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Investigating habitat value to inform contaminant remediation options: Case study ☆

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Abstract

Habitat valuation methods were implemented to support remedial decisions for aquatic and terrestrial contaminated sites at the East Tennessee Technology Park (ETTP) on the US Department of Energy (DOE) Oak Ridge Reservation in Oak Ridge, TN, USA. The habitat valuation was undertaken for six contaminated sites: Contractor's Spoil Area, K-901-N Disposal Area, K-770 Scrapyard, K-1007-P1 pond, K-901 pond, and the Mitchell Branch stream. Four of these sites are within the industrial use area of ETTP and two are in the Black Oak Ridge Conservation Easement. These sites represent terrestrial and aquatic habitat for vertebrates, terrestrial habitat for plants, and aquatic habitat for benthic invertebrates. Current and potential future, no-action (no remediation) scenarios were evaluated primarily using existing information. Valuation metrics and scoring criteria were developed in a companion paper, this volume. The habitat valuation consists of extensive narratives, as well as scores for aspects of site use value, site rarity, and use value added from spatial context. Metrics for habitat value were expressed with respect to different spatial scales, depending on data availability. There was significant variation in habitat value among the six sites, among measures for different taxa at a single site, between measures of use and rarity at a single site, and among measures for particular taxa at a single site with respect to different spatial scales. Most sites had aspects of low, medium, and high habitat value. Few high scores for current use value were given. These include: wetland plant communities at all aquatic sites, Lepomid sunfish and waterbirds at 1007-P1 pond, and Lepomid sunfish and amphibians at K-901 pond. Aquatic sites create a high-value ecological corridor for waterbirds, and the Contractor's Spoil Area and possibly the K-901-N Disposal Site have areas that are part of a strong terrestrial ecological corridor. The only example of recent observations of rare species at these sites is the gray bat observed at the K-1007-P1 pond. Some aspects of habitat value are expected to improve under no-action scenarios at a few of the sites. Methods are applicable to other contaminated sites where sufficient ecological data are available for the site and region.

Keywords: Habitat; Habitat quality; Ecological valuation; Remediation; Contaminated site; DOE

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1. Introduction

Ecological risk assessments may not typically contain enough information on habitat value to inform contaminant remedial decision-making based on ecological risk. This is especially true for sites with extensive ecological resources, such as the US Department of Energy's (DOE) Oak Ridge Reservation in East Tennessee, USA (Dale and Parr, 1998; Mann et al., 1996), and other DOE sites (Burger et al., 2003). Methods are needed to assess habitat value for candidate aquatic and terrestrial sites for remediation. Researchers have suggested that ecological risk assessments include detailed information on habitat value in the problem formulation stage (Kapustka et al., 2001). These data might include maps of land cover types, wildlife use patterns, land use, geomorphology, potential natural vegetation, surface water characteristics, disturbance regime, and other factors (Kapustka et al., 2001). Some regulatory agencies have indicated that information on habitat quality can be utilized with ecological risk assessments within remedial investigation reports to inform or to guide remedial decisions (S. Thoms, USEPA Region 4, pers. comm.. 9/2006; S. Alexander, US Fish & Wildlife Service, Tennessee Ecological Services Field Office, pers. comm.. 9/2006; Luftig, 1999). Researchers have previously recommended the use of additional ecological information for evaluating future long-term stewardship options (e.g., land use alternatives) as well as ecological risk assessments at DOE sites (Burger et al., 2003; Greenberg et al., 2003).

In a habitat valuation study that is summarized in a companion paper, we developed methods for valuing habitat for groups of species at contaminated sites (Efroymson et al., 2005; Efroymson et al., this issue). These methods are ecological rather than monetary. The methods were developed to inform remedial decision-making for six representative aquatic and terrestrial contaminated sites at the East Tennessee Technology Park (ETTP) on the DOE Oak Ridge Reservation (ORR) in East Tennessee. ETTP was formerly known as the K25 site. This paper summarizes the case study that was performed to implement the habitat valuation methods in Efroymson et al. (this issue).

The habitat valuation was performed for six remedial sites, three terrestrial and three aquatic: Contractor's Spoil Area, K-901-N Disposal Area, K-770 Scrapyard, K-1007-P1 pond, K-901 pond, and the Mitchell Branch stream (Fig. 1). Four of these sites are within the industrial use area of ETTP, and two, the Contractor's Spoil Area and the K-901-N Disposal Area, are in the Black Oak Ridge Conservation Easement. These sites represent terrestrial and aquatic habitats for vertebrates, terrestrial habitat for plants, and aquatic habitat for benthic invertebrates. Although this study is focused on specific sites, the habitat value results for terrestrial sites might be similar to those found at other frequently mowed, fescue-covered waste disposal areas (Contractor's Spoil Area), less frequently mowed waste disposal areas in powerline rights-of-way (K-901-N disposal area), highly industrialized areas (K-770 scrapyard), and water bodies in contaminated areas. The focus of this habitat valuation was on the current state of the environment, as well as a reasonable, no-action, future scenario about five decades in the future, if significantly different from current conditions. This study did not consider the extent to which habitat or its measures reflected contaminant effects; that was a goal that is more appropriate for the baseline risk assessment. Although this habitat valuation relied on some of the same evidence as the ecological risk assessment, this study (1) did not incorporate toxicity information, (2) was more field-based than the ecological risk assessment, and (3) was not intended to determine causality.

2. Methods

Metrics of habitat value for streams, ponds, and terrestrial ecosystems and criteria for scoring these metrics are described in the companion paper, Efroymson et al. (this issue). Several categories of metrics were selected from the literature on habitat valuation, habitat evaluation, habitat suitability assessment, and conservation prioritization. The primary determinant of habitat value was use by vertebrates, invertebrates, and plants (for food and water, reproduction, and migration or other movement). Additional metrics were developed for value added from the offsite spatial context. Rarity of species or communities were evaluated in a regional or national context, and habitat use value[3] was based in part on locally adjacent ecosystem features (Efroymson et al., this issue).

This habitat valuation informing a contaminant remedial decision process was conducted primarily using existing information, although this information was supplemented by additional statistical analyses, summaries of observations from authors' field notebooks that had not previously been summarized, bird counts at two of the sites, and a site visit with representatives of the US Environmental Protection Agency and the US Fish and Wildlife Service. Data from 2004 were used for most aquatic assessment endpoints because of apparent positive trends in some of the case study ecosystems. However, a range of benthic invertebrate data from 1998 to 2004 were used for Mitchell Branch because of high interannual variability, and unpublished 2005 data were used if there was an obvious change (e.g., the collection of grass carp from the 1007-P1 pond in 2005). Data from reference locations were summarized for a period of several years where possible. In studies of the ORR, regional reference ponds and streams were selected that did not include the major disturbances present from US Department of Energy industrial facilities (runoff, chemical contamination), but were sometimes found in areas supporting low to

[3]In this study, use value refers to the extent to which organisms use habitat, rather than human use value.

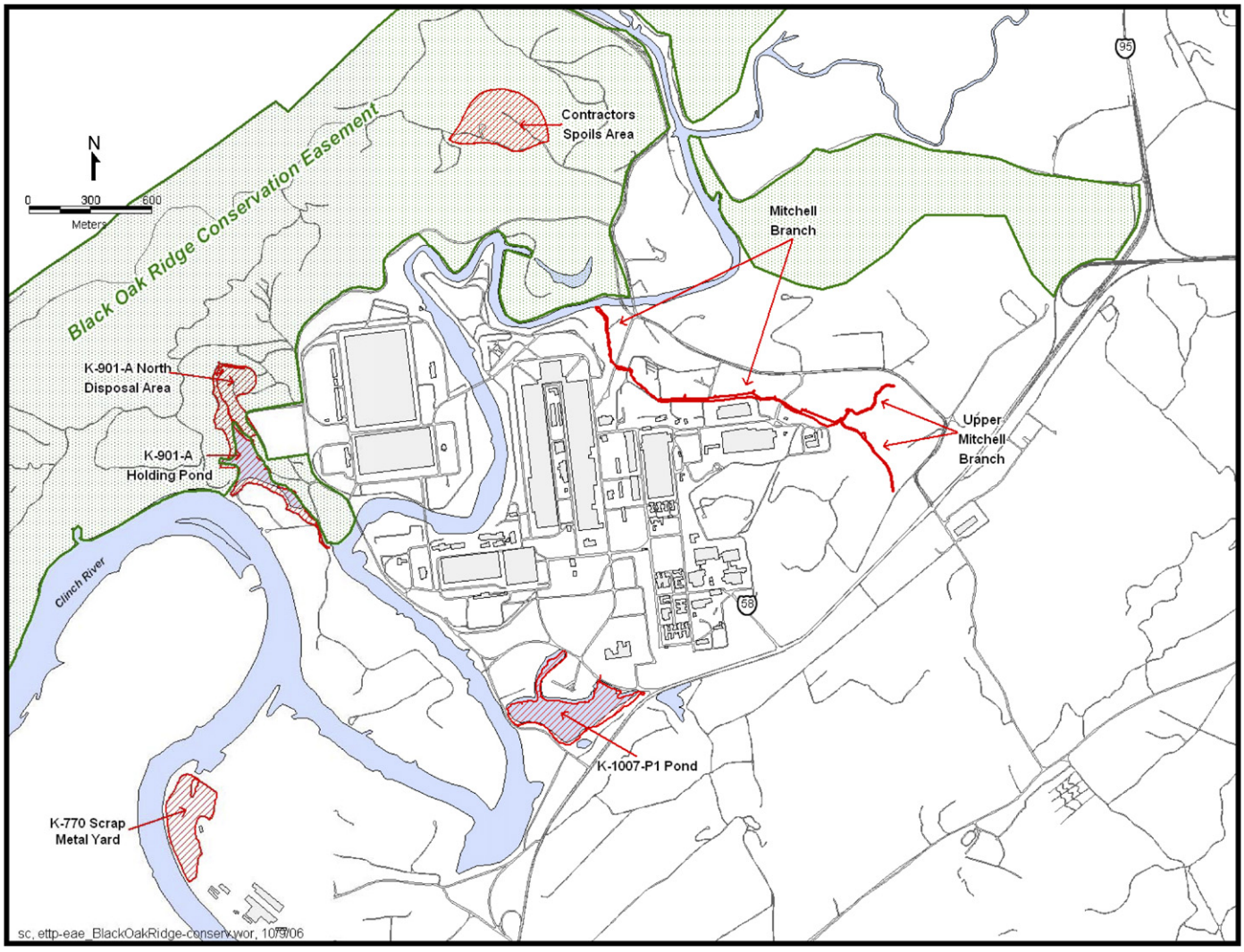

Fig. 1. Map of Black Oak Ridge Conservation Easement Area, showing location of Contractors Spoil Area and K-901-N Disposal area within the boundary of the easement.

moderate agricultural development. These reference water bodies provide a regional context for this study.

Major sources of local information included:

- Fish community (spring), invertebrate community (spring), and waterbird (monthly) surveys conducted through the Biological Monitoring and Abatement Program (BMAP) (Peterson et al., 2005a), including reference streams (Smith et al., 2005) and waterbird surveys by site (Efroymson et al., 2005 Appendix A).
- Fish community and pond vegetation surveys performed in support of the ETTP Site-wide Remedial Investigation (Peterson et al., 2005b).
- A summary of a bat acoustic survey conducted at the K-1007-P1 pond in 2004, as well as past studies and observations of bats on the ORR (Harvey and Britzke, 2004).
- A report describing a wetland survey of ETTP (Rosensteel and Awl, 1995).
- Results of wetland determination surveys conducted over the 1998–2004 time period at ETTP.
- Invasive plant species surveys at select locations along roads at ETTP.
- A site description of the Contractor's Spoil Area, entitled "Appendix A—Checklist for Ecological Assessments/Sampling, K25 Contractor's Spoil Area," February 2004.
- Surveys of rare vegetation and rare vegetation communities on the ORR by plant taxonomists and summarized in maps and biological significance ratings by the Nature Conservancy (TNC, 1995).
- Past observations and photographs.
- A map of future land use at the ORR.
- Site visits to all sites but the fenced K-770 scrapyard.

Survey information for mammals or birds was not available at the three terrestrial sites. Because the mammals on the ORR are primarily habitat generalists

(and therefore will probably not affect remedial decisions based in part on habitat value), and because trapping is a time consuming and rigorous exercise, we focused the only new vertebrate survey in support of this study on birds at the Contractor's Spoil Area and the K-901-N Disposal Area.

Four future scenarios of ecological change under the no-action remedial alternative were considered. These scenarios were selected because habitat and habitat value were expected to change significantly in the absence of remediation.

- A scenario whereby an unmaintained liner in Mitchell Branch fails or is removed.
- A scenario whereby mowing on the north and southeast sides of the K-1007-P1 pond ceases, and the riparian zone succeeds to bottomland deciduous forest.
- Lack of maintenance of the cap at the Contractor's Spoil Area, leading to succession of that area to forest.
- Succession of vegetation to forest at the K-770 scrapyard along the Clinch River.

Future habitat value was described qualitatively for conditions 50 years from now, but there is a high degree of uncertainty associated with these predictions. Fifty years is the minimum bound of the 50–200 year return interval for natural disturbances within eastern deciduous forests ecosystems (Runkle, 1985). Accordingly, this interval represents a reasonable expectation for the restoration of habitat value at these sites. However, because the recovery of rare, native fauna based on recovery of ecosystem diversity is not always predictable (Stewart et al., 2005), the discussion of future value was based on habitat use value rather than rarity.

3. Site descriptions

The boundaries of the six sites (Fig. 1) encompass areas known to contain disposal or contamination areas plus any adjacent land (for terrestrial sites) that have had soils collected for contaminant measurements.

3.1. Mitchell Branch

Mitchell Branch is a second-order stream, approximately 1900 m long, that enters ETTP from an area that is replete with seeps and springs, has diverse vegetation, including a mature forested floodplain, and may be habitat for rare plants. The downstream channelized portion of the creek runs between two filled ponds, continues on the north side of the main industrialized ETTP plant area, returns to a more natural form, and flows across a weir to Poplar Creek (Fig. 2).

In 1997–1998 an interceptor trench was constructed to collect and treat contaminated groundwater along Mitchell Branch. The removal action entailed the construction of a liner and a new interlocking (tri-lock) concrete substratum between storm drain (SD) 170 and SD 180 (Fig. 2). Prior to the removal action, the stream bottom consisted of fine gravel, silt and clay in this reach. The tri-lock bottom does not entirely discourage root growth; black willows (*Salix nigra*) have been observed to grow through the tri-lock material. The root development provides a partial substitute for microhabitats in which an unchannelized stream would undercut its banks. Also, the tri-lock material as a bottom substrate has spaces between blocks that can collect sediment and organisms. Pools and riffles have begun to develop from gravel inputs following extreme storm events. This structure is not very different from the bedrock that characterizes many headwater streams. Benthic and fish communities were initially severely impacted by the lining of Mitchell Branch, but have improved substantially since the removal action.

On the north side of the creek in the vicinity of SD 170, organic soils and seeps support a variety of wetland plant species, including black willow, cattails (*Typha latifolia*), bulrush (*Scirpus cyperinus*) and soft rush (*Juncus effusus*), as well as potential amphibian habitat. Non-native plants such as fescue (*Fescue* spp.) and honeysuckle (*Lonicera japonica*) are common to abundant. At SD 190, the creek has a more natural structure, with pools and riffles including 25-cm diameter holes. Vegetation succession along the creek banks is more advanced than in the tri-lock area, with large shrubs and small trees present. Uphill and north of SD 190, vegetation has been cleared near an accumulation area for excess excavated fill material. The weir below SD 190 serves as a barrier to fish movement at low flow but allows enough fish passage for new species to colonize the stream at higher flows.

Wetlands are present in the headwater areas. Palustrine forested broad-leaved deciduous (PFO1) wetlands extend downstream to a utility right-of-way, where they meet palustrine emergent persistent (PEM1) wetlands (Rosensteel and Awl, 1995). As of 1995, the dominant species in the PFO1 wetlands were red maple (*Acer rubrum*), sycamore (*Platanus occidentalis*), green ash (*Fraxinus pensylvanica*), tulip poplar (*Liriodendron tulipifera*), alder (*Alnus serrulata*), silky dogwood (*Cornus amomum*), poison ivy (*Toxicodendron radicans*), microstegium (*Microstegium vimineum*), leafy bulrush (*Scirpus polyphyllus*), and fowl manna grass (*Glyceria striata*) (Rosensteel and Awl, 1995). In the PEM1 wetlands (and portions of the PFO1 wetlands) are black willow, buttonbush (*Cephalanthus occidentalis*), seedbox (*Ludwigia alternifolia*), soft rush, lurid sedge (*Carex lurida*), monkeyflower (*Mimulus alatus*), bulrush (*Scirpus* sp.), false nettle (*Boehmeria cylindrical*), fox sedge (*Carex vulpinoidea*), grass-leaf rush (*Juncus marginatus*), American potato-bean (*Apios americana*), and arrowleaf tearthumb (*Polygonum sagittatum*) (Rosensteel and Awl, 1995).

As of 1995, five wetland areas were present in the developed portions of the ETTP site (Rosensteel and Awl, 1995). The first two are upstream of SD 190: a palustrine scrub-shrub broad-leaved deciduous (PSS1) wetland in

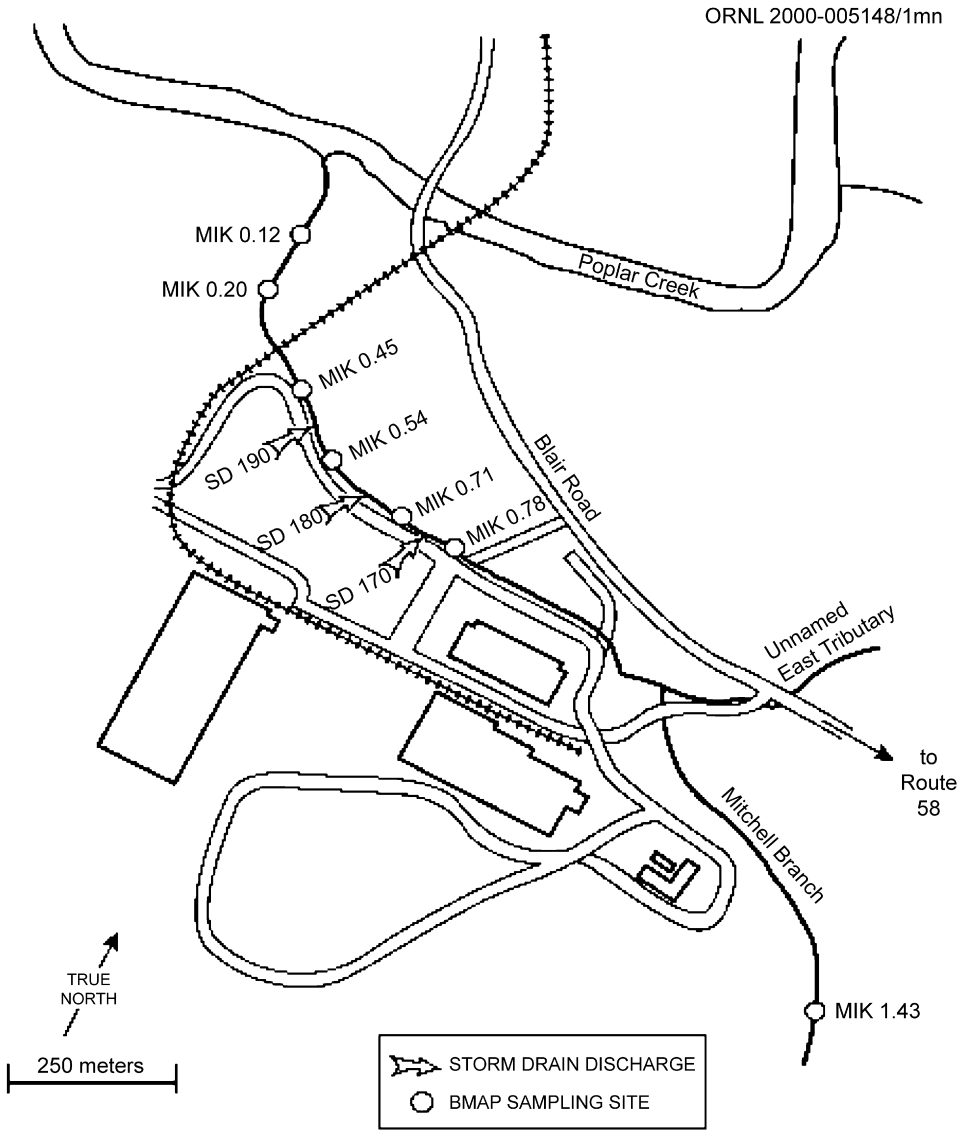

Fig. 2. Map of Mitchell Branch depicting the locations of biological monitoring sites in relation to select storm drains. MIK = Mitchell Branch kilometer, SD = Storm drain, BMAP = Biological Monitoring and Abatement Program.

a forested area and a PEM1 wetland. Another PEM1 wetland is located at a spring. As of 1995 the area supported hydrophytic species including black willow, bulrush, jewelweed (*Impatiens* sp.), cattail, horsetail (*Equisetum* sp.), ironweed (*Vernonia* sp.), fox sedge, soft rush, and peppermint (*Mentha* sp.) (Rosensteel and Awl, 1995). Downslope of SD190 is another PSS1 wetland originating from groundwater seeps. As of 1995, vegetation present included black willow, green ash, silky dogwood, rice cutgrass (*Leersia oryzoides*), and smartweeds (*Polygonum* spp.). Finally, a PSS1 wetland is located near the weir in a narrow area between the bottom of the steep sideslopes and the stream channel (Rosensteel and Awl, 1995, Peterson, unpublished report). Wetland trees and shrubs such as black willow, green ash, sycamore, box elder (*Acer negundo*), buttonbush, and silky dogwood dominate the narrow riparian zone. Herbaceous wetland vegetation include soft rush, bulrush, and lurid sedge.

3.1.1. Future no-action scenario

The no-action, future scenario is assumed to have habitat characteristics close to the current environment, with gradual succession of the riparian zone during the next several decades. The liner may fail in the future, and failure would increase the substrate complexity, possibly increasing diversity of the invertebrate community because of increased riffle structure and stimulating growth and succession of riparian vegetation and associated wildlife. The liner probably does not need be removed to improve habitat quality, because species richness would not likely improve from a return to a silty clay bottom, unless, after a long period of time, the stream were to develop meanders.

3.2. K-901A pond

The pond is located west of the main ETTP facility and has about a 6.8-ha surface, including wetlands, with

maximum depth of about 3 m (Fig. 1). In 1965–66, a weir was constructed between the wetland and the Clinch River to create the holding pond, which received chemicals and sludges from recirculating cooling water blowdown and served as disposal ground for contents of select cylinders including uranium hexafluoride, as well as oil via the storm drain system. In a 1997 removal action, the pond was completely drained to remove cylinders and other debris from the bottom, as well as contaminated fish. The pond was allowed to refill with water, and during a major high water event, fish from the Clinch River crossed the weir to the pond. The pond is much shallower than a few meters for most of its area, and these extreme shallow zones cannot support pelagic fish such as shad. Fish species richness is thought to represent the diversity of fish that crossed the weir in 1998. The sediments probably do not support a very diverse benthic invertebrate community, but the community has not been sampled. A large abundance of frogs has been observed in the shallow areas of the pond with few fish. A large snapping turtle has been found in the pond. Ospreys have been observed to feed.

Just north of the pond is a large 1–2 ha PSS1 wetland, which is somewhat unique on the ORR, because most wetlands on the ORR are small, relatively narrow, and associated with seeps. The wetland is dominated by willow and buttonbush (Rosensteel and Awl, 1995). The wetland supports *Juncus* (soft rush) but no cattails. Many dead black willow trees are present, perhaps because of utility right-of-way management activities, though we could find no history of herbicide use. The area surrounding the pond to the south has both open water and emergent wetland areas. Beaver are active here and near the outlet of the pond. As of 1995 the southern area supported red maple, sweetgum (*Liquidambar styraciflua*), ironwood (*Ostrya virginiana*), elm (*Ulmus rubra*), microstegium, and sedges (*Carex* spp.). K-901 has more wetland development in its bays than the K-1007-P1 pond, which has steeper banks. Riparian areas of the pond include hibiscus and buttonbush. The sloped, upland community adjacent to the pond and its margins is approximately 50% mature forest, approximately 40% old field to early successional forest, and 10% mowed and managed areas below powerlines. The gravel laydown area where the removal action was conducted in 1998 remains.

3.2.1. Future no-action scenario

In the no-action, future scenario, the K-901 pond has habitat characteristics close to the current environment, i.e., forested riparian zone predominating with continued management of vegetation below powerlines. Therefore, an explicit habitat valuation is not presented.

3.3. K-1007-P1 pond

This approximately 9.1-ha pond is located next to the main plant area of the ETTP site, bordered by a state highway to the southeast, a large mowed grassy and often saturated field to the north, a weir to Poplar Creek and a road to the west, and railroad tracks to the southwest (Fig. 1). The pond has received storm drainage and wastes from the 1950s to the present. The pond currently functions as a retention basin for stormwater. The primary contaminant of concern is polychlorinated biphenyls.

The banks of the pond are moderately to steeply sloped on the south end of the pond, with near flat topography on the north end. Typical of many impoundments, the land–water interface is abrupt, with little gradation typical of more natural pond systems. Various species that are tolerant of saturated soils grow on the banks, including planted bald cypress, black willow, and false indigobush. The pond receives high nutrient inputs from geese that graze on the mowed lawn. Powerlines cut across the area.

In a 2004 survey of vegetation around the K1007-P1 pond (Peterson et al., 2005b), only one small area along a point on the east end of the pond contained submerged, rooted vegetation. Two species were present: *Chara* sp. (an alga) and species of *Potamogeton*. A couple small individual plants of watercress were also present between bank rocks in other areas of the pond. The absence of emergent vegetation in the pond is due to grass carp. Emergent plants are prevalent in the waterways entering the pond. A southwest ponded area is fed by a clear stream flowing from the upland areas south of the highway, and contains an extensive area of natural wetlands. Cattails, bulrush, water plantain, and soft rush are common in this shallow area.

Narrow fringe wetlands are evident around the pond, especially toward the east and north end, but these areas are encroached upon by mowed areas [e.g., fescue, crab (*Digitaria* spp.) and Dallas (*Paspalum* spp.) grasses] and non-native plant species (e.g. *Lespedeza cuneata*). In many areas, especially along the east end, the grasses are mowed to the pond shore.

3.3.1. Future no-action scenario

In the no-action, future scenario, the K-1007-P1 pond would probably have ecosystem characteristics close to the current environment, i.e., mostly mowed riparian zone. However, it is possible that management practices could change so that the mowed area slowly succeeds to deciduous forest. The lack of mowing would discourage geese, decreasing the nutrient inputs to the pond, although some increased nutrient inputs would originate from leaves and wood.

3.4. Contractor's spoil area

The area was opened in 1974 as a borrow pit by the Tennessee Valley Authority (TVA) for construction of an electric substation. During the late 1970s the area was designated as a construction spoils and non-contaminated disposal area for ETTP, including a fly ash pile, a disposal area for spent, pressurized canisters, and a borrow pit. In 1982–1983, approximately 13,750 gallons of oil was

land-farmed on roads and through the area to suppress dust. The site was capped with fill to grade, clay, and topsoil (2 ft cover) and seeded with fescue in 1985. The facility is still used for burning scrap lumber. A small fraction of the area is cut by a powerline right-of-way. The area is drained by several riprapped ditches in the open grassy area and at the west boundary.

The fill area portion of this site is 3–3.2 ha. The open field portion of the site (including uncontaminated old field) is approximately 6 ha. The mowed area is still predominantly fescue and other lawn grasses and low-growing weeds. The surrounding upland, over 20% of the site, is a deciduous forested area that abuts Black Oak Ridge. The spoil area is within the Black Oak Ridge conservation easement land use zone (Fig. 3). On the north boundary, several large red maples and southern red oaks (*Quercus falcata*) were observed during a survey in December 2003, along with blackjack oak (*Quercus marilandica*), sweetgum, black cherry (*Prunus serotina*), red cedar (*Juniperus virginiana*), Virginia pine (*Pinus virginiana*), and white pine (*Pinus strobus*). Along the west boundary were Virginia pine and hickories (*Carya* spp.) in a mixed deciduous forest community. An old field plant community is in the northwest section.

3.4.1. Future, no-action scenario

After several decades of not maintaining the cap, it is assumed that seed dispersal will allow colonization, new tree roots would be able to break through the ground, and mowed and old field areas will undergo succession toward the forest communities represented on the adjacent land. Most of these tree roots are likely near the soil surface. For example, 70% of tree root endings for northern hardwood, cove hardwood, and oak-hickory forest associations in West Virginia are in the top 0.5 m of soil (Kochenderfer, 1973).

3.5. K-901 north disposal area

This 3-ha disposal area of unknown depth operated from the late 1940s to mid-1970s. The area received waste from on-site contractors and maintenance activities. Currently,

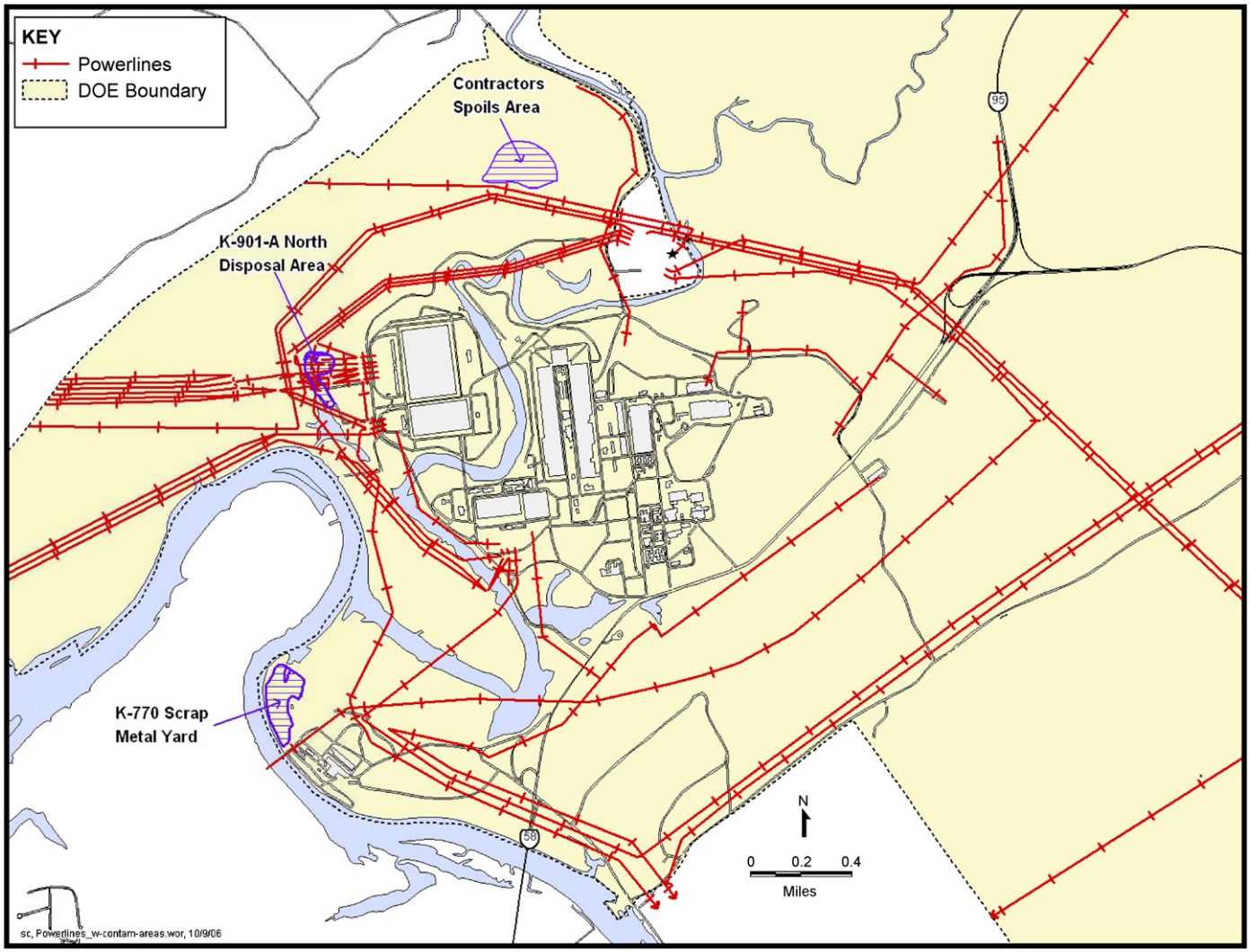

Fig. 3. Powerlines at the East Tennessee Technology Park, relative to three terrestrial contaminated sites.

the waste disposal area is covered with fescue, and four areas of radiological surface contamination are enclosed in fencing. The site is approximately 5–10% forested, 25–30% shrub/scrub, and the remainder maintained in an early successional state, with some portions mowed (Fig. 1). The vast majority of the area is covered by powerlines (Fig. 4), and most of these rights-of-way are mowed once a year, with TVA lines mowed every other year.

As of 1993, about 1.5% of the total US land area was unpaved rights-of-way (highways, power lines, gas lines and railroads), and Stephenson et al. (1993) assumed that a similar percentage existed in the Appalachian Forest Region. Powerlines are much more extensive at ETTP, and the powerline right-of-way on the K-901-N disposal area is probably 50 times that proportion (75%) (Fig. 4).

Much of the K-901-N area is on sloping upland topography, with dry soils and plant species adapted to disturbance. Most of the vegetative community is dominated by non-native or disturbance-adapted weeds, including upland grasses such as fescue, numerous composites [e.g., common and giant ragweed (*Ambrosia artemisiifolia and Ambrosia trifida*), goldenrod (*Solidago* sp.), sneezeweed (*Helenium* sp.), Japanese honeysuckle, and various disturbance adapted species in the pea family (clovers, vetches, and lespedezas)]. At the edges of the power lines, roads, and fence lines, as well as near and below the metal powerline supports or other areas less mowed, are a greater percentage of small trees, shrubs and woody vines. Small trees and shrubs associated with these early successional areas include sumac (*Rhus glabra* and *Rhus copallinum*), tulip poplar, redbud (*Cercis canadensis*), autumn olive (*Eleaganus umbellate*), red cedar, and sweetgum. Woody vines include two species of raspberries (*Rubus* spp.), grapes (*Vitus* spp.), and poison ivy.

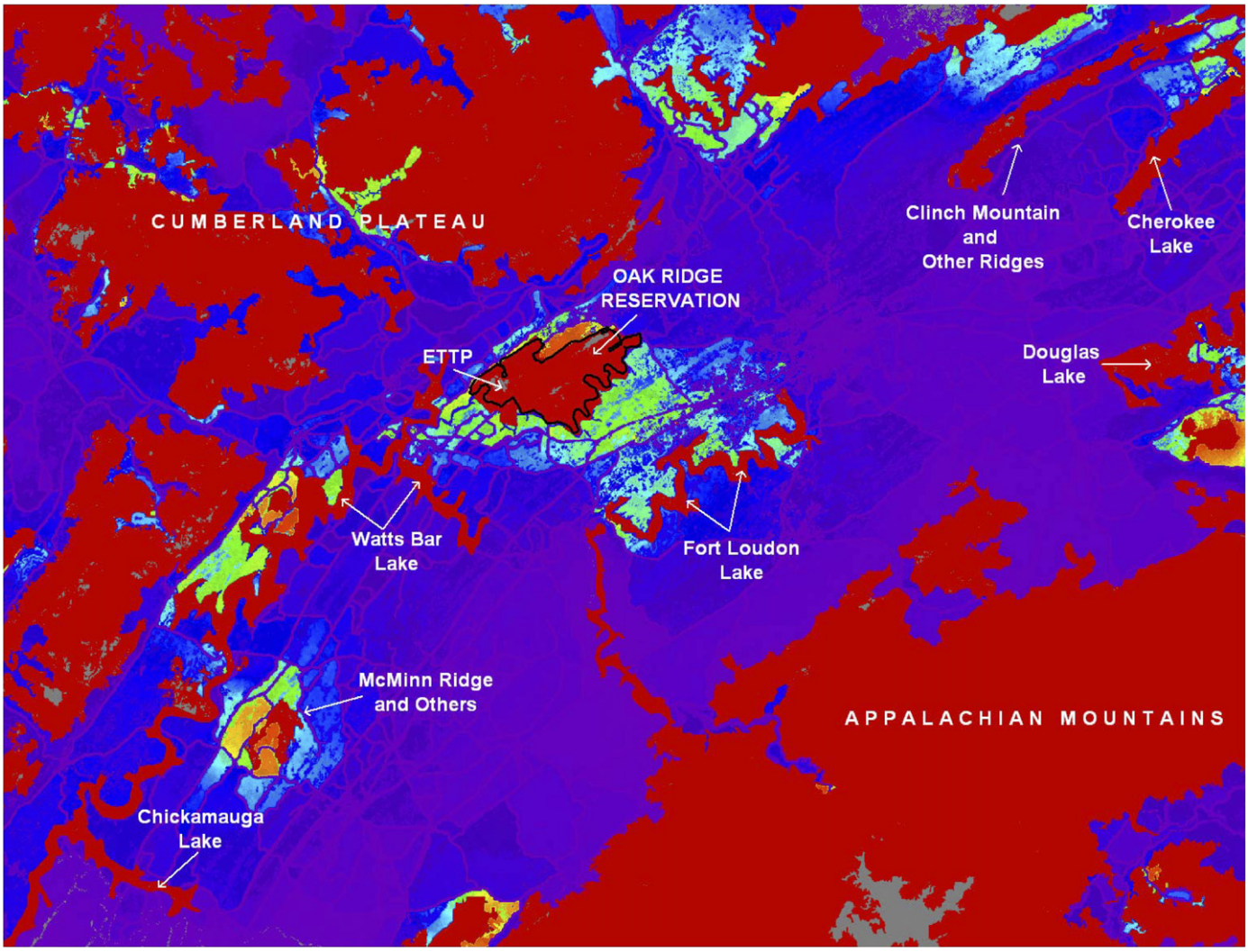

Fig. 4. Ecological corridors for forest-dwelling species identified using the Pathways Through Habitat (PATH) corridor analysis tool described in Hargrove et al. (2005). Forest "hubs" (large, intact forest tracts, some of which include lakes) from the Southeastern Ecological Framework (Carr et al., 2002) are strong corridor components depicted in red. Intervening landscape matrix is colored according to a gradient of trackway use by successful forest-loving dispersers with orange, yellow, green, blue, and purple indicating decreasing connectivity. The Oak Ridge Reservation is shown to be of principal importance in connecting hubs within the Cumberland Plateau with large forest hubs in the Appalachian Mountains through highly fragmented habitat. Color figure appears in PDF and HTML versions of this article downloadable from internet.

3.5.1. Future, no-action scenario

This site should remain in its current land cover state because of maintenance requirements for mowing under powerline rights-of-way.

3.6. K770 scrapyard

This 7.1-km site in the Powerhouse area (Fig. 1) has tens of thousands of tons of metal stored in piles with extensive gravel roads developed for moving scrap to and from the site. The scrap piles are in the process of being removed, including some topsoil. Large gravel pads have been found under vegetation during scrap removal.

The extensive and frequent disturbance of soils from roads and their construction, bulldozed areas, and scrap piles has resulted in a plant community highly adapted to disturbance. In the most recently impacted areas are various vines, such as Japanese honeysuckle, raspberries, grapes, and poison ivy, extending over metal buildings, paved areas, scrap metals, and fence lines. Areas near the Clinch River, if not paved or graveled, include shrubs and small trees, many of which are non-native, invasive, or adapted to disturbed conditions: privet (*Ligustrum sinense*), autumn olive, sumac, redbud, and red cedar. Tree and shrub species characteristic of bottomland communities that were identified in this area in 1998 in an early successional stage include tulip poplar, white ash (*Fraxinus americana*), red maple, and shrubs such as alder. Graminoid species at the site include non-native fescues, plantago (*Plantago* sp.), and microstegium. No jurisdictional wetlands are known to be present.

3.6.1. Future, no-action scenario

Gravel driveways and other bare ground would remain for several years under the no-action scenario, but vegetation cover would be expected to increase. Exotics such as privet could become established and dominate parts of the site. However, young forest cover would be likely to dominate after 50 years. Species such as sycamore, tulip poplar, white ash, red maple, and shrubs such as alder and spicebush (*Lindera benzoin*), all native, would probably dominate in this bottomland community. These species were identified along the east bank of the Clinch River at ETTP in 1998 surveys.

4. Results

4.1. Current habitat value

Mitchell Branch has medium habitat value in terms of taxa richness for fish, benthic invertebrates, and waterbirds (Table 1). The stream has apparently low habitat value

Table 1
Habitat valuation results for Mitchell Branch

Metric	Score	Explanation
Taxa richness—fish	Medium	Total of eight taxa of fish present in samples from two sites (MIK 0.45 and 0.71) in Spring 2004
Taxa richness—benthic invertebrates	Medium	Since 1998, mean taxonomic richness fluctuated between medium and high quality at MIK 0.78 (upstream of most storm drains), and between low and medium quality at MIKs 0.71 and 0.45
Taxa richness—waterbirds	Medium	Four of 15 waterbird species observed during surveys at ETTP in 2004 observed at Mitchell Branch
Number of sensitive fish species	Medium	Total of 1 sensitive species present in samples from two sites (MIK 0.45 and 0.71) in Spring 2004
Number of sensitive benthic invertebrate species	Medium	Since 1998, mean EPT taxonomic richness fluctuated between low and high quality in Mitchell Branch, depending on proximity to storm drains
Presence of shallow, slow-flowing areas for amphibian reproduction	High	Shallow wetland areas available for amphibian reproduction at the headwaters, near weir, and on the north side of stream between SD170 and SD180
Presence of waterbird rookery	Low–medium	No rookery present
Presence of non-native or invasive species—fish and benthic invertebrates	Medium–high	Stream too small for Asian non-natives such as common carp and grass carp and non-native mussels. Non-native fish species cannot be determined, because regional status of North American fish species is uncertain
Presence of non-native or invasive species—benthic invertebrates	Medium	Asiatic clam, *Corbicula fluminea*, present in lower Mitchell Branch only. Zebra mussel, *Dreissena polymorpha,* present in nearby reservoir, but not recorded in Mitchell Branch
Complexity of habitat structure	Medium	At MIK 0.78 and MIK 0.71 (remediated zone), RBP score 99 (below threshold of 131 for high value), with most parameters in middle range, but with low score for channelization of stream and high score for bank stability. At MIK 0.45 (downstream from remediated zone), RBP score 108 (below threshold of 131 for high value), with most parameters in middle range, but high score for bank stability
Abundance of rare species—fish	Low	No rare fish found in samples from two sites (MIK 0.45 and MIK 0.71) in Spring 2004

Table 1 (*continued*)

Metric	Score	Explanation
Presence of rare species—benthic invertebrates	Low or medium	Little known about rare aquatic insect species worldwide, and virtually nothing known in Tennessee. Possible rare or T&E species of mollusks on ORR inhabit bodies of water larger than Mitchell Branch. Spiny River Snail, *Io fluvialis*, and Anthony's River snail, *Athearnia anthonyi*, historically existed in lower Clinch River but not likely Mitchell Branch
Presence of rare community—wetlands	High	In addition to headwaters, stream seepage swamp is present on north side of stream between SD170 and SD180
Presence of movement corridor—fish	Medium	Most reaches of ETTP plant easily accessible by downstream fish, but weir prevents movement during low flow conditions
Presence of movement corridor—benthic invertebrates	Medium	Upstream areas of Mitchell Branch only slightly impacted, especially headwaters. Unimpacted tributaries not present, and proximity to unimpacted streams limited, so only most mobile insects likely colonize
Presence of movement corridor—avian piscivores	High	ETTP has largest abundance and diversity of avian piscivores on ORR and highest density of water bodies, including Mitchell Branch, K-901 pond, K-1007-P1 pond, Poplar Creek, and Clinch River. Heron rookery located on Poplar Creek
Stream density relative to Roane County, Lower Clinch River, and Southern Appalachian regional averages	Low	Stream density at ETTP probably significantly less than values for Roane County, Lower Clinch River, and Southern Appalachian regional averages because of extensive development at the industrial site
Riparian wetland coverage, relative to Southern Appalachian regional average	High	Riparian wetland coverage for Mitchell Branch greater than 2%, even in industrialized reach. Coverage similar to or greater than lengths of relatively unimpacted riparian wetlands along streams nearby in Bear Creek Valley
Forested riparian coverage, relative to Southern Appalachian regional coverage	Low	Although some young trees line portions of Mitchell Branch within ETTP plant, riparian zones are narrow, southern riparian zone width is limited by road, and length of riparian zone is far less than 60% of length of stream on each side
Forested riparian coverage, relative to Ridge and Valley regional coverage	Low	Length of riparian zone less than 30% of length of stream on each side
Adjacent amphibian habitat	Low	Wetlands in developed part of Mitchell Branch do not have buffer of good amphibian habitat
Adjacent reptile habitat	Low	Wetlands in developed part of Mitchell Branch do not have buffer of good reptile habitat

ETTP, East Tennessee Technology Park.
MIK, Mitchell Branch kilometer.
EPT, Ephemeroptera, Plecoptera, and Trichoptera.
ORR, Oak Ridge Reservation.
RBP, Rapid Bioassessment Protocols.
GIS, geographic information system.

with respect to rare fish species. Biota in the stream are recovering from previous habitat disturbances, and species richness is higher than would be indicated solely by stream channelization. The stream has high-value amphibian habitat in adjacent wetlands, but with little buffer by upland habitats suitable for amphibians or reptiles. Constrained by roads and other management activities, forested riparian coverage at Mitchell Branch is below Ridge and Valley and Southern Appalachian averages and has low habitat value (Table 1). Riparian width is much less than the 18 m recommended in Barbour et al. (1999), which is probably consistent with the threshold for designating a 30-m GIS pixel as forest in SAMAB (1996), from which the relevant forested riparian zone habitat value metric and scoring criteria were derived. ETTP does not have an unusually high stream density that would be indicative of high habitat value for organisms using streams.

The K-901 pond has medium habitat value for waterbirds and fish, with a high quality littoral habitat zone (Table 2). However, the habitat valuation metric related to sensitive fish species is low. The habitat corridor for waterbirds at ETTP appears strong, and the coverage of ETTP by water bodies in general is higher than the Southern Appalachian regional average. High value wetlands are extensive at the site, especially near the inflow areas. As a result, amphibian habitat has high value, with medium-value buffer by upland habitats suitable for amphibians or reptiles. The pond has low habitat value with respect to rare fish species and medium value as indicated by the presence of a non-native species. Riparian cover is high relative to ETTP and the Ridge and Valley province, but low or medium with respect to the Southern Appalachian region.

The most notable result for the K-1007-P1 pond is the observation of gray bats (*Myotis grisescens*), along with three more common bat species (Table 3). Gray bats forage for aquatic and terrestrial insects above lakes and along rivers. This pond has medium habitat value for fish generally and high habitat value for Lepomid sunfish, an

Table 2
Habitat valuation results for K-901 pond

Metric	Score	Explanation
Taxa richness—fish	Medium	12 species observed in samples in August 2004
Taxa richness—Lepomid sunfish species	High	Four species observed in samples in August 2004, indicating high quality littoral zone
Taxa richness—waterbirds	Medium	Six of 15 waterbird species observed during surveys at ETTP in 2004 observed at the K-901 pond
Number of sensitive fish species	Low	No sensitive species observed in August 2004
Presence of shallow areas for amphibian reproduction	High	Embayments of K-901 pond are shallow
Presence of waterbird rookery	Low–medium	Waterbird rookery not present at K-901 pond
Presence of non-native or invasive species—fish	Medium	One non-North American species, common carp, observed in August 2004
Number of non-native or invasive species—shellfish	Uncertain	Non-native species not surveyed in the K-901 pond, but Asiatic clam probably present, and zebra mussel may be present
Complexity of habitat structure	Medium	Pond has woody debris, root wads, gravel, emergent vegetation, overhanging vegetation, and shallows (<0.3 m depth), but not undercut banks, boulders, cobble, sand, aquatic vegetation, and deep areas (>3 m depth). Score is 6 of 12 characteristics
Abundance of rare species—fish	Low	No rare species in samples in August 2004
Presence of rare species—bats	Uncertain	Bats not surveyed at K-901 pond
Presence of rare community—wetlands	High	Extensive wetlands border northern areas of the pond
Presence of movement corridor—fish	Low	Pond rarely accessible by downstream fish, as evidenced by diversity of fish following fish removal during 1998 pond removal action. Routine movement unlikely
Presence of movement corridor—avian piscivores	High	ETTP has largest abundance and diversity of avian piscivores on ORR and highest density of water bodies, including Mitchell Branch, K-901 pond, K-1007-P1 pond, Poplar Creek, and Clinch River. Heron rookery located on Poplar Creek
Area of water coverage relative to Southern Appalachian regional average	High	Over 2% of ETTP (if the Clinch River is included) covered by water bodies
Riparian wetland coverage, relative to Southern Appalachian regional average	High	Wetlands at the north and south ends of pond comprise greater than 2% of riparian zone of pond
Forested riparian coverage, relative to Southern Appalachian regional coverage	Low–medium	About 60% of the pond riparian zone is forested, at the boundary between definitions of low or medium scores
Forested riparian coverage, relative to Ridge and Valley physiographic regional coverage	High	About 60% of the pond riparian zone is forested, i.e., above 40% threshold for high proportion of forested riparian coverage
Adjacent amphibian habitat	Medium	Forested area around at least 25% of wetlands should provide these habitat services
Adjacent reptile habitat	Medium	Forested area around at least 25% of wetlands, as well as steeper shoreline to K-901-N disposal area should provide these habitat services

ETTP, East Tennessee Technology Park.

indicator of a high quality littoral zone, and waterbirds. The pond has low habitat value with respect to rare fish species. The pond has limited areas of high-value amphibian habitat in adjacent wetlands, with little buffer by upland habitats suitable for amphibians or reptiles. However, the high wetland coverage relative to the Southern Appalachian regional average indicates high habitat value for wetland species. The low forested riparian coverage, compared to Ridge and Valley ecoregion and Southern Appalachian averages, indicates lower forested riparian habitat value than wetland habitat value (Table 3). It is unknown to what extent the nutrient influx from Canada geese affects the habitat value for aquatic organisms.

The contractor's spoil area encompasses low-value mowed grass, mostly fescue, high-value deciduous forest, and a small fraction of medium- or high-value old field vegetation (Table 4). Thus, the spatially averaged value of many habitat value measures is medium. Habitat value for forest and edge bird species averages medium across the area, although without the forest edge, the mowed area would have low-value habitat for birds. The grass is probably suitable for reptiles, but less so because it is a mowed monoculture. The entire area lies within the Black Oak Ridge conservation easement, which increases the likely duration of its habitat use, particularly the forest, and the use value added based on spatial context (Table 4). The habitat value for the fescue-covered area is probably the most important habitat value for regulatory agencies to focus on, as remedial decisions will affect this area, primarily. This subset of the site currently has low value in terms of plant diversity, especially native species, and bird diversity, but high potential for future value because of its location and lack of paved areas.

The majority of the K-901-N Disposal area lies in a powerline right-of-way, and, as such, is characterized by annually mowed grass, biennially mowed grass, and shrubland with a small fraction of forest that provide

Table 3
Habitat valuation results for K-1007-P1 pond

Metric	Score	Explanation
Taxa richness—fish	Medium	17 species observed in August 2004
Taxa richness—Lepomid sunfish species	High	Four species observed in August 2004, indicating high quality littoral zone
Taxa richness—waterbirds	High	12 of 15 waterbird species observed in ETTP surveys in 2004 were at pond
Number of sensitive fish species	Medium	One sensitive species, spotted sucker, observed in August 2004
Ambient dissolved oxygen concentrations—fish	Medium–high	On one of two sample dates in September 2004, dissolved O_2 concentrations in water column below 5.5 mg/L (4.8 mg/L) at dam. Possible that concentrations are below water quality criterion for long periods during summer
Ambient dissolved oxygen concentrations—benthic invertebrates	Medium	On one of two sample dates in September 2004, dissolved O_2 concentrations in water column below 5.0 mg/L (4.8 mg/L) at dam. Likely that concentrations below invertebrate threshold for slight impairment for long periods during summer, especially close to sediments
Presence of shallow areas for amphibian reproduction	Low–medium	Pond has only a few floodplain pools at north and southwest end of pond that cannot be accessed by fish
Presence of waterbird rookery	Low–medium	Waterbird rookery not present
Number of non-native or invasive species—fish	Low	One non-North American species, common carp, observed in samples taken in August 2004. Common carp and grass carp collected in 2005
Presence of non-native or invasive species—shellfish	Low	Pond not surveyed for shellfish. Asiatic clams have been observed, and zebra mussels could be present
Complexity of habitat structure	High	Pond has woody debris, root wads, undercut banks, boulders, gravel, emergent vegetation, overhanging vegetation, shallows (<0.3 m depth), and deep areas (>3 m depth), but not cobble, sand, or aquatic vegetation. Score is nine of 12 characteristics
Abundance of rare species—fish	Low	No rare fish species present
Presence of rare species—bats	High	Gray bats (as well as three more common species) observed in Anabat survey conducted in August 2004
Presence of rare community—wetlands	High	Forested wetland seep located at southwest side of pond. Floodplain pools also found along north end of pond
Presence of movement corridor—fish	Medium	Pond accessible by upstream fish and perhaps rarely by downstream fish during extremely high flows
Presence of movement corridor—avian piscivores	High	ETTP site has largest abundance and diversity of avian piscivores on the ORR and highest density of water bodies, including Mitchell Branch, K-901 pond, K-1007-P1 pond, Poplar Creek, and Clinch River. Heron rookery located on Poplar Creek
Area of water coverage relative to Southern Appalachian regional average	High	Over 2% of ETTP site (if the Clinch River is included) or of a smaller area is covered by water bodies
Riparian wetland coverage, relative to Southern Appalachian regional average	High	Riparian wetland coverage much greater than 2%
Forested riparian coverage, relative to Southern Appalachian regional coverage	Low	Less than 60% of pond riparian zone forested
Forested riparian coverage, relative to Ridge and Valley regional coverage	Low	Less than 30% of pond riparian zone forested
Adjacent amphibian habitat	Low–medium	With exception of small areas to southwest and north, combination of mowing and roads surrounding wetlands and pond provides very little buffer area for amphibians
Adjacent reptile habitat	Low–medium	With exception of small areas to southwest and north, combination of mowing and roads surrounding wetlands and pond provides very little buffer area for amphibians

ETTP, East Tennessee Technology Park.
BMAP, Biological Monitoring and Abatement Program.

medium habitat value (Table 5). Although plants have not been formally surveyed at this site, plant species richness, especially of native species, apparently varies across the site, with fescue and other mowed areas having low species diversity and percent natives, scrub-shrub areas having medium or high species richness, and forest probably having medium species richness and high percent natives. The bird species richness is consistent with medium habitat value, with substantial edge perimeter between grass patches, shrub/scrub patches, and forest patches to support even more early successional bird species. Habitat value for reptiles appears high. Plants have not been surveyed for rarity. The entire area also lies within the Black Oak Ridge conservation easement; therefore its habitat use value is expected to endure (though management of the powerline right-of-way will continue).

We did not have access to many areas within the K-770 Scrapyard, so there is some uncertainty about values of habitat for different groups of species (Table 6). Central areas of the site visible from the road and those visible from the river by boat have low vegetation cover and low habitat value with substantial gravel road cover and bare ground. Large areas dominated by non-native species have low habitat value. In general, the K-770 Scrapyard is clearly of

Table 4
Habitat valuation results for the Contractor's Spoil Area

Metric	Score	Explanation
Major vegetation cover	Medium	$\frac{2}{3}$ of area low-value mowed grass, and $\frac{1}{3}$ high-value deciduous forest
Percent impervious surface or bare ground	Medium–high	Site has very little impervious surface or bare ground. However, cap over spoils area may be somewhat impervious to tree roots for a few decades
Taxa richness—forest breeding birds	Medium	13 species recorded, which is 62% of 21 species, the largest number recorded during any one survey at East Fork Ridge Road/McNew Hollow Road area of ORR, which contains similar forested habitat to this site
Taxa richness—early successional or edge breeding birds	Medium	17 species recorded, which is 68% of 25 species, the largest number recorded during any one survey at Freels Bend Area of Three Bend Scenic and Wildlife Management Refuge Area. Fescue field on majority of site provides little habitat value
Habitat suitability relationship—reptiles	Medium	Grass available for turtles, lizards and snakes, but mowed
Presence of non-native or invasive species—plants	Low	Over 50% of area covered by fescue. Invasive plant surveys at ETTP have not included this site
Complexity of vertical habitat structure	Low–medium	Mowed grass has low habitat-value structure, and adjacent deciduous forest has medium habitat-value structure
Length of edge between patches	Medium	Only two patches present, forest and mowed grass
Presence of special wildlife breeding areas	Low–medium	Special wildlife breeding areas absent
Presence of rare species—plants	Low–medium	Most of area surveyed by L. Pounds (personal communication, June 13, 2005), and no rare species found
Age of vegetation	Medium	High value for forest, low value for mowed grass
Presence of rare species—birds	Low	Rare birds absent
Presence of rare terrestrial vegetation community	Low–medium	Most of this area surveyed by Larry Pounds (personal communication, June 13, 2005), and no rare communities found. Also, area not designated as rare community
Designation of land as a preliminary conservation site on the ORR based on Biological Significance Rankings of the Nature Conservancy (TNC, 1995)	Medium	Area designated as BSR5 (of general biodiversity interest)
Part of ecological corridor linking deciduous forests from Cumberland Plateau to Great Smoky Mountains	High	Deciduous forest part of ecological corridor identified in Fig. 5. Spoil area probably receives high vertebrate traffic because of adjacency to forest, but somewhat uncertain at the resolution of the data on which Fig. 5 is based
Adjacency to conservation area	High	Site is part of Black Oak Ridge conservation easement (Fig. 3)

BSR, biological significance ranking.
ETTP, East Tennessee Technology Park.
ORR, Oak Ridge Reservation.

low habitat value for most plant or animal species. In contrast, localized areas of shrub/scrub and early successional forest along the Clinch River have medium habitat-use value for plants, although many areas are dominated by non-natives (e.g., privet).

4.2. Future habitat value under the no-action alternative

4.2.1. Failure of Mitchell Branch liner

Removal of the liner would cause short-term decreases in fish and invertebrate diversity; gradual failure would not. Also, in the short term, species richness would not be likely to improve from a return to a silty clay bottom, because the stream would still have a channelized structure with few cobbles. After 50 years, one might expect increasing habitat use value as exemplified by species richness of benthic invertebrate and fish because of increased riffle structure, undercut banks, meanders, and aged riparian vegetation. Still, these might not yet have "high" scores, especially if the stream boundaries and riparian zone are still constrained by roads and other management activities. In summary, after 50 years, succession of riparian vegetation would improve plant species diversity and that of associated wildlife.

4.2.2. Succession of riparian zone at the K-1007-P1 pond to deciduous forest

Under this scenario, riparian zone vegetation and songbird diversity would be expected to increase. Willow species, such as the black willow present at this site, are a typical component of natural riparian forests in this region (Stephenson et al., 1993). Waterbird diversity would probably also increase to an even higher level, based on the fact that White Oak Lake has higher waterbird diversity and is a forested site. (Also, anecdotal evidence suggests that the abundance of waterbirds is higher when Canada geese are not present.) Wood ducks, hooded mergansers, herons, egrets, and probably bufflehead and ring-necked ducks would benefit from the forest growth. A forested riparian zone is likely to be unfavorable for

Table 5
Habitat valuation results for the K-901-N disposal area

Metric	Score	Explanation
Major vegetation cover	Medium	Major vegetation cover low value mowed grasses and old field vine and shrub communities (medium value), with 5–10% high value forest
Percent impervious surface or bare ground	High	Site has very little impervious surface or bare ground
Taxa richness—early successional or edge breeding birds	Medium	18 species recorded, which is 72% of 25 species, the largest number that have been recorded during any one survey at Freels Bend Area of Three Bend Scenic and Wildlife Management Refuge Area
Habitat suitability relationship—reptiles	High	Grass available for turtles, lizards and snakes
Presence of non-native or invasive species	Low–medium	Autumn olive, fescue, and Japanese honeysuckle dominant in many areas of the site. Many early successional areas have native species such as tulip poplar and sumac. Small area of forest predominantly native
Complexity of vertical habitat structure	Medium	Area has over 50% ground cover and 50% shrub cover (2 elements of good vertical habitat structure)
Length of edge between patches	High	Numerous patches of shrub/scrub present
Presence of rare species—plants	Low–medium	Area never surveyed (L. Pounds, pers. comm., June 13, 2005), but highly unlikely that rare species present in these ecosystem types
Age of vegetation	Low	Vegetation young, including mowed grass, old field, and shrub/scrub
Presence of rare species—birds	Low	Rare birds absent
Presence of rare terrestrial vegetation community	Low–medium	Area not designated as rare community and never surveyed by Larry Pounds (personal communication, June 13, 2005), but unlikely that rare community was missed in site visits
Designation of land as a preliminary conservation site on the ORR based on Biological Significance Rankings of the Nature Conservancy (TNC, 1995)	Low	Area not designated as conservation site, and vegetation not surveyed at site in support of this study. However, management of site within powerline right-of-way suggests that this would not be biologically significant site
Part of ecological corridor linking deciduous forests from Cumberland Plateau to Great Smoky Mountains	Medium–high	At high spatial resolution, this site is part of ecological corridor identified in Fig. 5, which includes all of ORR except for plant areas. However, because it is not adjacent to large tract of forest, highest-use corridor may not include this site
Adjacency to conservation area	High	The site is part of Black Oak Ridge conservation easement (Fig. 3)

ORR, Oak Ridge Reservation.

shorebirds such as greater and lesser yellowlegs, killdeer, other sandpipers and plovers, etc. The K-1007-P1 pond is probably large enough that open-water species such as loons, grebes, and canvasbacks would not be significantly deterred by a forested riparian zone, and osprey should be unaffected. The riparian zone would provide improved habitat for amphibians and reptiles, especially near wetlands in the north slough area. It is unknown how the removal of nutrient input from goose excrement and the addition of new, forested riparian cover would affect fish and benthic invertebrate diversity. It is not known if wooded riparian areas would positively or negatively affect the likelihood of the gray bat foraging at the pond or waterbirds using the pond. In summary, after 50 years, succession of riparian vegetation would be expected to improve plant species diversity and that of most waterbirds, amphibians and reptiles.

4.2.3. Succession of contractor's spoil area to deciduous forest

After 50 years, tree roots would be expected to penetrate the soil cap easily, and eventually, the current fescue-covered portion of this site would become deciduous forest with species similar to those on adjacent Black Oak Ridge. Clearly, the species richness of native vegetation would increase dramatically. The species richness of forest interior birds would increase on the site, and that for edge species could increase or decrease, depending on the quality of edge habitat. Reptile diversity could also increase or decrease. The site would become part of the forest corridor connecting the Cumberland Plateau to the Great Smoky Mountains (Fig. 5). In summary, after 50 years, the habitat use value for vegetation and birds would be expected to increase substantially.

4.2.4. Succession of K-770 area to deciduous forest

After 50 years, tree roots would be expected to penetrate the gravel roads and pads, and eventually (but perhaps in a longer time frame than 50 years), the current grassy and shrub/scrub portions of this site would develop into bottomland deciduous forest characteristic of this region, including several of the tree species already present on the site (Stephenson et al., 1993). The species richness of native

Table 6
Habitat valuation results for the K-770 Scrapyard

Metric	Score	Explanation
Major vegetation cover	Low–medium	Much of site is road and scrap infrastructure, and mowed or vine covered areas. Also, areas of scrub/shrub and early successional forest present
Percent impervious surface or bare ground	Low	Up to 50% of the visible area covered by gravel or scrap
Taxa richness, breeding birds—edge species	Low–medium	Information not available, but given sparse and managed vegetation cover and human presence, unlikely that bird diversity is high
Taxa richness—waterbirds	Low–medium	No information available concerning waterbirds along Clinch River at K770 scrapyard, but given sparse and managed vegetation cover, human presence, and absence of shallow water areas and an accessible riparian slope, unlikely that bird diversity is high
Habitat suitability relationship—reptiles	Medium	Site has grass to support turtles, lizards, and snakes, including gravel for snakes to bask. However, current disturbance of area during removal of scrap will likely keep some reptiles away
Presence of non-native or invasive species	Low	Abundant to dominant zones of privet, autumn olive, Nepal grass, and Japanese honeysuckle. Invasive species surveys at ETTP have not included site
Complexity of vertical habitat structure	Low	Large areas of site covered by road or scrap with no vertical habitat. Vegetated zones, which are largely ground and/or shrub cover, unlikely to exceed 50% (two of elements of good vertical habitat structure)
Length of edge between patches	Low–medium	Edges of vegetation patches low in gravel-covered areas where vegetation cover is low. Closer to Clinch River, more habitat patches are present with corresponding medium or high edge between them
Presence of rare species—plants	Low	Vegetation surveys limited to periphery of site: rare community unlikely
Age of vegetation	Low	Vegetation cover primarily grasses, vines, and shrubs
Presence of rare species—birds	Low–medium	Area never surveyed for rare birds, and they are not expected
Presence of rare terrestrial vegetation community	Low but uncertain	Area not surveyed by Larry Pounds (personal communication, June 13, 2005) and not designated as rare community
Designation of land as a preliminary conservation site on the ORR based on Biological Significance Rankings of the Nature Conservancy (TNC, 1995)	Low	Area not designated as conservation site, and vegetation not surveyed at site in support of study. However, extensive coverage of the site by scrap and gravel suggests this would not be biologically significant site
Part of ecological corridor linking deciduous forests from Cumberland Plateau to Great Smoky Mountains	Medium	At high spatial resolution, site is part of ecological corridor identified in Fig. 5, which includes all of ORR except for plant areas. Also, narrow band of small trees along riverbank connects forest to immediate north and south of site. However, because it is fenced, highly disturbed, and not adjacent to large tract of forest, highest-use corridor probably does not include site
Adjacency to conservation area	Low	Site not adjacent to conservation area (Fig. 3)

ETTP, East Tennessee Technology Park.
ORR, Oak Ridge Reservation.

vegetation would probably increase dramatically and the percent forested riparian zone would likely increase to levels at or above regional averages. The species richness of forest birds would increase on the site, and that for edge species would probably also increase, because many of them are probably absent due to noise and other human disturbance. Reptile diversity could increase or decrease. The site would become part of the forest corridor connecting the Cumberland Plateau to the Great Smoky Mountains (Fig. 5). In summary, after 50 years, the habitat use value for vegetation and birds would be expected to increase.

5. Discussion

5.1. Spatial context

The ORR, a National Environmental Research Park, has high habitat value as a rather contiguous tract of vegetated land in the context of increasing development in East Tennessee (Dale and Parr, 1998). The natural vegetation of the ORR is the most significant area of preserved natural vegetation in the Ridge and Valley Physiographic Province in Tennessee (Mann et al., 1996). The ORR supports 1100 species of vascular plants, 21 of

which are rare (Parr, 2000). Complete bird and other vertebrate lists for the ORR are presented in Efroymson et al. (2005). A large tract of land across Black Oak Ridge has been designated as a conservation easement (Fig. 3). The ORR has been shown to be of principal importance in connecting forested hubs within the Cumberland Plateau with large forest hubs in the Appalachian Mountains through highly fragmented habitat (Fig. 5). Based on clusters of rare plants and vegetation communities, 81 sites were ranked by The Nature Conservancy as having very high or high significance nationally for conservation (TNC, 1995; Parr, 2000). A primary question in this study was the importance of the habitat use value and species and community rarity of the six study sites compared to the ORR and region.

Metrics of habitat value in this study were not evaluated with respect to a consistent spatial scale. Often, more information was available about local regional reference habitat value or landscape statistics for the Ridge and Valley Physiographic Province or the Southern Appalachian region than for the ORR. Species rarity was determined based on federal or state listing status. Thus, habitat values were evaluated rather inconsistently at variable spatial scales.

In this study, the use values added from spatial context of the six sites were important measures of habitat value. Early investigations of habitat value did not consider principles of landscape ecology, such as connectivity, adjacency, and fragmentation of lands and waters (Margules and Usher, 1981). We did not use some of the GIS-based measures of habitat value that are components of GIS-based methodologies such as CrEAM, and remotely sensed measures would probably improve our understanding of habitat value for inaccessible sites like the K770 scrapyard. Moreover, distance-based measures of habitat suitability (distance to roads, distance to streams, distance to weirs) that can relate to species richness and abundance (Conner et al., 2003) are not used here. However, the corridor and adjacency measures of habitat value illustrate the importance of considering spatial context.

5.2. Habitat value scores

As expected, there was significant variation in habitat value among the six sites, among measures for different taxa at a single site, between measures of use and rarity at a single site, and among measures for particular taxa at a single site with respect to different spatial scales. Most sites had aspects of low, medium, and high habitat value. Few high scores for current use value were given. These include: wetland plant communities at all aquatic sites, Lepomid sunfish (littoral zone) and waterbirds at 1007-P1 pond, and Lepomid sunfish and amphibians at K-901 pond. The habitat complexity was high at the K-1007-P1 pond, which might be an indicator of high value habitat for benthic invertebrates, but many of the measures are bank measures rather than bottom measures. In addition, all aquatic sites (plus the Clinch River and Poplar Creek) create a high-value ecological corridor for waterbirds, and the Contractor's Spoil Area and possibly the K-901-N Disposal Site have areas that are part of a strong terrestrial ecological corridor. The only example of recent observations of rare species at these sites is the gray bat observed at the K-1007-P1 pond.

5.3. Improving habitat value

Some aspects of habitat value are expected to improve under at least a few no-action scenarios: if mowing near the 1007-P1 pond ceases and the riparian zone succeeds to bottomland deciduous forest; if the cap is not maintained at the Contractor's Spoil Area, leading to succession of that area to forest; if vegetation at the K-770 scrapyard along the Clinch River is allowed to succeed to forest; and possibly if an unmaintained liner in Mitchell Branch fails or is removed. Any of these scenarios and associated habitat values may change if land or water areas are managed differently from the assumptions described above. Mowing of the K-901 powerline right-of-way will continue, but plant and bird species richness would probably increase if mowing were carried out less frequently or avoided during the bird breeding season. The planting of native grasses in early successional areas such as the Contractor's Spoil Area, the K-901-N Disposal Area, and the shoreline of K-1007-P1 pond would increase vegetation and bird diversity and possibly increase the rate of succession to forest. Powerline rights-of-way are corridors for the spread of invasive plants, and native grasses could serve as a buffer against exotic spread at sites like the K-901-N disposal area. Similarly, non-native or invasive species could move into the shoreline if mowing ceased near 1007-P1 pond, so the planting of willows, silky dogwoods, and similar species might bring substantial ecological benefits. Whether or not the Mitchell Branch liner fails or is removed, species richness of fish and benthic invertebrates would likely return to reference conditions if minor restoration actions occurred, such as pool creation, a little armoring, vegetation planting, and/or other structural additions such as the addition of boulders. Removal of grass carp from the 1007-P1 pond would allow vegetation to grow, increasing the diversity of fish and waterbirds.

A question that arose during this study was the importance of constrained plant succession (e.g., under powerline rights-of-way) in determining habitat value. Except for one measure of rarity (age of vegetation), this analysis did not address this comparative question. Part of the answer depends on whether it is better to have forest birds or early successional birds, which is a subjective preference. Other habitat valuation methodologies have not addressed the value of succession. For example, in CrEAM, USEPA Region 5's Critical Ecosystem Assessment Model, a method of determining

"ecosystem ecological significance" on a spatially explicit basis (see discussion in Efroymson et al., this issue), the category "temporal continuity of land cover type" could reflect succession, but the developers of this methodology believed that changes from one land cover type to another over time typically reflect human management activities rather than ecological succession (M. White, EPA, personal communication, June 2005).

5.4. Multiple metrics

Given that indices are not used to score measures of habitat value in this study, the question arises concerning how all of these metrics may be evaluated together. Weight-of-evidence guidance for ecological risk assessment may be useful here. Evidence is judged based on relevance, quantity, quality, and uncertainty of data, among other criteria (Suter et al., 2000). Relevance comprises factors such as direct versus indirect measures and appropriate spatial scale. For, example, we suggest relying on more direct measures of use (species richness) than less direct (complexity of habitat) if the scores are in conflict. However, even direct measures of use (species richness) should be accompanied by the consideration of the presence of invasive or other non-native species. For some habitat value parameters (use by vegetation), the use of multiple indirect measures is recommended, because direct measures (species richness) are not available. Moreover, we recommend that the spatial scales of analysis be adjusted to the needs of risk managers. If only a fraction of a site (e.g., Mitchell Branch, Contractor's Spoil area, K-770 scrapyard) is under consideration for remediation, then the user of this analysis can sometimes extract habitat value information for just that fraction (e.g., the industrialized portion of Mitchell Branch, the fescue-covered disposal area of the contractor's spoil area, or the gravel-covered areas of the scrapyard). Some habitat value information may be ignored; habitat suitabilities for most mammals at these sites are not very important, because the mammals on the ORR (other than bats) are generalists. In this study, the precision of scoring criteria is also an important determinant of the reliability and uncertainty of habitat value judgments. For example, data for waterbird species richness at reference sites were not available, so the scoring criteria have been set arbitrarily. Also, we have not adjusted expected species richness values for pond areas, though larger ponds would be expected to host more species.

5.5. Extrapolation of results

Habitat valuations of other contaminated sites at ETTP may benefit from the results of this study. Although, for example, we cannot directly transfer the valuation results from the six study sites to other candidates for remediation, we can offer guidance for doing rapid valuation studies. All terrestrial areas covered by mowed fescue or impermeable or barren ground would be expected to have low habitat use value for plants and vertebrates. Forested and early successional areas could have medium or high value for plants and vertebrates. The reason that the valuation at these sites has not been so straightforward is the presence of multiple highly disturbed and less disturbed habitat patches within a site and (in the case of the K-770 scrapyard) lack of access to the site. An important question is whether the habitat value results would have been the same in the absence of direct measures of habitat use (species richness). The answer is no. The estimate of habitat value based on habitat complexity alone was often not the same as that based on fish, lepomid sunfish, benthic invertebrate, or waterbird species richness. One might have guessed that the bird taxa richness in the forest at the Contractor's Spoil Area would have medium value, but by our measure, it had high value. Similarly, the only way to get to the observation of gray bats at the K-1007-P1 pond was through direct surveys.

5.6. Use of habitat valuation results

Perhaps the most important question to answer is how this specific habitat valuation information will be used. A report on this habitat valuation was appended to the Remedial Investigation-Feasibility Study for the ETTP Site (DOE, 2006). Possible general uses of habitat valuation results are described in the companion paper (Efroymson et al., this issue). It is possible to see some influence of this study in the development of potential remedial alternatives. This habitat valuation provided information that supported the development of the no-action alternative for the K-901 pond. This study also showed that long-term habitat impacts of the Mitchell Branch liner have not been severe, and thus this study might support a decision not to remove the liner. One potential remedial alternative for the K-1007-P1 Pond has been designated the "Ecological Management and Enhancement Alternative." The goals of this alternative are to enhance habitat for some groups of fish while reducing it for those that accumulate PCBs, partly by increasing macrophyte density (Peterson et al., 2005b). Even if this remedial alternative is not selected, it is important to note that the discussion has been framed, at least in part, by an evaluation of natural resource benefits. We expect to see far more contaminant remedial alternatives proposed in the future that involve less excavation and more biomanipulation and ecological restoration.

6. Conclusions

A new method for assessing habitat value of contaminated aquatic and terrestrial sites was implemented at ETTP in Oak Ridge, TN, USA. Significant variation in habitat value was observed among six sites, among measures for different taxa at a single site, between measures of use and rarity at a single site, and among measures for particular taxa at a single site with respect to

different spatial scales. High scores for current use value included: wetland plant communities at all aquatic sites, Lepomid sunfish (littoral zone) and waterbirds at 1007-P1 pond, and Lepomid sunfish and amphibians at K-901 pond. Moreover, all aquatic sites (plus the Clinch River and Poplar Creek) create a high-value ecological corridor for waterbirds, and the Contractor's Spoil Area and possibly the K-901-N Disposal Site have areas that are part of a strong terrestrial ecological corridor. The only site with rarity value was the K-1007-P1 pond over which a gray bat was observed.

The strengths of the method are that general habitat valuation metrics can be operationalized for groups of organisms at any aquatic or terrestrial site and that land managers can focus on metrics of habitat value that are of most concern to them. The weakness is that supporting data may not be available for all aspects of habitat value. The method and metrics are data-intensive—not only with respect to the site of interest but with respect to the regional context. Moreover, habitat corridors may not be obvious without data-intensive models. Because of its high ecological resource value, history of contamination, and use as a research park, the Oak Ridge Reservation has extensive data sets for use in this type of valuation. Furthermore, extensive regional and broader data were available from the Southern Appalachian Man in the Biosphere program. Even so, aspects of the case study habitat valuation were data-limited. For example, habitat valuation metrics were not developed for mammals because of a lack of monitoring data at the case study sites. The use of the habitat valuation methods by assessors at other contaminated sites may be limited to narrower sets of species.

Along with ecological risk assessment, habitat valuation provides science to inform remedial decision-making. Sometimes this valuation may show that the no-action alternative provides greater habitat value than remediation.

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