Protection of Biota on Nonpark Public Lands: Examples from the US Department of Energy Oak Ridge Reservation[1,2]

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ABSTRACT / Security buffers of Department of Defense (DoD) and Department of Energy (DOE) reservations provide long-term habitat protection for many rare and endangered species. The importance of these government-owned reservations as nationally valuable resources has been relatively unrecognized. During the last 50 years, the DOE Oak Ridge Reservation (ORR) has been a relatively protected island in a region of rapidly expanding urbanization and land clearing. Consisting of the Oak Ridge National Environmental Research Park and associated lands surrounding DOE facilities at Oak Ridge Tennessee, the unique nature of the ORR in the surrounding landscape is clearly visible from the air and has been documented using remote sensing data. Although forests dominate much of other regions of eastern Tennessee, this 15,000-ha tract of mostly natural forest habitat is unique in the southern Ridge and Valley physiographic province, which is otherwise widely developed for pasture, marginal cropland, woodlot, and urban uses. Twenty state-listed and federal-candidate plant species are known to be present on the ORR. This richness of species, which are provided protection by state and federal laws, exceeds that of the Great Smoky Mountains National Park on a species area basis and is an index of the value of the ORR both regionally and nationally in conserving biodiversity. With the end of the Cold War, changing DoD and DOE missions combined with increasing development pressure contribute to uncertainty in the future management of security reservations.

Many public lands in the United States, such as national parks and national forests, traditionally have been managed for their importance in the protection of biotic resources. These lands provide protected havens for native biota and reservoirs for wildlife that supply species to surrounding areas. Large protected tracts provide space for area-sensitive species that otherwise may be absent or scarce in the region.

However, other long protected areas that are less well known for their role in conservation are the security reservations of both the US Department of Defense (DoD) and US Department of Energy (DOE). Many DoD and DOE lands are potentially unique as protected areas because the criteria used to select the lands differ substantially from those that apply to most other national public lands. Many national forest, park, and Bureau of Land Management (BLM) lands have been designated as public land by the federal government because of their low economic value (Huston 1993). DoD and DOE lands were chosen for other criteria: location relative to energy supplies, water transport, or isolation for national security, for example. DOE and DoD lands have been managed primarily to provide a security buffer around agency mission activities. Other land uses on these government-owned reservations have been subordinate to agency missions and have included timber management and a limited amount of grazing, other agricultural use, and hunting. As a result, DoD and DOE lands have often protected biotic communities under represented in other US public lands. As urban

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and agricultural development has expanded, natural ecosystems have decreased in areas surrounding these DoD and DOE security reservations. These ecosystems are often representative of types that were once abundant and widespread in the United States but are increasingly threatened by human development (Noss and others 1995). As agency missions have changed over the years, the protected status of security reservations has also changed, especially at the DOE facilities where large security buffer areas have become less important as missions have shifted away from production of nuclear weapons components. With the end of the Cold War and intensifying development pressure, the future of security reservations is uncertain. DOE is currently evaluating the future use options for its land areas.

The Nature Conservancy and DoD have recently undertaken biological inventories of DoD lands to search for and protect rare species and habitats on military reservations (Nickens 1993). DOE reservations, such as the Oak Ridge Reservation (ORR) in Tennessee, the Hanford reservation in Washington (Gray and Rickard 1989), and the Savannah River Site in South Carolina (Cohn 1994) also contain examples of natural ecosystems supporting rare species on lands surrounded by increasing development. Undeveloped areas of many DOE reservations, including the ORR, are managed as National Environmental Research Parks—important research reference areas for experimental comparisons with human land use in surrounding areas. Designation of the DOE ORR as a mangement unit in the Southern Appalachian Man and the Biosphere (SAMAB) regional biosphere reserve is additional recognition of the importance of these sites both for research reference areas and protection of biotic diversity (Franklin 1977, Franklin and others 1990, MAB Task Force 1974).

Like other government-owned security buffer areas around DoD and DOE facilities (Cohn 1994, Gray and Rickard 1989, Nickens 1993), the ORR's plant and animal life is situated in a relatively intact ecosystem that is highly diverse when compared with surrounding areas in the same physiographic province. The ORR—protected from land-use development that has affected the surrounding private land for the last 50 years—provides an invaluable reference point for determining the effects of human activities on natural resources in general and in the Ridge and Valley physiographic province in particular. Current management of the ORR includes control of access (the ORR is generally closed to the public), maintenance of security buffers around production and research facilities, enhancement of ecological research opportunities, and conservation of natural resources, including inventories of populations and designation of protected natural and research reference areas (Cunningham and others 1993, Pounds and others 1993). Managment decisions are made by the Oak Ridge Operations DOE Land Management committee, which receives recommendations from an ORR Resource Management Organization (RMO). The RMO evaluates potential impacts to all aspects of operation and management of the ORR including security, emergency management, site development, environmental compliance, as well as ecological concerns.

The future of the ORR is uncertain. DOE is currently evaluating options for future use including acquiring input from external stakeholders and assessing biodiversity of the ORR through the Nature Conservancy (1995). External pressure to use DOE land for economic growth has always been important and will continue to affect management decisions. For example, during the early years of the ORR, a forest management program was established to make economic use of the "unused" land inside the security buffer and some preexisting hayfields have continued to be managed for economic return. Changes in international and national politics and economics and changing national priorities have affected DOE missions and have paralleled increasing pressures on DOE to release ORR land for industrial or residential development. Although the future of DOE and DoD lands is uncertain, their importance to conservation of biodiversity in the United States should not be overlooked.

Using the ORR as an example of the importance of DoD and DOE lands in conservation, this paper details the history of the ORR, its current biological significance relative to the surrounding landscape, and the relationship of past and present management of the ORR to the persistence of important biological resources. Remote-sensing data, biotic and land-use reconnaissance information, and intensive biotic surveys with emphasis on endangered, threatened, and sensitive plant species are used. Plant species are emphasized because more information on them is currently available than for other organisms on the ORR.

History of ORR

The ORR, consisting of the Oak Ridge National Environmental Research Park and associated lands surrounding DOE facilities at Oak Ridge, Tennessee, is about 15,000 ha of mostly contiguous native forest. As with other DOE and DoD sites, the federal government acquired the ORR's approximately 1000 individual farmsteads consisting of forest, woodlots, open-grazed woodlands, and fields as a security buffer for military activities (Figure 1) (Fielder and others 1977). Agricultural practices of the time resulted in severe erosion on

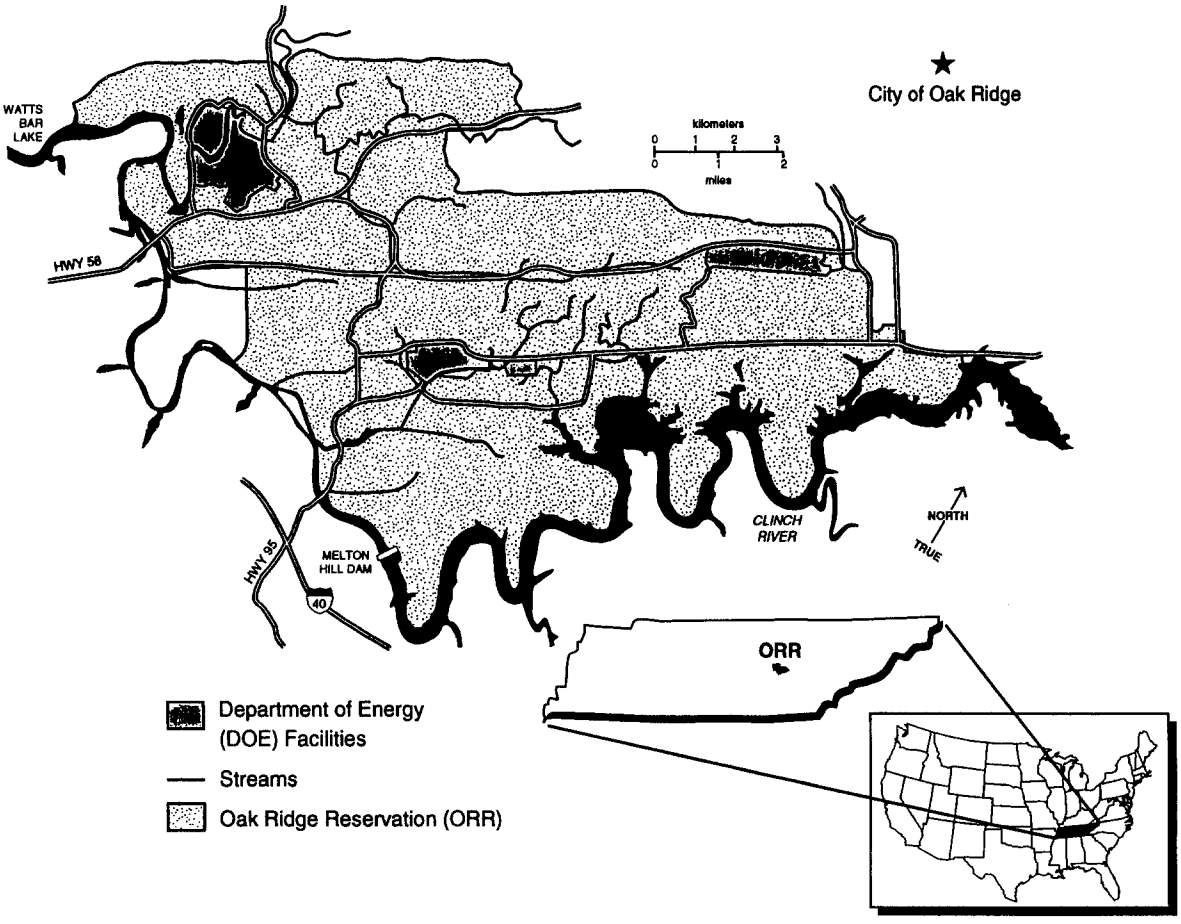

Figure 1. The Oak Ridge Reservation.

most slopes. Except on very steep slopes, most of the forest was cut for timber—although not necessarily cleared—and many partially cut forest areas were used as rough pasture (Dale and others 1990).

After public access to the ORR lands was restricted in 1942, natural succession and planting of pines resulted in reestablishment of forests on most of the reservation. Between 1948 and 1954, many of the abandoned fields were planted with native and nonnative pine plantations. By 1977, less than 1000 ha was maintained as experimental pasture, hay, or cropland (Strock 1970). Some of that agricultural land is no longer part of the ORR, and much of the remainder is in early successional vegetation. From 1965 to 1986, the ORR was selectively logged and pine plantations replaced some natural regeneration as part of a timber management program. Forests are not currently managed for timber production.

In the mid-1950s, white-tailed deer (*Odocoileus virginianus*) became reestablished on the ORR. Because of steadily increasing collisions of vehicles with deer and liability concerns, public deer hunts are now conducted annually. Currently, all of the ORR is a wildlife management area, managed by the Tennessee Wildlife Resources Agency (TWRA) (Parr and Evans 1992).

Of the nearly 24,000 ha originally included in the ORR in 1942, about 8500 ha have been released from federal ownership to the City of Oak Ridge, primarily during the 1950s as the city was incorporated. In subsequent years, other federal agencies have received about 1200 ha, including a future industrial park site, and additional areas have been released to the City of Oak Ridge for residential, commercial, and industrial use, including two highway corridor industrial parks, a commercial/office park, a residential area, and an area whose future is currently undecided. Of the remaining 15,000 ha of the ORR, less than 3000 ha contain developed sites for the three DOE facilites, less than 1400 ha are in waste sites or remediation areas, and about 8700 ha is Research Park.

Within the undeveloped areas of the ORR, current natural resource management emphasizes legal compli-

ance issues, such as threatened and endangered species and wetlands. Management decisions incorporate best management practices for streams and wetlands and, when economically feasible, enhance targeted natural populations and ecosystems.

Land-Cover Patterns

All areas of the ORR are relatively pristine when compared with the surrounding region, especially in the Ridge and Valley province. From the air, the ORR is clearly a large and nearly continuous island of forest within a landscape that is fragmented by urban development and agriculture. Satellite imagery, aerial photographs, and surface reconnaissance were used to develop a land-use cover map of the ORR and surrounding lands to document this pattern (Chatfield and Graham 1993).

Results of the remote-sensing analyses show that in 1984 and 1987, about 70% of the ORR was in forest cover and less than 2% remains as open agricultural fields (Figure 2). The forests are mostly oak–hickory (*Quercus–Carya*), pine–hardwood (*Pinus*–hardwood), or pine. Communities are generally characteristic of the intermountain regions of Appalachia. Oak–hickory forest, which is most widely distributed on ridges and dry slopes, is the dominant association. Minor areas of other hardwood forest cover types are found throughout the ORR; however, these were not identifiable from the remote-sensing data. They include northern hardwoods, a few small natural stands of hemlock (*Tsuga canadensis*) or white pine (*Pinus strobus*), and floodplain forests.

Successional and planted native shortleaf (*Pinus echinata*) and Virginia (*P. virginiana*) and nonnative loblolly (*Pinus taeda*) pines have been important forest components on the ORR on old fields. Following episodic outbreaks of the native southern pine beetle, hardwoods, such as tulip-poplar (*Liriodendron tulipifera*), have replaced pines through natural succession in some of these areas (Figure 3).

Unique Biotic Features and Land Use

As is the case for other DOE sites (Gray and Rickard 1989, Reynolds and others 1986), the ORR is both a refugium for rare species (Table 1) and an area of recruitment to surrounding environments. Although few data are available to characterize emmigration of biota from the ORR (see wildlife discussion below), many ecological communities with unique biota, often including rare species, are known to exist within the larger framework of mixed hardwood and pine forest on the ORR. These communities were not detectable by the remote sensing because their spectral characteristics were indistinguishable from others; they were identified instead during botanical surveys. A preliminary report on biodiversity of the ORR by the Nature Conservancy (1995) recognized 69 distinct conservation sites and three large landscape complexes important because of concentrations of rare species, rare communities, and large blocks of relatively high-quality vegetation. Biologically important communities on the ORR, including six Tennessee State Registered Natural Areas, occur in areas of uncommon soil types, river bluffs, seeps and springs, and in large expanses of forest (Pounds and others 1993). Cedar barrens, river bluffs, and wetlands are habitat for most rare species on the ORR.

Cedar Barrens

Cedar barrens (DeSelm 1994, DeSelm and Murdock 1993, DeSelm and others 1969), also called xeric limestone prairie (Baskin and others 1994), are naturally occurring forest openings on shallow, flaggy limestone soils throughout the Ridge and Valley province. In general, barrens are convenient for construction, off-road vehicles, and dumping. They are generally unsuitable for tillage crops but are sometimes used for intensive grazing, which has resulted in species impoverishment (DeSelm 1989, DeSelm and others 1969). In contrast to sites in surrounding areas, species assemblages typical of barrens have persisted on the ORR in many locations (Figure 4) (Cunningham and others 1993, Pounds and others 1993). Many of these openings have decreased in size during the past 50 years, perhaps because of too much protection from disturbance. Future management of these areas may need to include controlled burning, selective removal of encroaching forest, or intermittent grazing, which are thought to be important for maintaining barrens (DeSelm 1994, DeSelm and Murdock 1993) and to ensure their long-term persistence. Currently, these areas are not actively managed except for mowing in rights-of-way.

One of the ORR's cedar barrens hosts one of the largest known populations of tall larkspur (Table 1) in the world. Absent from adjacent areas that were recently grazed, this population expanded rapidly on a newly created 90-m-wide utility corridor and is abundant in older utility corridors managed by annual winter mowing after seed capsule maturation. Another unique barrens complex that was originally part of the ORR is Crowder Barrens State Natural Area, which contains four state endangered plant species (Somers 1989): prairie goldenrod (*Solidago ptarmicoides*), slender blazing star (*Liatris cylindracea*), earleaf foxglove (*Agalinus auriculata*), and tall larkspur. (The latter two are also candidates for federal listing.) The Crowder barrens experienced an intermittent disturbance regime for several

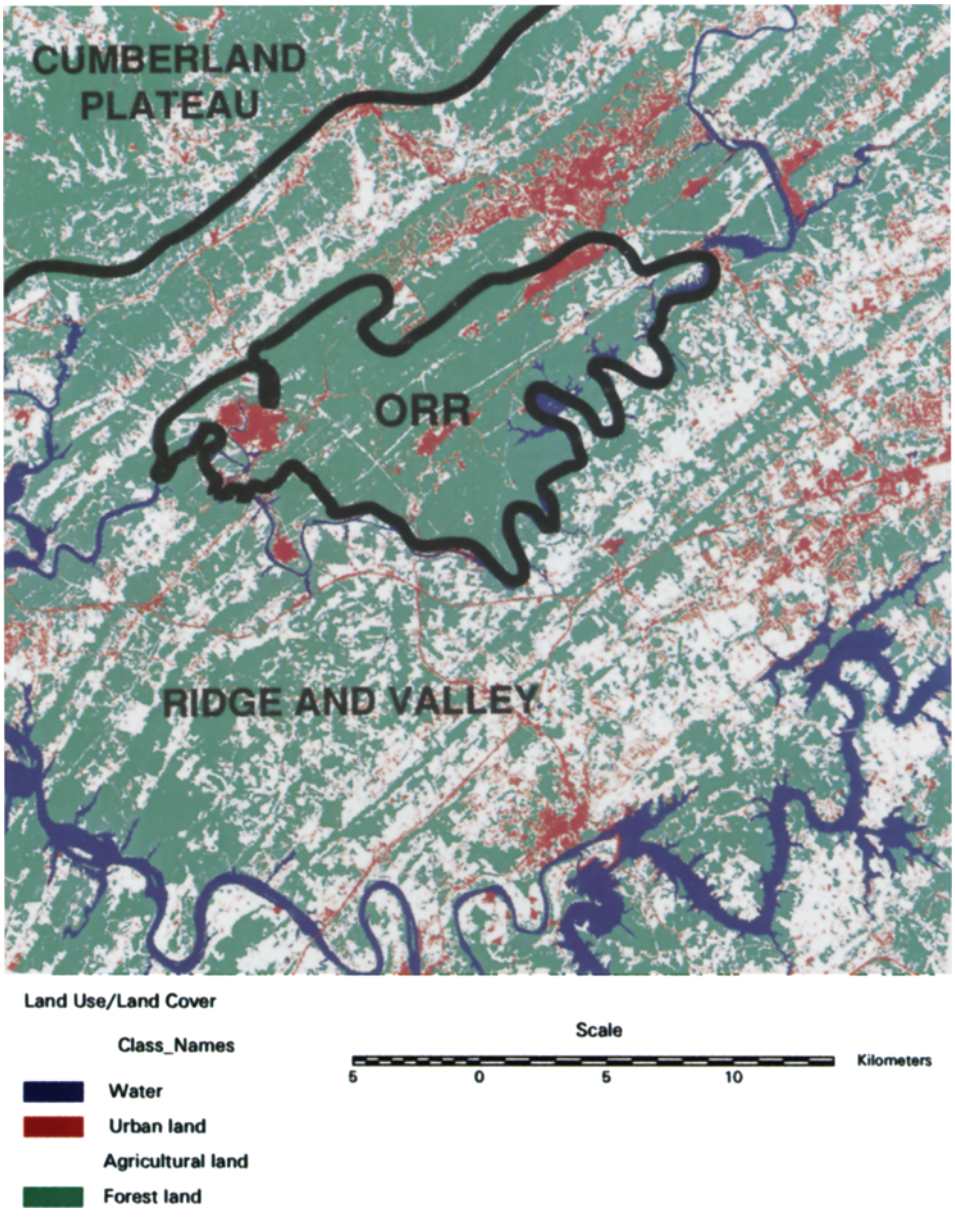

Figure 2. Regional land-use map. Figure prepared from a 1984 Landsat Thematic Mapper image by R. Washington-Allen and T. Chatfield.

years as a maneuvering ground for military tanks by the national guard. Disturbances at these two sites were apparently compatible with the persistence of these rare plant species. Discussions among ecologists at Oak Ridge National Laboratory, US Fish and Wildlife Service, Tennessee Department of Environment and Conservation, and the Nature Conservancy are currently underway to plan active management of tall larkspur populations on the ORR.

River Bluffs

Limestone river bluffs occur on the ORR where the Clinch River and its major tributaries have cut through alternating limestone and siltstone ridges (Figure 5). A series of dams on the Tennessee River and its tributaries has resulted in permanent flooding of most lower slope and bluff habitats along rivers and lower reaches of major streams in the Ridge and Valley province of Tennessee. Below Melton Hill Dam (Figure 1), where less suitable habitat is permanently flooded on the ORR, some river bluff communities have greater vertical distribution than above the dam. River bluffs on the ORR range from sheer cliffs to steep rocky slopes. Five state-listed species, including three candidates for federal listing (USDI-FWS 1993) (spreading false foxglove, Appalachian bugbane, Carey's saxifrage, northern bush-

Figure 3. Tulip poplar (*Liriodendron tulipifera*) on an abandoned field adjacent to native forest and young pine plantation.

Figure 4. Typical cedar barren on the ORR.

honeysuckle, and butternut) (Table 1) are found in these communities. River bluff communities are generally less susceptible than cedar barrens to ongoing habitat loss because they are too steep and rocky for agricultural use and generally unsuited to intensive urban development other than home construction, trampling, and canopy removal in highly valued lake-front or lake-view property. These sites are not actively mangaed on the ORR. Future management decisions will be based on field studies currently in progress.

Wetlands

Wetlands in the Ridge and Valley province, as in most of the United States, have been lost because of permanent flooding by impounded rivers, drainage, conversion to agricultural use, fill, and urban develop-

Table 1. Status of ORR rare plants[a]

Species	Status[b] Federal	State
Aureolaria patula (spreading false foxglove)	C2	E
Cimicifuga rubifolia (Appalachian bugbane)	C2	T
Delphinium exaltatum (tall larkspur)	C2	E
Juglans cinerea (butternut)	C2	T
Cypripedium acaule (pink lady-slipper)		E
Liparis loeselii (fen orchid)		E
Diervilla lonicera (northern bush-honeysuckle)		T
Fothergilla major (mountain witch-alder)		T
Hydrastis canadensis (goldenseal)		T
Lilium canadense (Canada lily)		T
Panax quinquifolius (ginseng)		T
Platanthera flava var *herbiola* (tuberculed rein-orchid)		T
Platanthera peramoena (purple fringeless orchid)		T
Elodea nuttallii (Nuttall's waterweed)		S
Saxifraga careyana (Carey's saxifrage)		S
Spiranthes ovalis (lesser lady's tresses)		S
Carex gravida (heavy sedge)		S
Draba ramosissima (branching Whitlow grass)		S
Juncus brachycephalus (small-headed sedge)		S
Scirpus fluviatilis (river bulrush)		S

[a]Nearly half of all state-listed or federal-candidate species currently growing on the ORR are found in or near wetlands.

[b]E = endangered; T = threatened; C1 = proposed federal listing likely; C2 = candidate for federal listing, more information needed; S = special concern in Tennessee (USDI-FWS 1993, Somers 1989).

ment. Because wetland soils are often productive when drained, wetlands are probably more affected by agricultural use in the surrounding region than are other natural communities.

On the ORR, biologically important wetlands occur along intermittent stream drainages in cleared utility corridors that parallel ridges and in wet meadows and marshes associated with streams and seeps (Figure 6) (Cunningham and Pounds 1991, Pounds and others 1993). Although most wetland species found in the ORR's wetlands are common and widespread throughout the region, at least nine wetlands are biologically important, containing state-listed or federal-candidate species. Two are recognized as state-registered natural areas including the unique Hembree Marsh State Natural Area. Nearly half of all state-listed or federal-candidate species on the ORR are found in or near wetlands (Table 1), including three orchids, two sedges, the Canada lily, river bulrush, and Nuttall's waterweed.

All of these species and communities are assumed to be vulnerable to prevailing land use outside the ORR, especially alteration of hydrology of wetland habitats, grazing, and other agricultural use. Before enforcement of wetland protection regulations, urban development destroyed many wetland habitats. In recent years, a "no net loss of wetlands" policy on the ORR has effectively protected these species, even in areas where development or environmental restoration projects have taken place. Additionally, beaver populations have reestablished on the ORR within the last 10 years. The long-term biotic effects of this active restorer of wetlands are not known, but their damming of major streams and tributaries is creating additional temporary wetlands. Currently, management of wetlands consists of delineation, mapping, and avoidance of wetlands and floodplains. Populations of wetland orchids are often dynamic, and optimal management of habitats for these species is not currently known.

Wildlife

In contrast to the protection of plant species, which may be effective on fairly small areas, large blocks of land are often necessary to provide adequate protection for many species of wildlife. The large protected area of the ORR provides a refugium for about 60 reptilian and amphibian species; more than 120 species of terrestrial birds; 32 species of waterfowl, wading birds, and shorebirds; and about 40 mammalian species (Parr and Evans 1992). As part of current environmental restoration projects, extensive data on the distribution and occurrence of wildlife throughout the ORR are being collected and will contribute to future management decisions. At present, undisturbed limestone caves and adjacent bluffs are known to provide habitat on the ORR for the federal-candidate (USDI-FWS 1994a) green salamander (*Aneides aeneus*) and may also be used by the recently reported federally endangered (USDI-FWS 1991) gray bat (*Myotis grisescens*). Although none of the rare large mammalian predators have resident populations on the ORR (the area is not large enough to support them) (Kroodsma 1987), smaller mammalian predator populations and several protected raptorial birds are known to use the ORR for either foraging or breeding (Parr and Evans 1992).

The protected natural ecosystems adjacent to river reservoirs and embayments bordering the ORR have also provided unique opportunities for waterbirds. These include successful nest platforms for state threatened osprey (*Pandion haliaetus*), two rookeries of great blue herons (*Ardea herodias*), feeding areas for the black-crowned night heron (*Nycticorax nycticorax*), and foraging and nesting areas for a large nonmigratory population of Canada geese (*Branta canadensis*) (Parr and Evans 1992, Pounds and others 1993).

Figure 5. Rocky slope and limestone bluff on the ORR adjoining Melton Hill Lake.

Figure 6. Forested wetland on the ORR.

The ORR is known to be both a reservoir and source for several species whose young leave the reservation. These include white-tail deer (*Odocoileus virginianus*) (Story and Kitchings 1982), bobcat (*Lynx rufus*) (Kitchings and Story 1979), fox (*Vulpes* sp.) (Greenberg and others 1988), osprey, and great blue heron. American wild turkey (*Meleagris gallopavo*), which were introduced to the ORR in 1986 and 1987 (Minser and others 1992), have been so successful that they are now trapped and exported to other areas by TWRA to establish breeding flocks, as deer have been in the past. The Canada goose population has also been extremely successful and will be used to stock other areas.

Long-term protection of large blocks of natural vegetation on the ORR has provided many headwater streams of high water quality. Most streams of similar soil and topographic position in the surrounding region are highly impacted by agricultural use, land clearing,

and development. The Tennessee dace (*Phoxinus tennesseensis*), listed by Tennessee as in need of management, is restricted to very small, generally less than 2-m-wide, low-gradient woodland tributaries in the upper Tennessee River drainage. Fewer than 40 populations of this species are known to exist. It is abundant in seven streams on the ORR, which may be a stronghold for the species (Etnier and Starnes 1993). Stream management zones provide some protection of habitat for the dace, but entire watersheds require careful management to ensure maintenance of water quality and streamflow.

As natural habitats around the globe continue to shrink and conflicts arise over attempts to protect listed species, increasing attention is being focused on populations of neotropical migrant land birds, amphibians, and other fish and wildlife that are declining at an alarming rate but are not legally protected as rare species. The relatively pristine natural condition of the ORR provides a protected environment for species vulnerable to characteristic human activities, especially those species that require large blocks of contiguous forest.

The importance of forests in the Tennessee Valley flyway to small migratory land birds is currently being investigated (Ford and Cooper 1993). Because few large blocks of forest remain in this region of the Ridge and Valley province, indivdual remaining blocks of forest may be critical to some species for foraging and resting. Many species sensitive to nest predation and parasitism (Terborgh 1989) are more likely to nest successfully in the large contiguous forest blocks of the ORR than in the surrounding region. Some neotropical migrant birds reported to nest on the ORR, including the red-eyed vireo (*Vireo olivaceous*), federal-candidate cerulean warbler (*Dendroica cerulea*), and Louisiana water thrush (*Seiurus motacilla*) (Anderson and Shugart 1974) as well as the local migrant red-shouldered hawk (*Buteo lineatus*) and resident pileated woodpecker (*Dryocopus pileatus*), have the maximum probability of occurrence in blocks of contiguous forest greater than 3000 ha (Robbins and others 1989). Although some area-sensitive species apparently will nest in much smaller areas, some, such as the cerulean warbler, are rarely found in forest patches of less that 700 ha, and all are more likely to be present near large blocks of forest (Robbins and others 1989).

Historically, there has been no active management of the ORR to meet the needs of these woodland species. Current management includes identification of important landscape areas and allowing natural succession or planted native pines and hardwoods to revegetate sites previously planted in nonnative loblolly pine. Recently identified nesting areas of the grasshopper sparrow (*Ammodramus savannarum*), listed by Tennessee as in need of management, are in active hayfields. The mowing schedule of these areas has been modified to enhance nesting success.

Biotic Significance of Protection of Representative Ecosystems

As is true for many DoD and DOE reservations, parts of the ORR were farmland at one time. Agricultural practices of the region 50 years ago included row crops grown on highly erodable soils and overgrazing. Both practices resulted in severe erosion and loss of productivity, but most early farming practices did not result in extensive eradication of native plant populations as do many current practices. Fescue grass, a highly invasive exotic that tends to crowd out native species, became widely used only after World War II (DeSelm 1994). Comparatively complete barrens communities that were used for pasture prior to 1942 (DeSelm and others 1969) have survived on the ORR, while some pastures on similar soil types in counties adjacent to the ORR are dominated by fescue. Mowed and heavily grazed barrens lose more that 15 and 65% of typical barrens species, respectively (DeSelm 1989).

The presence of 20 species of listed plants (Table 1) is an important indicator of the unique character of ecosystems on the ORR, in contrast to the surrounding region's extensive land clearing and urbanization. The ORR is richer in federally listed and candidate plant species, on an area basis, than the Great Smoky Mountains National Park (GSMNP), one of the richest centers of biodiversity in the eastern United States (Table 2). Although this comparison ignores abundance, vigor, and relative importance of the ORR and GSMNP to individual species, it does highlight the value of the ORR Ridge and Valley site to biodiversity and reflects the massive loss or degradation of habitat of plant species originally found in habitats suitable for agriculture and urban development in the Ridge and Valley province.

The difference in distribution and extent of forest habitats on the ORR compared with the surrounding area is clearly visible from an aerial view. The ORR is unique in its location and composition in the Ridge and Valley province. Other large contiguous blocks of forest and protected lands are located either on the Cumberland Plateau to the west or in the Blue Ridge province to the east. The only other large protected block of forest in the Ridge and Valley province in Tennessee is Chuck Swann Wildlife Management Area, a large forested tract north of the ORR. The valleys of the Chuck Swann refuge are flooded by Norris Lake, however, leaving only the forested ridges above water.

Table 2. Comparison of the ORR with Great Smoky Mountains National Park (GSMNP)[a]

	Area (ha)	Federally listed or candidate species (N)	Number per ha	Approximate elevation range (m)	Total number of vascular plant species
GSMNP	439,000	13	3.0×10^{-5}	1500	1300[b]
ORR	30,316	4	13.2×10^{-5}	180	1000[c]

[a]The ORR is richer in federally listed (USDI-FWS 1994b) or candidate plant (USDI-FWS 1993) species, on an area basis, than the Great Smoky Mountains National Park (GSMNP), one of the richest centers of biodiversity in the eastern United States.

[b]White (1982).

[c]Cunningham and others (1993).

Two major challenges face ORR and other DOE and DoD natural resource management in the future: responding to development pressure and pursuing economically viable active management options. Management will continue to be structured primarily by agency missions, and secondarily by economic, compliance, and liability issues. However, in contrast to the sometimes negative public image of DOE and DoD reservations as polluted, radioactive, or munitions-strewn wastelands, many reservations also provide high-quality habitat for threatened and endangered species. All of the agency management constraints provide opportunities for enhancement and conservation of selected species and ecosystems.

Conclusions

Management of the DOE ORR as a security buffer has resulted in long-term habitat protection for many important species because of the history, edaphic features, and lack of traditional land use and development on ORR lands during the last 50 years. Ecosystems on the ORR contian one of the largest known populations of federal-candidate tall larkspur and originally contained one of the region's highest quality cedar barren communities. After experiencing prevailing land-use and development pratices up to the time of acquisition, it has become a natural laboratory of ecosystems that have experienced 50 years of natural processes. It also contains large blocks of contiguous forest that provide habitat for area-sensitive species, protection for species vulnerable to human activities, and opportunities for comparison of natural ecosystem functions of the Ridge and Valley with the surrounding region. Although the importance of park and national forest lands to conservation is widely recognized, protected ecosystems like those found on DOE reservations—in regions of rapidly expanding urbanization and land clearing—are less well known. Ongoing surveys of DoD reservations by the Nature Conservancy and of DOE reservations by researchers at National Environmental Research Parks are identifying reservoirs of listed species, further emphasizing the importance of these public lands to the conservation of biotic diversity. The future of natural resources on the ORR and other DOE and DoD lands is uncertain. The interplay between changing political needs and agency missions, the continuing pressure for economic development, and public demands for protection of natural resources will determine future mangement opportunities. Increasing public awareness of ecological issues and the need for compliance with environmental laws will ensure some protection of specific resources such as threatened and endangered species. Other important ecological attributes that are not protected by law, including cedar barrens, large blocks of native forest, and native riparian and valley communities of the ORR are certain to be threatened with future industrial and residential development.

Note Added in Proof

A preliminary assessment of biodiversity of the ORR by the Nature Conservancy completed in May 1995 noted 272 occurrences of significant plant and animal species and communities. Using Natural Heritage Network ranking systems, 81 conservation areas were identified as being of high or very high significance on the basis of clusters of rare species and plant communities. Three large areas comprising about two thirds of the relatively undeveloped regions of the ORR were identified that should be protected as ecologically important landscape complexes.

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Literature Cited

Anderson, S. H., and H. H. Shugart. 1974. Habitat selection of breeding birds in an east Tennessee deciduous forest. *Ecology* 55:828–837.

Baskin, J. M., C. C. Baskin, and E. W. Chester. 1994. The big barrens region of Kentucky and Tennessee: further observations and considerations. *Castanea* 59:226–254.

Chatfield, T. A., and R. L. Graham. 1993. A land use/land cover map of the Oak Ridge Reservation and surrounding lands. Unpublished report, Environmental Sciences Division, Oak Ridge, Tennessee, 38 pp.

Cohn, J. P. 1994. A national natural laboratory: a look at the Savannah River Site, an ecological study area that shelters wild animals and dead nuclear reactors. *Bioscience* 44: 727–730.

Cunningham, M., and L. Pounds. 1991. Resource management plan for the Oak Ridge Reservation. Volume 28: wetlands on the Oak Ridge Reservation. ORNL/NERP-5, Oak Ridge, Tennessee, 48 pp.

Cunningham, M., L. Pounds, S. Oberholster, P. Parr, L. Edwards, B. Rosensteel, and L. Mann. 1993. Resource management plan for the Oak Ridge Reservation. Volume 29: rare plants on the Oak Ridge Reservation. ORNL/NERP-7, Oak Ridge, Tennessee, 93 pp.

Dale, V. H., L. K. Mann, R. J. Olson, D. W. Johnson, and K. C. Dearstone. 1990. The long-term influence of past land use on the Walker Branch forest. *Landscape Ecology* 4: 211–224.

DeSelm, H. R. 1989. The barrens of Tennessee. *Journal of the Tennessee Academy of Science* 64:89–95.

DeSelm, H. R. 1994. Tennessee barrens. *Castanea* 59:214–225.

DeSelm, H. R., and N. Murdock. 1993. Grass-dominated communities. Pages 87–141 *in* W. H. Martin, S. G. Boyce, and A. C. Ecternacht (eds.). Biodiversity of the southeastern United States. Upland Terrestrial communities. John Wiley & Sons, New York.

DeSelm, H. R., P. B. Whitford, and J. S. Olson. 1969. The barrens of the Oak Ridge Area, Tennessee. *American Midland Naturalist* 81:315–330.

Etnier, D. A., and W. C. Starnes. 1993. The fishes of Tennessee. University of Tennessee Press, Knoxville, Tennessee.

Fielder, G. F., Jr., S. R. Ahler, and B. Barrington. 1977. Historic sites reconnaissance of the Oak Ridge Reservation, Oak Ridge Tennessee. ORNL/TM-5811, Oak Ridge, Tennessee, 95 pp.

Ford, B., and B. Cooper. 1993. Tennessee partners in flight: birds and biodiversity. *Tennessee Wildlife* 16:5–12.

Franklin, J. F. 1977. The biosphere reserve program in the United States. *Science* 195:262–267.

Franklin, J. F., C. S. Bledsoe, and J. T. Callahan. 1990. Contributions of the long-term ecological research program. Bioscience 40:509–523.

Gray, R. H., and W. H. Rickard. 1989. The protected area of Hanford as a refugium for native plants and animals. *Environmental Conservation* 16:251–260, 215–216.

Greenberg, C. H., M. R. Pelton, and P. D. Parr. 1988. Gray fox ecology in the Oak Ridge Environmental Research Park: food habits, home range, and habitat use. ORNL/NERP-3, Oak Ridge, Tennessee, 160 pp.

Huston, M. A. 1993. Biological diversity, soils, and economics. *Science* 262:1676–1680.

Kitchings, J. T., and J. D. Story. 1979. Home range and diet of bobcats in eastern Tennessee. Pages 47–52 *in* Proceedings of the bobcat research conference, National Wildlife Federation science and technology series 6. National Wildlife Federation, Front Royal, Virginia.

Kroodsma, R. L. 1987. Resource management plan for the Oak Ridge Reservation. Vol. 24: threatened and endandgered animal species. ORNL/ESH-1/V24, Oak Ridge, Tennessee, pp. 6–12.

MAB Task Force. 1974. Criteria and guidelines for the choice and establishment of biosphere reserves. MAB Report Series 22. UNESCO, Paris, 61 pp.

Minser, W. G., S. G. Seibert, and J. C. Cole. 1992. Wild turkey use of oak hickory forests and associated pine plantations in eastern Tennessee. Unpublished report, Department of Forestry, Wildlife, and Fisheries, University of Tennessee, Knoxville, Tennessee, 17 pp.

Nature Conservancy. 1995. Oak Ridge Reservation, biodiversity, and the common ground process: preliminary biodiversity report on the Oak Ridge Reservation. Unpublished report. 3 April 1995, 75 pp.

Nickens, E. 1993. Operation conservation. *Nature Conservancy* March/April:24–29.

Noss, R. F., E. T. LaRoe, III, and J. M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biological report 28. US Department of the Interior, National Biological Survey, Washington, DC 66 pp.

Parr, P. D., and J. W. Evans. 1992. Resource management plan for the Oak Ridge Reservation. Vol. 27: wildlife management plan. ORNL/NERP-6, Oak Ridge, Tennessee, 56 pp.

Pounds, L. R., P. D. Parr, and M. G. Ryon. 1993. Resource management plan for the Oak Ridge Reservation. Volume 30: Oak Ridge National Environmental Research Park natural areas and reference areas-Oak Ridge Reservation environmentally sensitive sites containing special plants, animals, and communities. ORNL/NERP-8, Oak Ridge, Tennessee, 20 pp.

Robbins, C. S., D. K. Dawdon, and B. A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic states. *Wildlife Monographs* 103:34 pp.

Somers, P. 1989. Revised list of rare plants of Tennessee. Tennessee Department of Conservation's Rare Plant Scientific Advisory Committee. *Journal of the Tennessee Academy of Science* 3:179–184.

Story, J. D., and J. T. Kitchings. 1982. White-tailed deer (*Odocoileus virginianus*) on the Department of Energy's Oak Ridge Reservation: 1981 status report. ORNL/TM-6803/S4, Oak Ridge, Tennessee, 24 pp.

Strock, W. G., Jr. 1970. Forest management plan, AEC Oak Ridge Reservation: 1970–1975. ORNL/TM-3175, Oak Ridge, Tennessee, 28 pp.

Terborgh, J. 1989. Where have all the birds gone? Princeton University Press, Princeton, New Jersey, 207 pp.

USDI-FWS (US Department of Interior, Fish and Wildlife Service) 1991. Endangered and threatened wildlife and plants. 50 CFR 17.11 & 17.12, 15 July 1991.

USDI-FWS (US Department of Interior, Fish and Wildlife Service) 1993. Plant taxa for listing as endangered or threatened species: notice of review. *Federal Register* 58:51143–51189.

USDI-FWS (US Department of Interior, Fish and Wildlife Service) 1994a. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species; proposed rule. *Federal Register* 59:58981–59028.

USDI-FWS (US Department of Interior, Fish and Wildlife Service) 1994b. Endangered and threatened wildlife and plants; reorganization and republication of list of endangered and threatened plants. *Federal Register* 59:49848–49859.

White, P. S. 1982. The flora of the Great Smoky Mountains National Park: an annotated checklist of the vascular plants and a review of previous floristic work. Research/Resource Management Report SER-55. GSMNP, Gatlinburg, Tennessee, 167 pp.