are then interpreted to provide information such as latitude and longitude or bearings for navigation, positioning, or mapping.

3.3.13 *graminoid*—a grass (Poaceae), sedge (Cyperaceae), or rush (Juncaceae).

3.3.14 *habitat*—the collection of biological, chemical, and physical features of a landscape that provide conditions for an organism to live and reproduce.

3.3.15 *habitat suitability index*—a calculated value that characterizes a specified landscape unit (for example, a polygon) in terms of the features and conditions that are favorable for a particular species. Values range between 0.0 (unsuitable) and 1.0 (ideal).

3.3.16 *herb*—a plant with one or more stems that die back to the ground each year; (that is, graminoids and forbs).

3.3.17 *home-range*—the area around an animal's established home, which is traversed in normal activities. (See *foraging-range*.)

3.3.18 *physiognomy*—the surface features of an area.

3.3.19 *population*—a group of individuals of the same species occupying a habitat small enough to permit interbreeding.

3.3.20 *remote sensing*—the use of satellites or high-altitude photography to measure geographic patterns such as vegetation.

3.3.21 *shrub*—woody plant typically smaller than a tree when both are mature (typically with DBH < 10 cm), often with multiple main stems from the base. Should be defined specifically at start of project.

3.3.22 *tree*—woody plant with a single main stem from the base, typically > 2 to 3 m tall when mature (typically DBH > 10 cm). The operational definition should be stated explicitly for each project.

4. Habitat Approaches

4.1 Naturalists and wildlife managers have understood, at least in qualitative terms, the importance of critical habitat for various life history stages (for example, nesting sites, winter range, etc.). Animals are drawn to suitable physical structure and food availability, while avoiding areas of lower quality. The term habitat, though often used loosely as an indication of environmental quality, refers to the combination of physical and biological features preferred by a particular species. Habitat that is great for prairie chicken is unacceptable for barred owls. Different habitat preferences reflect evolution and adaptation of species separating from each other in "*n*-dimensional niche space" (**8**). There are differential area use rates by different species. Animals are drawn to particular features of the landscape for foraging, loafing, nesting/birthing, etc. Some species are attracted to disturbance zones and edges, but others avoid such areas.

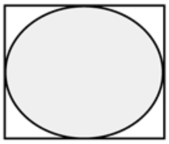
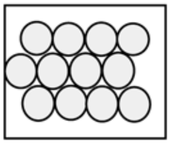
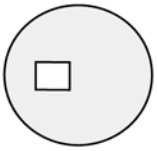
4.2 Habitat Suitability Index (HSI) Models have been developed for many species of interest. Characterization of habitat for certain species was formalized by the U.S. Fish and Wildlife Service in the 1990s (**9**). Currently, more than 160 HSI models have been published, though usage is limited for quantitative predictions of population densities (**6**). Rand and Newman (**10**) describe the applicability of HSI models for EcoRA in general terms, but provide no examples of its use and do not give specific details to integrate habitat information with exposure assessment or risk characterization. Freshman and Menzie (**11**) describe two approaches to take into account spatial differences in contaminant concentrations with respect to foraging activities and the proportion of a local population likely to be exposed to the contaminants. Their approach does not incorporate HSI models formally, but does demonstrate the fundamental concepts for such use. Hope (**12-14**), Wickwire et al. (**15**), Linkov et al. (**16, 17**) and Linkov and Grebenkov (**18**) have used placeholder habitat values to illustrate the effect of habitat on cumulative exposure levels. Kapustka et al. (**5, 19**) and Linkov et al. (**20**) have described procedures to use HSIs as the habitat quality parameter for use in estimating exposure levels. The U.S. EPA Office of Solid Waste conducted an exploratory program in which they characterized vegetation types and physical features within a 2-km radius of more than 200 chemically contaminated sites. The focus was on using habitat characteristics to modify estimates of risk. Landscape relationships were used to incorporate ecological dynamics into risk assessments by another group within the U.S. EPA. The Program to Assist in Tracking Critical Habitat (PATCH) model used a GIS platform that allows user input in defining polygons and their characteristics (**21**); www.epa.gov/wed/pages/models.htm). This program has been incorporated into HexSim(**22**). The Army Risk Assessment Modeling System (ARAMS) (www.wes.army.mil/el/arams/arams.html) developed modules that use habitat quality assessments to improve the realism of exposure assessments. Loos et al. (**23**) developed a receptor-oriented cumulative exposure model (Eco-SpaCE) for wildlife species that includes relevant ecological processes such as spatial habitat variation, food web relations, predation, and life history characteristics. Johnson et al. (**24**) found that a spatially explicit exposure model based on the general procedures outlined in this Standard provided good agreement with field observations and therefore produced more accurate risk estimates than conventional deterministic approaches. Loos et al. (**25**) provided a comparative review of approaches used to model exposures experienced by humans and wildlife. Wickwire et al. (**26**) discussed the rationale for using spatially explicit exposure models and also describe some of the impediments that may be deterring a broader use of such approaches.

5. Identifying Scenarios where Habitat Value can be Important in EcoRAs

5.1 Heterogeneous landscapes coupled with heterogeneous distribution of contaminants introduce great uncertainty in exposure estimates for any species (Fig. 1). In such situations, the relative size of the site to the home range of the species does not matter. Two other cases occur in which habitat modifications of exposure estimates would reduce uncertainty; one in which contaminant distribution is heterogeneous and home range is small relative to the area of the site, the other in which habitat is heterogeneous and the home range is very large relative to the contaminated area. The combination of homogeneous habitat and homogeneous contaminant distribution precludes using habitat conditions as a modifier of exposure regardless of the home range to site area relationship. Homogeneous contaminant distribution also makes habitat conditions moot for species with home ranges equal to or less than the site. Finally, with homogeneous habitat conditions, exposure estimates for species having home ranges equal to or larger than the contaminated area would not be improved.

6. Significance and Use

6.1 Explicit consideration of landscape features to characterize the quality of habitat for assessment species can enhance the ecological relevance of an EcoRA. This can help avoid assessing exposure in areas in which a wildlife species would be absent because of a lack of habitat or to bound exposure estimates in areas with low habitat quality. The measure of

Spatial relationship habitat agent	**homogeneous homogeneous**	**homogeneous heterogeneous**	**heterogeneous heterogeneous**	**heterogeneous homogeneous**
	O	O	+	O
	O	+	+	O
	O	O	+	+

Cases where habitat characterization may be useful in reducing uncertainty of exposure estimates (+) and cases where habitat considerations may be moot (O). Adapted from Kapustka et al., 2001, (**5**).

FIG. 1 Contingency Table Illustrating Relationships of Home Range (Circle) Relative to Site Size (Square).

habitat quality is used in place of the commonly used Area Use Factor (AUF). Greater ecological realism and more informed management decisions can be realized through better use of landscape features to characterize sites.

7. Interference

7.1 Observed population density in field tests often is lower than expected based on HSI values (**6**). Such information can be interpreted as a deficiency. However, it can also be that expectations of precision are too great and beyond the capability of the model (**7**). HSI model predictions should be viewed as an indication of potential carrying capacity generalized over time, rather than a static predictor of population density, and then the models can be useful. An environmental factor governs the maximum response attainable by an organism; at any interval along a parameter gradient, other variables may curtail attainment of the potential. In statistical descriptions, the relationship can be characterized as having increasing variance as the quality of habitat increases. If applied to wildlife populations, limiting factors such as food supply, predation, or human disturbance may override the apparent quality of habitat for the species of interest. Thus in low habitat quality areas, the observed populations are near zero; but in higher quality habitat areas, observed populations may range from near zero to some predicted maximum.

7.2 Metabolic energy requirements may result in animals in poor-quality habitats to forage longer and consume more food to obtain basal metabolic needs (**13**). Caution should be exercised when interpreting results, especially for individuals confined entirely within contaminated areas.

7.3 If site data are evaluated as part of a calibration step, caution should be exercised when interpreting results as individuals may move some distance away from the area in which they received a particular exposure (**13**).

8. Sampling Design

8.1 Typically, site-specific information is required to quantify variables used in calculating indices of habitat quality. The Principal Investigator has the responsibility to design a sampling plan that will yield sufficient information, governed by project specific data quality objectives [ASTM E1923-97(2003) Standard Guide for Sampling Terrestrial and Wetlands Vegetation; (**27, 28**)]. Information needs are dictated by the selection of assessment species and the respective habitat quality models.

8.2 Precision is, in essence, the repeatability of a measurement. Precision is seldom possible without repeating a study exactly, which is rarely feasible or possible for field studies. Bias occurs when samples are not representative of the landscape being sampled. Bias can occur when a sampling scheme is purposely, or inadvertently, designed to measure only certain parts of a landscape (when a complete representation is desired), or when sampling units are chosen to yield certain results. Sampling is most susceptible to bias in the sampling design, where plot or point placement determines what landscape feature is sampled. Randomization of sampling locations will eliminate much bias, but choice of statistical methods and sampling units should also be examined for bias.

9. Calibration and Standardization

9.1 Though useful information may be obtained from direct application of habitat quality index models, added value may result from calibration of model parameters to population density data generated at or near the project area during recent times (within a period that generally reflects current ecological conditions).

10. Procedure

10.1 *Overview:*

10.1.1 The U.S. EPA (**1, 3**) described an overall process for the performance of EcoRAs. Specifically it provides a framework for incorporating habitat quality characteristics into exposure and effects calculations; however, it proposed no specific methods for doing so. This guide describes the steps within the three stages (problem formulation, analysis, and characterization) of the U.S. EPA EcoRA process. The procedures that follow describe the steps to incorporate landscape features into the environmental management process. Specifically, an iterative approach is recommended to guide selection of appropriate assessment species, keyed to wildlife distribution ranges, and to a database of habitat suitability models. The choice of assessment species is cross-linked with the EPA exposure handbook species (**2**). Data collection needs for reconnaissance-, screening- and definitive-level characterization of habitat quality for potential assessment species are dictated by the project specific sampling and analysis plan that would be used to generate spatially explicit descriptions of habitat quality for various assessment species. Finally, calculations are presented that allocate exposure estimates using both habitat quality and spatial variations in chemical concentration or intensity of other agents (for example, magnitude of biological or physical stressor impinging on the assessment species).

10.1.2 Habitat considerations can be incorporated into the U.S. EPA Framework (**1**) for EcoRAs and the 8-step guidance (**3**) for conducting risk assessments at superfund sites (**5**). Ecological risk assessments should be performed only in those cases where ecological receptors occur or would likely occur, but for the influence of one or more agents (Fig. 2). A simple reconnaissance of the project area by qualified persons should be conducted at the earliest stages of a project in order to ascertain the actual or potential occurrence of ecological receptors. If receptors are not present or would not likely occur (for example, an asphalt parking area in an urban/industrial zone), then it would be impractical to proceed with an EcoRA.

10.2 *Problem Formulation Phase:*

10.2.1 The key goals of problem formulation are to outline the potential problem and develop a plan for analyzing and characterizing risk. Three interdependent products of problem formulation are the identification of assessment species, identification of assessment endpoints, and construction of the conceptual model of the site (**3**). The EPA framework can be expanded to incorporate species-specific habitat quality into the iterative steps used in problem formulation. Selection of contaminants of concern and developing an analysis plan are not affected by the inclusion of habitat considerations in the process.

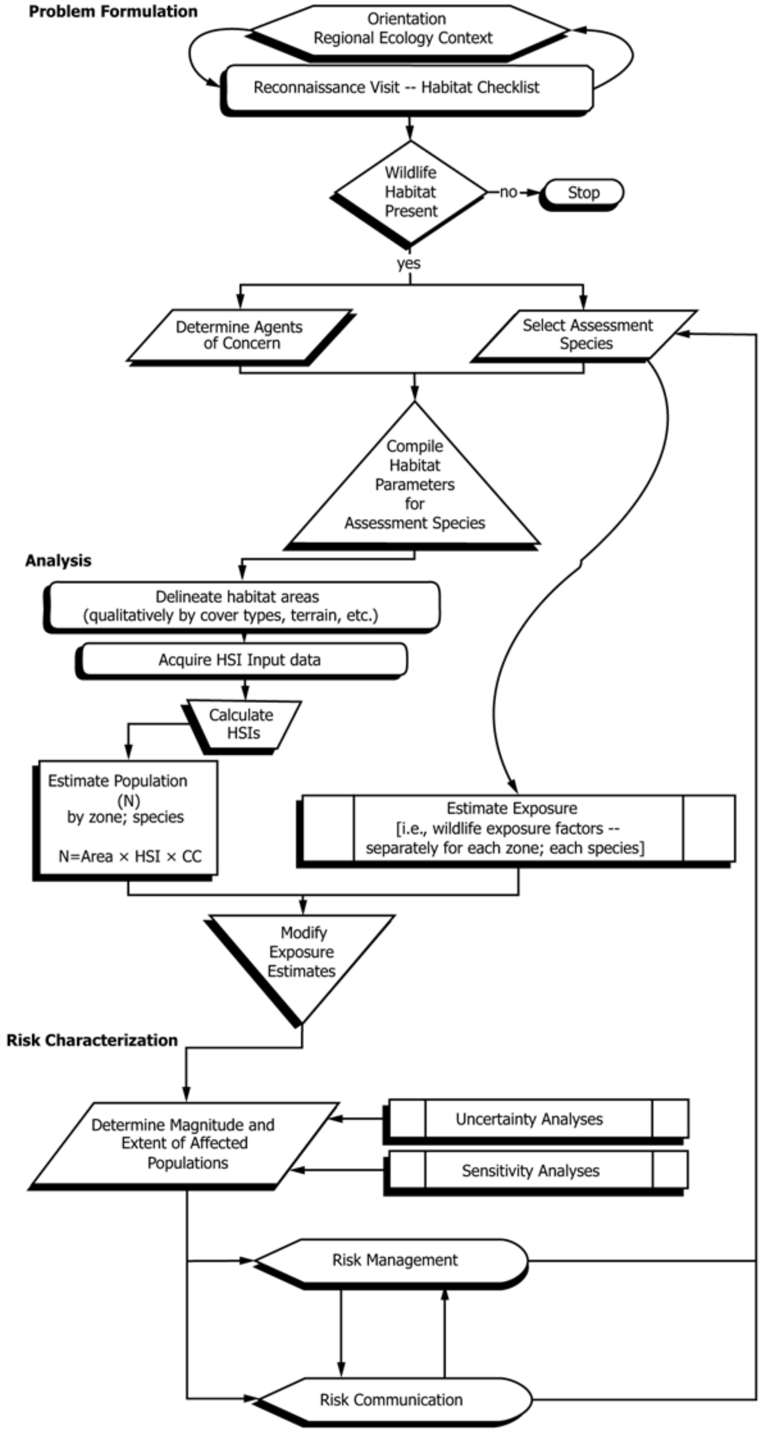


FIG. 2 Process Flow-Diagram Illustrating the Places Where Habitat Considerations can be Used in the Ecological Risk Assessment Framework (CC=carrying capacity)

10.2.2 *Landscape Mapping:*

10.2.2.1 Early in problem formulation, landscape cover types should be identified and mapped. Also, other features critical to particular wildlife use patterns that can affect ecological resources, such as areas subject to human activities, should be noted. Mapping creates a picture of the site that is critical to determining the interaction of the stressors with the receptors, and such relationships are used in computing habitat suitability for many species. Even very coarse resolution landscape maps can be informative as to whether a risk assessment is even necessary. For example, if no suitable habitat exists at the site (for example, if the site is entirely paved), an EcoRA may not be warranted. Mapping unit resolution should be considered carefully, as it has consequences for subsequent decisions in the EcoRA process. Apparent homogeneity of the landscape, spatial extent of stressors of interest, potential home-range/foraging range of wildlife species, and cost are important factors in defining the appropriate mapping unit resolution.

10.2.3 *Ecological Context of the Site:*

10.2.3.1 Readily available information about the site and its surrounding's ecological characteristics should be compiled. This may include information on geomorphology, potential natural vegetation, fauna, climate, surface water characteristics, disturbance regime, and land uses. There are two reasons for gathering this information. The first, in conjunction with the habitat map, is to identify a suite of species from which appropriate assessment species may be selected. The second is to aid in developing the site conceptual model by identifying the likely spatial and temporal patterns of use of the site by organisms, and identify and evaluate potential exposure pathways. Species lists from publications, reports, or interviews with local experts should be compiled.

10.2.3.2 Information from the mapping and data compilation steps may be compiled in an environmental checklist. Key questions that may be addressed by the checklist include:

(1) What is the environmental setting; including natural areas (for example, upland forest, on-site stream, nearby wildlife refuge) as well as disturbed/man-made areas (for example, waste lagoons)?

(2) What are the on- and off-site land uses (for example, industrial, residential, or undeveloped; current and future)? What type of facility existed or exists at the site?

(3) What are the suspected agents at the site?

(4) Which habitats present on site potentially are affected by biological agents, chemicals, or otherwise disturbed?

(5) Have biological agents or chemicals migrated from source areas and resulted in "off-site" impacts or the threat of impacts in addition to on-site threats or impacts?

(6) What species that are likely or known to be present on the site might comprise suitable assessment species?

10.2.4 *Selection of Assessment Species:*

10.2.4.1 The suite of species used for the EcoRA ultimately must be assessable; that is data must be available to calculate or to infer exposure to and effects of stressors. Frequently, surrogate species are used to represent broadly defined groups of potentially important species defined primarily by trophic levels (that is, a mammalian herbivore, an avian insectivore, or a top carnivore). The ecological relevance of the species used in the assessment is frequently a contentious point of debate. But monetary constraints typically limit the opportunities to perform the assessment anew using more relevant species. If a broader suite of species were considered as assessment species at the outset, such arguments could be avoided. To do so requires a structured approach that considers all potential species at a site and documents in the administrative record the rationale for narrowing the list to a manageable number.

10.2.4.2 The central premise of our approach is that the highest quality EcoRAs are those that focus on assessment species for which both wildlife habitat requirements/preferences and exposure parameters (dietary preferences, feeding rates, metabolic rates, etc.) are known. To achieve a high quality EcoRA using species for which such information is missing requires considerable commitment of time and money in order to obtain the requisite data. High profile sites (that is, sites of great interest to the public or with societal importance) may warrant the expenditures to gather the information. However, for most sites collection of basic biological or ecological data is beyond consideration. In such situations, a transparent process could facilitate communication among stakeholders and improve acceptance of the risk assessment.

10.2.4.3 A prioritized list of potential assessment species relevant to a particular site should be developed from a comprehensive wildlife species list compiled from prior knowledge of the site. Priority might be given to species according to their perceived societal value, availability of relevant descriptions of habitat requirements for the species in the project area, and information regarding exposure parameters. Criteria also may include trophic position within the food web to reflect appropriate exposure considerations for the agent of concern. The list of potential assessment species determine which landscape features should be evaluated in order to characterize habitat quality. Once the candidate assessment species have been identified, the habitat models can be used to develop the sampling plan.

10.2.4.4 Habitat Suitability Index (HSIs) models provide one means of characterizing habitat quality. The majority of the variables used in terrestrial and wetland HSI models are routine measurements of vegetation or other landscape-level features (**5**, **19**). These include parameters such as percentage canopy cover, distance between cover types (for example, forest edge to water; forest patch to forest patch), or other features that can be acquired from aerial imagery. Other variables require on-site determination, such as height of shrub canopy, percentage herbaceous cover under a forest canopy, size-class distribution of trees, etc. Still others require detailed quantification of plant community structure variables, such as the number of nesting cavities in large trees. Alternative measures of habitat quality maybe used; to do so, simply substitute the HSI values with the values from the alternative method throughout the rest of this Standard Guide.

10.2.4.5 Examination of particular HSI equations also reveals differences in sensitivities of the variables. Qualitative sensitivity features of the models have been coded in a comment field in the database. For scoping- or screening-level assessments, estimates of variables that are particularly difficult to quantify can provide a rapid, preliminary indication of the importance of gathering particular data. By examining the list of variables, the preferred and alternative methods that may be used to generate the required data, and reviewing the sensitivity of the variables, those variables that can be satisfied using aerial images, routine on-site survey methods, and specialized or detailed on-site survey procedures can be rapidly identified. It then is a relatively straightforward process to devise a progressive sampling plan from reconnaissance-level through definitive-level EcoRAs consistent with E1923-97(2003) Standard Guide for Sampling Terrestrial and Wetlands Vegetation. The plan can be structured to maximize the number of models satisfied with different levels of sampling effort. Such a plan can also be used to produce a financial risk assessment for a project, (that is, what are the benefits of obtaining all the information at once versus deferring certain data collection procedures into later stages of risk assessment).

10.3 *Analysis Phase:*

10.3.1 The overall objectives of this phase of the EcoRA process are to estimate exposure and characterize potential stressor effects to the assessment species. Minor modifications of the EcoRA process **(3)** are appropriate to incorporate habitat characterization that can be used to modify the exposure estimates (Fig. 2). In particular, the measure of habitat quality is substituted for the commonly used AUF as shown in 10.4.

10.3.2 There are structural differences among HSI models that are dictated by species' foraging preferences and ranges. Some species key on several cover types (for example, requiring a mixture of forest, shrubland, grasslands, or agricultural fields) to provide shelter and food; other species tend to use the interior portions of individual patches or cover types. Calculation of the HSI for some species can be done on each habitat polygon delineated over a site (Fig. 3). Calculations of HSIs for other species may circumscribe several polygons. The panel in the upper left shows HSIs for each polygon; a stylized chemical plume is shown as an overlay in the upper right panel; and the delineation of habitat-chemical polygons with labels (a1, a2, etc) in the lower right panel indicate subdivisions of polygons for which localized risk estimates would be calculated. These steps would be repeated for each assessment species and the cumulative risk values for each polygon would reflect the localized levels of risk; an area-weighted site-wide risk value could also be obtained.

10.3.3 *Situation A*—For species with relatively small home ranges; estimating the numbers of animals in each habitat subdivision.

10.3.3.1 The number of animals likely to use an area is a function of their social organization, their territory or home range sizes, and the quality of the habitat. For any species, the density of individuals will vary across a site depending on the spatial variation in habitat quality, with higher densities (with smaller home ranges) inhabiting areas of higher habitat quality. The number of individuals of a given species that are likely to inhabit any habitat subdivision can be approximated using the area of the subdivision, the HSI score for that subdivision, and information on either the range of the animals' density or home range sizes, as illustrated in the following equations.

For use with home range data:

$$N_s = \frac{A_s}{HR_s} \tag{1}$$

For use with density data:

$$N_s = A_s \times CC_s \tag{2}$$

where:

N_s = the number of individuals likely to inhabit the subdivision,

A_s = the area of the subdivision,

HR_s = the approximate home range size of the animals within the subdivision, and

CC_s = the approximate carrying capacity of the subdivision where carrying capacity is an expected density estimate.

HR_s in this equation is a function of the HSI score for the subdivision and information from the literature on the approximate range of sizes of home ranges used by the species. We assume that animals that inhabit areas of medium quality habitat (scoring about 0.5 on the HSI scale) will have home ranges and densities that approximate the central tendency. Conversely, areas that score closer to the two extremes (0.0 and 1.0) will have home ranges and densities that are closer to the minimum and maximum, respectively.

10.3.4 *Situation B*—For species with relatively large home ranges; estimating the proportion of time animals would spend in each area of contamination.

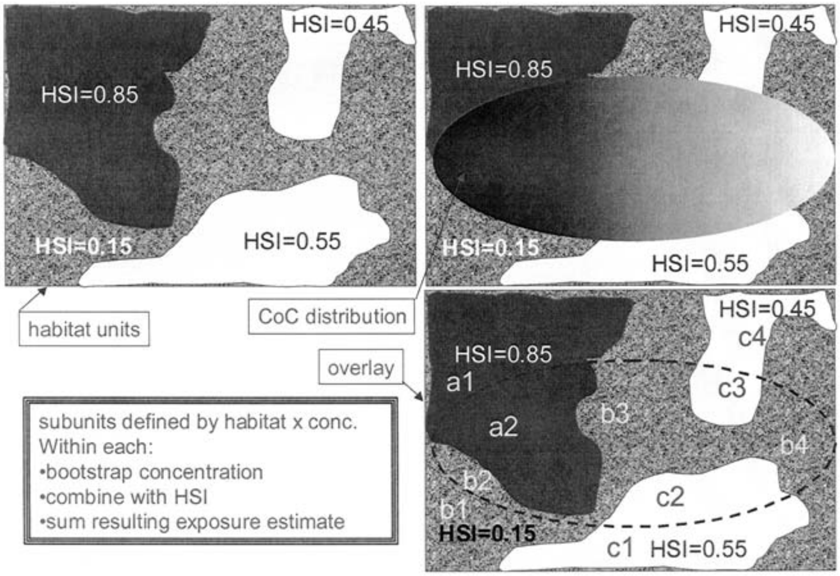


FIG. 3 Simplified Polygon Layout to Illustrate Application of Habitat Quality Indices to Characterize Differential Exposure Relationships Across a Landscape

10.3.4.1 The proportion of its time that a wide-ranging organism is likely to spend on a site will be a function of the size of the site relative to its home range requirements, the quality of the habitat on the site relative to its surroundings, and the rate at which habitat quality may change through time.

10.3.4.2 If the contaminated site's habitat quality is approximately equal to that of the site surroundings, the proportion of its time that an animal will spend on the site can be estimated using a simple proportion calculation (if the site is roughly 25 % of the animals home range, then it will spend approximately 25 % of its time there and get 25 % of its diet (or accidental ingestion) there.

10.3.4.3 If the habitat on the site is of lower or higher quality than the surroundings, the animal is likely to spend proportionally less or more of its time there. However, the relationship between habitat quality and use in a wide-ranging organism is unlikely to be linear. No matter how good the habitat on the site is, it is unlikely that the organism will be able to obtain all its life-history requirements there – it will be predisposed to spend some of its time in the surroundings. Also, an efficient organism living in an area of temporally varying habitat will probably want to track shifts in habitat quality, and thus visit all parts of its home range, at least intermittently.

10.3.4.4 Once again, this time allocation may be estimated using HSI scores, except that on this occasion we require an HSI score that represents the habitat quality in the areas that the organism may use off-site. By comparing the size of the site relative to the animals' home range and the habitat quality on- and off-site or within any subdivision of the site, we can approximate time allocation, as illustrated in Eq 3.

$$P_s = \frac{\dfrac{A_s}{HR_s}}{\sum_{s=1}^{n}\left(\dfrac{A_s}{HR_s}\right)} \tag{3}$$

where:

P_s = proportion of time spent foraging in sub-area s,
A_s = area of sub-area s, and
HR_s = home range size associated with habitat quality in sub-area s.

10.3.4.5 As in Eq 1, HR_s in this equation is a function of the HSI score for the subdivision and information from the literature on the approximate range of sizes of home ranges used by the species. We assume that animals that inhabit areas of medium quality habitat (scoring about 0.5 on the HSI scale will have home ranges that approximate the central tendency of home range sizes reported in the literature. Conversely, areas that score closer to the two extremes (0.0 and 1.0) will have home ranges that are closer to the minimum and maximum, respectively.

10.4 *Risk Characterization Phase:*

10.4.1 As in the analysis phase, risk characterization calculations also differ according the relative size of home ranges of the assessment species and contaminated areas. The two alternative approaches follow.

10.4.2 *Determining Risk for Species Relatively Small Home Ranges:*

10.4.2.1 Once the density of animals in each habitat subdivision is determined, the proportion of the site population exposed at contaminant concentrations higher than acceptable levels can be easily determined. The appropriate contaminant concentration in each habitat subdivision is input into individual based wildlife exposure models (**5**) to characterize exposure in each habitat subdivision. The proportion of the population at risk is then determined by summing the number of individuals in sub-areas where exposure is above an acceptable threshold, then dividing this number by the total number of individuals in all sub-areas.

10.4.3 *Estimating Exposure to Organisms with Relatively Large Home Ranges:*

10.4.3.1 An HSI is a numerical index that represents the capacity of a given habitat to support a selected fish or wildlife species. For habitat evaluation, the value of interest is an estimate or measure of habitat condition in the study area, and the standard of comparison is the optimum habitat condition for the same evaluation species. Therefore HSI = (Study Area Habitat Conditions)/(Optimum Habitat Conditions). The HSI has a minimum value of 0.0, which represents unsuitable habitat, and a maximum value of 1.0, which represents optimal habitat. An HSI model produces an index value between 0.0 and 1.0, with the assumption that there is a relationship between the HSI value and carrying capacity. HSI models can be used in cases where the required output is either a measure of the probability of use of an area by individuals or by a population. In applying HSIs to exposure assessment for animals with exclusive or non-exclusive home ranges larger than the contaminated site, HSI output should be viewed as a measure of the probability of an individual using a given subsection of its home range. For this type of application, output from the HSI model can be used to estimate the proportion of its time that an individual will spend exploiting a given area within its home range. For organisms with home ranges smaller than the contaminated area, the HSI of a section of the site may be treated as a surrogate for carrying capacity or population density. For organisms with large home ranges the proportion of time that the organism spends on the site is incorporated as an Area Use Factor (AUF) in the dietary exposure equation as follows:

$$ADD_{pot} = \sum_{s=1}^{m} P_s \left[\sum_{j=1}^{n}\left(C_{js} \times FR_{js} \times NIR_j\right) + \left(D_s \times FS \times FIR_{total}\right)\right] \tag{4}$$

where:

ADD_{pot} = potential average daily dose,
P_s = AUF; the proportion of time spent foraging in sub-area s (Eq 2),
C_{js} = average concentration of contaminant in food type j in sub-area s,
FR_{js} = fraction of food type j contaminated in sub-area s,
NIR_j = normalized ingestion rate of food type j,
D_s = average contaminant concentration in soils in sub-area s,
NIR_{total} = normalized ingestion rate summed over all foods, and
FS = fraction of soil in diet.

10.4.3.2 The AUF is incorporated as illustrated in Eq 5.

$$ADD_{pot} = \sum_{s=1}^{m} P_s \left[\sum_{j=1}^{n} (C_{js} \times FR_{js} \times NIR_j) + (D_s \times FS \times FIR_{total}) \right] \quad (5)$$

where:

P_s = AUF; the proportion of time spent foraging in sub-area s (Eq 3),
C_{js} = average concentration of contaminant in food type j in sub-area s,
FR_{js} = fraction of food type j contaminated in sub-area s, and
D_s = average contaminant concentration in soils in sub-area s.

11. Reporting

11.1 Because the explicit use of habitat quality measures in EcoRAs is relatively new, the Principal Investigator may wish to present a comparison of the risk assessments with and without consideration of habitat-modified exposure estimates.

12. Keywords

12.1 exposure assessment; habitat quality; habitat quality indices; landscape ecology

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