
NATURAL RESOURCES JOURNAL

Volume 44
Issue 4 *Fall 2004*

Fall 2004

National Wildlife Refuge System: Ecological Context and Ingegrity

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National Wildlife Refuge System: Ecological Context and Integrity

ABSTRACT

The Refuge Improvement Act of 1997 established a statutory mission and management standards for the National Wildlife Refuge system. The U.S. Fish and Wildlife Service subsequently issued a policy for ensuring the biological integrity, diversity, and environmental health of the system. This policy requires understanding the management objectives of each refuge in a local, regional, and national context. An assessment of the refuge system in a national and regional context reveals that refuges are typically smaller than many conservation holdings and are unevenly distributed across the conterminous U.S. Western rangelands, coastal wetlands, and northern grasslands; wetlands are the best-represented ecosystems, while temperate forests have the poorest representation. In contrast to other agency holdings or management designations in the national protected areas network (e.g., national parks, national forests, wilderness areas), refuges tend to occupy sites at lower elevations and that have higher productivity and soil quality. This difference points to the important contribution of the refuges in providing much needed ecological balance within the national protected areas network. However, the ecological integrity of the refuge system is challenged by the proximity of individual refuges to development. Overall, the refuges are becoming islands in a landscape matrix of urban and agricultural development. This creates future challenges for meeting management objectives to ensure the biological integrity, diversity, and environmental health of the system. If the policy to ensure biological integrity, diversity, and environmental health of the refuge system is to be successful, it may be more important to address issues about what happens on adjacent lands than uses within refuges.

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INTRODUCTION

At the dawn of the twentieth century, when the population of the United States was 80 million, President Theodore Roosevelt boldly set aside a few acres of land from the public domain as a wildlife preserve. This first step created what is now known as Pelican Island National Wildlife Refuge, which in turn led to the rich and varied complex of refuges and wildlife management areas of today. The National Wildlife Refuge System, managed by the U.S. Fish and Wildlife Service (FWS), is one of the most biologically rich systems of preserves in the world. Based on a diverse list of congressional and executive authorities,[1] the refuge system contains land for waterfowl production, for threatened and endangered species, and for a vast multitude of game and non-game species. The refuges include everything from caribou, moving several thousand miles in a single year, to desert hole pupfish, whose entire range is less than an acre. These are the lands that the FWS is charged to manage as we enter the twenty-first century. The system contains more than 500 refuges and 30,000 Waterfowl Production Areas and encompasses more than 93 million acres. These lands provide refuge for wildlife and at the same time serve as a playground for a population that has nearly quadrupled since Pelican Island was established.

During the 94 years following the creation of the first National Wildlife Refuge (NWR), the primary emphasis for establishing new refuges was to protect migratory birds, especially waterfowl. This was in response to the vision of those who recognized the need to provide secure areas for migratory birds as development pressures increased across the country. The result was a "system" of refuges providing habitat for tens of millions of waterfowl and other migratory birds. The system provides sanctuary on wintering, breeding, and staging habitats from Alaska to Puerto Rico, and it also provides space for recreational uses that are wildlife dependent. While this early focus was on migratory birds, the result was a system that can be built upon to meet the new challenge of providing habitat for thousands of endangered plants, animals, and ecosystems threatened by human populations and land development.

The National Wildlife Refuge System Improvement Act of 1997 (Improvement Act)[2] and the subsequent FWS policies for management of biological integrity, diversity, and environmental health define the content and context of the refuge system. The Act provides a much-

1. MICHAEL. J. BEAN & MELANIE J. ROWLAND, THE EVOLUTION OF NATIONAL WILDLIFE LAW 287–89 (3d ed. 1997).

2. 16 U.S.C. §§ 668dd–668ee (2000).

needed statutory mission and clear management standards for the Refuge System. Writing about the Improvement Act in 1999, Bruce Babbitt, then Secretary of the Interior, said, "This law provides a firm foundation for a system of lands about to enter the challenges and opportunities of a new millennium."[3] The "foundation" metaphor seems appropriate because the law provides general requirements that will take most of their meaning from how they are interpreted and implemented by the FWS.[4] As we would construct a house on a foundation, the FWS is building a system of policies and guidelines based on the Improvement Act that will structure the future management of the refuge system. The boldest provision of the Improvement Act arguably requires that "in administering the system" the FWS is to "ensure that the biological integrity, diversity, and environmental health of the System are maintained."[5] The FWS has defined this general provision in regulations and guidelines[6] and now is working to implement this requirement in practice, especially when developing Comprehensive Conservation Plans for each refuge.

Growth in population, along with economic development and increased need for public recreation, challenges the ability of the FWS to maintain biological integrity, diversity, and environmental health in the refuge system. While the policy seems geared toward controlling activities on refuges, it also suggests that the role of the refuges in the system has to be considered within landscape-level contexts, both regional and national. In many cases, humans influence or dominate the context. Regardless of how the implementation of the Improvement Act evolves, and of the extent to which the FWS can actively participate in decisions about activities that occur outside refuge boundaries, management within refuges will be greatly influenced by what occurs outside their boundaries. The agency's ability to meet the intent of the Improvement Act and the integrity, diversity, and health policy may also depend on dealing with many and varied "external threats." To frame this challenge, we discuss the implications of geographical distribution, occurrence in geophysical space, size, land cover attributes, and ecological context of the current refuge system.

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3. U.S. FISH & WILDLIFE SERV., FULFILLING THE PROMISE: THE NATIONAL WILDLIFE REFUGE SYSTEM, VISIONS FOR WILDLIFE HABITAT, PEOPLE, AND LEADERSHIP vii (1999), *available at* http://training.fws.gov/library/Pubs/Fulfillprom.pdf (last visited Dec. 21, 2004).

4. Kevin Gergely et al., *A New Direction for the U.S. National Wildlife Refuges: The National Wildlife Refuge System Improvement Act of 1997*, 20 NAT. AREAS J. 107, 107-12 (2000).

5. 16 U.S.C. § 668dd(a)(4)(B) (2000).

6. U.S. FISH & WILDLIFE SERV., U.S. FISH AND WILDLIFE SERVICE MANUAL, 601 FW 3, *available at* http://policy.fws.gov/series.html (last visited Dec. 21, 2004).

The integrity, diversity, and health policy[7] seeks to balance a systematic view of all refuges and a focus on management within individual refuge boundaries. For example, the policy states, "On refuges, we typically focus our evaluations of biological diversity at the refuge scale; however, these refuge evaluations can contribute to assessments at larger landscape scales."[8] The policy acknowledges that the scale of concern for maintaining integrity, diversity, and health alters management objectives. It goes even further by providing guidance to managers[9] on procedures for dealing with threats from outside refuge boundaries that may "injure or destroy" the biological integrity, diversity, or health of a refuge. However, the prescriptions for management outside refuges are strongly tempered by cautionary language about respecting private property rights.[10] Also, the mandate that managers deal with external threats is clouded with language in the policy suggesting that the time and effort expended on dealing with external threats, and the rate at which the manager escalates his/her efforts to deal with them, should be dependent upon the severity of the threat and the "resources at risk." Given these concerns about entering into property rights conflicts, it may be too soon to know how aggressive or timid the FWS will be in dealing with external threats. However, the policy clearly requires managers to look at the refuge at multiple scales when evaluating any refuge's contribution to integrity, diversity, and health. This article takes some initial steps toward meeting this requirement.

These steps involve a coarse-scale analysis, characterizing the refuge system in terms of how it contributes to the protected area network in the United States and how well it represents the variety of ecosystems found in the country. On one level, this may be viewed as simply an example of how to begin a needed review, looking at the refuges as a system and examining the context in which they exist. Even with this cursory examination, some important issues are identified. The mosaic of the human-dominated landscape surrounding many refuges presents a challenge for protecting the system as it currently exists. This study may emphasize that challenge because the coarse scale of the analysis does not account for many threats that exist within refuge boundaries, including invasive species, historical uses that have occurred, recreational impacts and disturbances, and the many other

7. *Id.* 601 FW 3.11.
8. *Id.* 601 FW 3.10(B)(2).
9. *Id.* 601 FW 3.20.
10. ROBERT L. FISCHMAN, THE NATIONAL WILDLIFE REFUGES: COORDINATING A CONSERVATION SYSTEM THROUGH LAW 131 (2003).

issues that refuge managers must deal with every day. However, analysis shows that refuges are not evenly distributed in space, are inconsistent in terms of size and how they represent ecosystem types, and are situated in a landscape that has impacts on how well they may maintain the natural (or semi-natural) composition, structure, and function of its biotic components, which raises some important questions. One question is, if the refuge system does not represent the full range of ecosystem types in the United States, should it, or which ecosystem types do we want to focus on? Another question is, given some limitations to the system as it exists, how do we go about protecting it?

The policy related to biological integrity, diversity, and health of the system identifies objectives and procedures for protecting and enhancing the refuge system. Primarily, the policy depends on three broad strategies. It relies first on management within refuge boundaries and second upon land acquisition to expand the reserve system. Last, it calls on reaching out to partners, neighbors, and others to influence management of lands that are not part of the refuge network, but where management actions might be directed in a way to avoid adverse impacts to refuges and to the integrity of the system as a whole. The proper role of government and the effect public agencies should have when dealing with private landowners and other private interests is a question of policy and a contentious political issue. No suggestion is being made here that the FWS should push headlong into negotiations with private property owners and other interests operating on the edge of federal lands in order to protect refuge lands from outside nuisances. But clearly the mandate to protect the integrity, diversity, and health of the refuges is going to sometimes run at odds with outside influences because the lands around many refuges are increasingly managed for agriculture or are facing pressures from urbanization. What happens outside refuges may be more important to the integrity, diversity, and health of the system than what happens within. The FWS should assess these impacts carefully. Until then, there is no way to know if policies can be erected, and if they will be politically supported, to engage adjacent landowners in an effort to ward off adverse impacts to the refuges.

Geographical Distribution of Refuges

Understanding overall system integrity, diversity, and health across the country requires consideration of the distribution and characteristics of the national mosaic of ecosystems. Ecological regions, or ecoregions, are useful for ecosystem assessment and management

because they correspond to the biotic and abiotic properties of ecosystems. Ecoregions also represent opportunities for human uses of ecosystems, which provide an ecological context for interpreting regional disturbances and risks to ecosystems.[11] The regions also serve as a reporting framework that reveals distinct patterns in environmental data because the regions correspond to the spatial distribution of natural resources. We use the 84 conterminous U.S. ecoregions defined by Omernik[12] to summarize the variability of refuge integrity, potential biodiversity, and health. Omernik's ecoregions reflect the geographical concurrence of climate, physiography, geology, soil, vegetation, and land use.

An ecoregion-based summary of the conterminous U.S. refuges encoded in a recently updated version of the Protected Areas Database[13] shows that the refuges are distributed unevenly across the landscape (Figures 1 and 2). There are approximately 16,000 square miles of refuges in the lower 48 states. Nearly 50 percent of the refuges are found in just eleven of the 84 ecoregions (Table 1). Those eleven ecoregions have one percent or more of their area in refuges, with the Southern Florida Coastal Plain having the greatest representation with 3.7 percent of its area in the refuge system. If total refuge area is considered rather than percent area (numbered in Table 1), refuges are concentrated in three major ecoregion groups—western rangeland ecoregions, Atlantic and Gulf coastal ecoregions, and northern grassland ecoregions. Central and southern ecoregions with higher portions of wetlands generally have higher numbers of refuges, and arid western ecoregions often have significant areas included in the refuge system. Our analysis shows that 15 ecoregions, primarily in forested areas, have no refuges at all.

Analysis of the distribution of refuges among ecoregional boundaries is important to the FWS policy regarding integrity, diversity, and health. Analysis of that distribution shows that not all ecoregions are well represented in the refuge system. The policy may require analysis at multiple scales and also may emphasize actions within refuges. But it is equally true that the policy addresses appropriate actions outside refuge boundaries [14] and is linked to acquisition policies[15] by stating that the

11. Sandra A. Bryce et al., *Ecoregions: A Geographic Framework to Guide Risk Characterization and Ecosystem Management*, 1 ENVTL. PRACTICE 141, 146-51 (1999).

12. James M. Omernik, *Ecoregions of the Conterminous United States*, 77 ANNALS ASS'N OF AM. GEOGRAPHERS 118, U9-U24 (1987).

13. Dominick A. DellaSala et al., *An Updated Protected Areas Database for the United States and Canada*, 21 NAT. AREAS J. 124, 129, 131 (2001). We used an updated and modified version of the database referenced here.

14. U.S. FISH & WILDLIFE SERV., *supra* note 6, 601 FW 3.20.

15. *Id.* 601 FW 3.17.

FWS should identify acquisitions that contribute to the integrity, diversity, and health of the *"[s]ystem at all landscape scales."*[16] Our analysis shows glaring deficiencies with regard to representation of different major land cover types. Should the refuge system be focused on particular species, land cover types, or ecoregions, or should the refuge system strive for broader ecological representation?

Distribution in Geophysical Space

The geophysical characteristics of ecosystems strongly influence ecosystem productivity and biodiversity. Previous research has shown that lands set aside for conservation purposes are located most often in areas with little potential for high levels of ecosystem productivity (*e.g.*, areas at high elevations where soils restrict vegetation development).[17] The elevation, soil productivity, and vegetation index-based productivity profiles were summarized for the conterminous U.S. refuges in order to determine if refuge geophysical characteristics followed the trends reported by Scott et al.[18]

Conterminous U.S. refuges span an elevation range from sea level to nearly 11,000 feet. The average elevation of the full conterminous U.S. refuge system is 1280 feet. The median elevation, however, is 372 feet due to the previously mentioned preponderance of coastal zone refuges. Unlike other federally managed natural areas, refuges tend to occur at lower elevations. For example, our analysis shows the average elevation of national parks is 2218 feet and wilderness areas, an administrative overlay designation, average 4688 feet.

Soil capability ratings have been established for all U.S. soils and provide an indication of the potential for vegetation development.[19] While soil capability classes were not defined to represent ecological potential, they do provide an indication of overall land quality. Generally, the lower the capability class the more limited the vegetation growth. The area in each of the eight land capability classes shows that while most lands in the federal conservation network have soils with severe limitations, refuges have higher capability ratings than U.S. Forest Service, National Park Service, and Bureau of Land Management lands (Figure 3).

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16. *Id.* (emphasis added).

17. J. Michael Scott et al., *Nature Reserves: Do They Capture the Full Range of America's Biological Diversity?*, 11 ECOLOGICAL APPLICATIONS 999, 999-1007 (2001).

18. *Id.* at 1001.

19. *See generally* A.A. Klingebiel & P.H. Montgomery, LAND-CAPABILITY CLASSIFICATION (1961).

Relative levels of ecoregional productivity can also be inferred from remote sensing-based measures of seasonal vegetation conditions. Research has also shown that net primary productivity can be inferred using time-integrated vegetation index transformations from multi-spectral remotely sensed data.[20, 21] Relative refuge productivity was estimated using the maximum greenness measure for the 1990 to 2000 period.[22] Refuge maximum greenness index values averaged 0.77, indicating a high level of peak seasonal biomass. Refuges have the highest level of seasonal vegetation biomass of all federal public land holdings, although the greenness index values for national forests are nearly as high (0.76). In contrast, Bureau of Land Management holdings have a maximum normalized difference vegetation index (NDVI) average of 0.44, wilderness areas have an NDVI average of 0.68, and the national parks have an NDVI average of 0.69.

The collective profile of elevation, soils, and remote sensing-derived productivity measures for the refuges illustrates that refuges are a geophysical anomaly in the federal conservation network. As such, the refuge system broadens the ecological potential of the federal system.

An important point for refuge management, stemming from this and the previous analysis, is that it is vital to define what the system should be. The law and the policy state that the FWS must address the integrity, diversity, and health of the system and the refuges. Should we have a robust system of refuges that represent all ecoregions or land cover types? Should they represent the range of abiotic conditions across the national landscape? Or should the FWS clearly define a system that meets complementary objectives with other reserve systems, such as the National Park System?

Size of Refuges

The size of refuges varies considerably. While the median refuge area is 5550 acres, refuges range in size from small island-based holdings less than 25 acres in size to large 600,000-acre or larger refuges in Nevada (Figure 4). There are more small refuges than large. The mean size, however, is 20,186 acres, and yet half of the refuges are less than the

20. Bradley C. Reed et al., *Measuring Phenological Variability from Satellite Imagery*, 5 J. VEGETATION SCI. 703, 704–05 (1994).

21. *See* Jingyun Fang et al., *Interannual Variability in Net Primary Production and Precipitation*, 293 SCIENCE 1723 (2001), *full text of these technical comments available at* http://www.sciencemag.org/cgi/content/full/293/5536/1723a (last visited Dec. 12, 2004).

22. This was calculated from an NDVI time series derived from the Advanced Very High Resolution Radiometer. Maximum greenness uses a zero to one scale to express correspondence to peak vegetation biomass.

5550-acre median size and collectively represent only 4.5 percent of the total refuge lands. Nearly 20 percent of the refuges are less than 1000 acres in size. There are significant variations in refuge sizes among ecoregions (Figure 5) with the largest refuges found in the western Great Plains and Great Basin ecoregions and the smallest in urbanized coastal ecoregions.

The coterminous U.S. refuges we examined were often divided into a number of discontinuous parcels. While geospatial refuge data needed to assess average or median parcel size is still being refined, clearly, the size of contiguous refuge holding is considerably smaller than the overall median or average size of individual refuges. Refuges represented by more than ten individual parcels are most often associated with impounded water bodies (*e.g.*, Charles W. Russell NWR in Montana) or in the prairie pothole states of the northern plains or with coastal areas, primarily along the Mid-Atlantic and Gulf Coast states. In the majority of cases where refuges are made up of multiple parcels, the proximity to one another was quite close; however, any fragmentation of ownership, no matter how minor, undoubtedly complicates managing for ecological integrity.

Land Cover of Refuges

A summary of the land cover composition of refuges using the U.S. Geological Survey National Land Cover Database[23] shows that the shrub vegetation is the largest single cover type found on refuge lands (27.2 percent). As noted earlier, there are a number of very large refuges in central semi-arid and western arid ecoregions. Wetlands cover 28 percent, grasslands are 11.1 percent, forest cover 10.5 percent, and open water covers nearly 14 percent of the area in refuges (Table 2). Over seven percent of refuge area is in anthropogenic landscapes (urban and built-up and agricultural). The land cover of the refuge system offers significant contrasts to the overall cover of the conterminous United States. The percentage of refuge area covered with wetlands is nearly five times greater, while the forest cover of refuges is almost four times lower. As noted earlier, the geographical distribution of refuges emphasizes ecoregions with significant amounts of wetlands and provides little representation of forested areas, a reflection of the vision prior to the RIA. Again, this points to the need to clarify from a national policy perspective what the system should be in order to be able to

23. *See* James E. Vogelmann et al., *Completion of the 1990's National Land Cover Data Set for the Conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources*, 67 PHOTOGRAMMETRIC ENG'G & REMOTE SENSING 650, 650–62 (2001).

interpret the results of analyses of the relevance of refuges at ecoregional or national scales.

Ecological Context

The lands adjacent to refuges are a reflection of the larger national landscape and define a buffer that can mitigate or exaggerate the impacts of the anthropogenic landscape. To understand the potential impacts on refuges, the land cover composition for lands within 10- and 50-km buffers surrounding each refuge was summarized (Figure 6). The overall fraction of anthropogenic lands (urban and built-up and agricultural) within both the 10- and 50-km buffers are higher than the anthropogenic average across the whole of the conterminous United States. A closer inspection of individual refuges shows that:

- One hundred seventy two refuges, or nearly 40 percent, of the refuge holdings have greater than 50 percent anthropogenic cover within either the 10- or 50-km of refuge boundaries.
- Thirty-four, or over seven percent, of the refuge holdings have greater than 20 percent of the land within 10-km of refuges in urban cover.
- Twenty-four, or over five percent, of the refuge holdings have greater than 20 percent of the land within 50-km of refuges in urban cover.

Figure 7 maps the ecoregions with the highest levels of anthropogenic land cover within 10-km of refuges. The influence of Midwestern and Great Plains agriculture is evident. Figure 8 shows the ecoregions with the highest level of urbanization around refuges. The maps, along with the small sizes of the refuges, suggest that many refuges are islands of habitat in an anthropogenic landscape. As mentioned earlier, the NWR integrity, diversity, and health policy considered the influence of surrounding lands on refuges and provided guidance to managers on addressing outside threats. The approach is cautious, but that section of the policy has tremendous importance, as the discussion above indicates. It is unlikely, and perhaps inappropriate, to suggest that federal land acquisition will be the primary tool to address resource conflicts that may arise because refuges are often situated in an anthropogenic-dominated landscape. With little recourse for solving problems by management actions within refuge boundaries, this analysis suggests that cooperative relationships with parties outside refuge boundaries may be a critical factor in striving to enhance the integrity, diversity, and health of the system.

Threats

The extent of development surrounding many refuges presents challenges for refuge managers. Land use change brings a host of potentially adverse consequences, including reduced water quality, alteration of surface water flows, increased risk of invasives, and habitat alteration, all of which may threaten the ecological integrity of individual refuges.

The risks associated with land use change vary from ecoregion to ecoregion and management strategies for coping with change will need to be adapted to the specific threats associated with each refuge. For example, the refuges of the southeastern United States will likely be affected by the dramatic changes associated with plantation forestry. Short-rotation pine plantations are transforming much of the southeast and natural forests and agricultural lands at rapid rates. This change is fragmenting the matrix of land surrounding refuges, and the intensification of management practices associated with timber management and harvesting is creating significant changes in ecosystem biogeochemistry.[24] Urbanization in coastal regions is a threat to refuges due to changes in hydrologic regimes and loss of habitat in the lands surrounding refuges. Land use changes surrounding prairie refuges are not as direct and, in fact, some of the changes may even be favorable. The implementation of the Conservation Reserve Program in the mid-1980s transferred some croplands to grasslands, which provides at least some level of habitat improvement. At the same time, some rural land uses are intensifying due to ethanol development and the expansion of animal confinement operations, and the changes are impacting water bird habitat and populations.[25]

Threats from adjacent lands require attention, but it is also important to consider the impacts on refuges from changes occurring far away. Changes in atmospheric chemistry and climate variability are the result of accumulated land use and land cover change occurring around the world. The changes, while not as obvious as transformations occurring on the borders of refuges, create threats for the ecological integrity of refuges. Climate change will have the most significant effects

24. *See* Jerry A. Griffith et al., *Landscape Trends in Mid-Atlantic and Southeastern United States Ecoregions*, 32 ENVTL. MGMT. 572, 581-83 (2003).

25. Kenneth F. Higgins et al., *A Case Study of Changing Land Use Practices in the Northern Great Plains, U.S.A.: An Uncertain Future for Waterbird Conservation*, 25 Special Publ'n (2) WATERBIRDS 42 (2002).

on refuges in ecoregions with more extreme conditions such as arid and semi-arid areas and areas with high latitudes and elevations.[26]

DISCUSSION

Based on the wording in the Improvement Act and the policy, we see three primary approaches to setting conservation goals. These are (1) management practices on refuges that contribute to the integrity, diversity, and health of the system; (2) land acquisition to fill in the system in a complementary manner; and (3) an effective approach to engaging landowners outside refuges if land uses conflict with these refuge management objectives. The analyses presented here, which evaluate implications of the size, geographical distribution, occurrence in geophysical space, and ecological context of refuges, is evidence of the importance of all three approaches.

The integrity, diversity, and health clause of the Improvement Act requires that these issues be addressed at multiple spatial scales, from local to regional to national. Our analysis looks at the refuge system in these contexts and draws implications by comparison to the group of other protected areas in the nation as a whole. One measure of ecological integrity is the extent to which the refuge system captures the ecosystem diversity of the country. Geographically the coverage is uneven and not all ecoregions are represented.

The external threats to refuges pose a significant challenge to refuge managers. The most immediate threat is land cover conversion and intensification of land uses in the areas bordering refuges. Preserving the ecological integrity of refuges will require consideration of the conversion of habitat outside of refuges. Refuge managers will need to reach out to adjacent landowners and collectively develop strategies and plans that enhance or at least maintain the conservation potential of refuge ecosystems. The concept of the biosphere reserve suggests that preserving a core reserve (*i.e.*, refuges) is enhanced by creating buffers of surrounding lands. These buffers would be protected on a gradient where human activity would be most restricted closest to the core and least restrictive farthest from the core. This strategy of actively planning for buffer land has been used by the National Park Service in some instances with promising results. For example, implementing this policy has shown to have a very positive effect in reducing land conversions in the heavily developed New Jersey Pine Barrens.[22]

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26. *See* Osvaldo E. Sala et al., *Global Biodiversity Scenarios for the Year 2100*, 287 SCIENCE 1770, 1771 (2000).

Refuges in the lower 48 states are concentrated in coastal ecoregions especially on the Gulf and Atlantic coasts and in the Midwest and Great Basin areas. Fifteen ecoregions have no refuges. At the national level, underrepresented ecoregions are covered by other elements of the protected areas network (*e.g.*, national parks and private nature reserves), and this should be considered prior to any new acquisitions. New acquisitions should complement the system as a whole. Additions to existing reserves within an ecoregion may enhance the integrity, diversity, and health of individual refuges and thereby contribute to the goals of representation, resiliency, and redundancy at the ecoregion and national level thus achieving overall biological integrity, diversity, and health. Additional gains may be obtained by adding to existing reserves or working with adjacent landowners on land issues as discussed in detail above.

We found that the largest refuges are in the western Great Plains and Great Basin areas, while the smallest are found in urbanized coastal areas. Additionally, refuges are found at lower elevations relative to other components of our protected areas network and the protected areas system as a whole.[27] Finally, refuge lands tend to be found on more productive areas than reserves in other systems. Thus, rather than being restricted to rocks and ice (*e.g.*, higher elevations and poor soils), they are found at lower elevations on richer soils. They nicely complement the protected areas in the nation not managed by the FWS. The median size of refuges, 5550 acres, is somewhat misleading as over half of the refuges are composed of two or more parcels. Collectively those refuges at or less than the median area comprise less than five percent of the area in refuges and this figure would be much smaller had we considered the Alaskan refuges.

Most refuges are too small to maintain viable populations of midsized carnivores and mid- to large-sized herbivores[28] and fall short of what is required to maintain many ecological processes (*e.g.*, fire disturbance regimes) and to sustain evolutionary processes. Additionally, Czech[29] found that the refuge system has carrying capacity for evolutionarily viable populations for 44 percent, demographically viable populations for 52 percent, and outbreeding viability for 74

27. Scott et al., *supra* note 17.

28. Christine M. Schonewald-Cox, *Conclusions: Guidelines to Management: A Beginning Attempt*, *in* GENETICS AND CONSERVATION: A REFERENCE FOR MANAGING WILD ANIMAL AND PLANT POPULATIONS 414, 415 (Christine M. Schonewald-Cox et al. eds., 1983).

29. Brian Czech, *The Capacity of the National Wildlife Refuge System to Conserve Animal Species in the United States*, CONSERVATION BIOLOGY (forthcoming 2005).

percent of the species he studied. Similarly, Davison et al.[30] found that the median size of refuges established for threatened and endangered species was 80 percent smaller than the median for all refuges in the conterminous United States. These findings highlight that maintaining viable populations for all but the smallest species in these areas will be challenging and suggest several strategies for maintaining or enhancing biological integrity, health, and diversity of refuges and the refuge system. The integrity of individual refuges could be enhanced with additions or assurances that land use practices on adjacent lands would not be injurious to species targeted by refuges. Additionally, consideration might be given to focusing acquisition of new refuges on species with smaller area requirement (*e.g.*, plants, invertebrates, and smaller vertebrates), especially threatened and endangered species.

Refuges are not representative of the cover types at the scale we mapped. Forested areas of all types are underrepresented while shrublands, grasslands, and wetlands are overrepresented. These results will change in detail as higher resolution land cover data is used to conduct future analyses. Rather than attempting to acquire representative examples of all cover types, it is our belief that refuges might best meet their mission by focusing on those habitats that harbor species underrepresented in the current system of nature reserves.[31] One option would be to focus on species of particular interest to the FWS, such as threatened and endangered species or migratory neotropical migrants, which in this later case would require a significant shift in emphasis from wetlands and rangelands to eastern deciduous forest.

We found our assessment of the ecological context of refuges to provide the most compelling information for future decision making by the FWS. Refuges are often islands of wildlife habitat in an anthropogenic landscape, a landscape that is becoming increasingly hostile to wildlife movements. In other words, it is a landscape that houses external threats to the long-term biological integrity, health, and diversity of refuges and the refuge system. To overcome these threats, refuge managers must find ways to build partnerships with adjacent landowners and create programs that provide landowners with incentives to enhance ecological integrity and benefits to wildlife.

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30. Robert P. Davison et al., *Opportunities for the National Wildlife Refuge System to Provide Greater Conservation Benefits for Threatened and Endangered Species, in* ENDANGERED SPECIES ACT AT 30: CHALLENGES AND PROSPECTS (D. Goble et al. eds., Island Press, forthcoming 2005).

31. J. Michael Scott et al., *Gap Analysis: A Geographic Approach to Protection of Biological Diversity*. 123 Wildlife Monographs (1993).

Current policy addresses this topic but is cautionary. This will be a tremendous challenge for the FWS.

In conclusion, what happens on adjacent lands may be more important than land use activities in the refuges. The current refuge system has limitations. The refuges are often small, fragmented, and surrounded by lands where human uses could affect the relative security of the refuge lands. An important component of the new law and policies will be how the FWS should engage its neighbors, and whether cooperative relations can be achieved that will optimize protection of refuge resources. This is already occurring in some cases. Examples of refuges that are working with neighbors to the benefit of refuge species include Coachella Valley, Antioch Dunes, Charles M. Russell, San Diego, and San Bernadino national wildlife refuges.

Refuges are an important component of a larger protected areas system that includes national parks, wilderness areas, private natural areas, and land trust lands. While the refuge system does not fully represent all the ecosystems of the United States, it is an important part of the system of protected areas and complements other major public land holdings. Future decisions regarding new acquisitions should be made in the context of that larger system.

APPENDIX

FIGURES AND TABLES

Figure 1: Distribution of National Wildlife Refuges in the conterminous United States. The refuge data are from the Protected Areas Database created by DellaSala et al. (2001). We used an updated and modified version of the database referenced here.

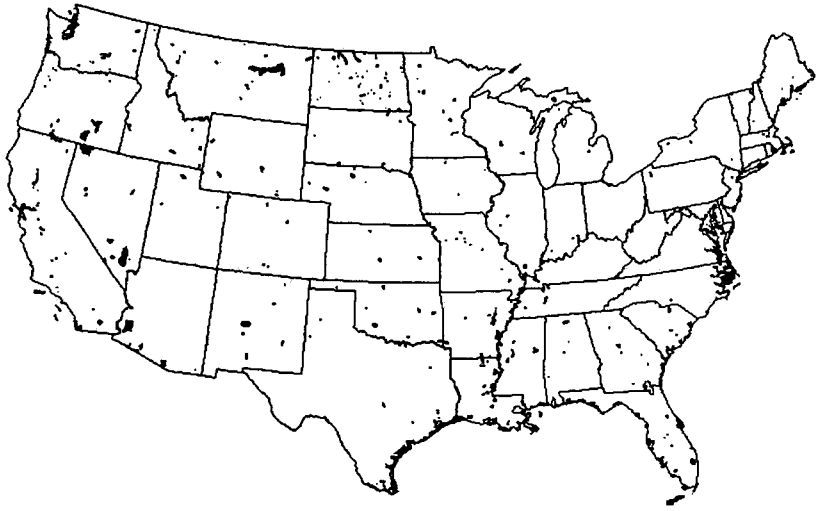

Figure 2: The Number of refuges per ecoregion is unevenly distributed with greater representation in coastal and inland regions but few refuges in temperate forest-dominated ecoregions.

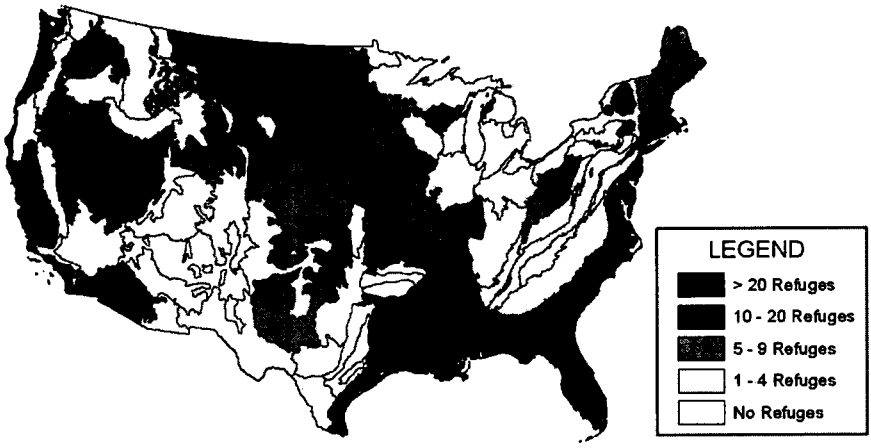

Figure 3: Soil Capability ratings for refuges, National Park Service, U.S. Forest Service, and Bureau of Land Management holdings. Classes 1 through 3 are most favorable for vegetation development while classes 4 through 8 have increasing restrictions to growth.

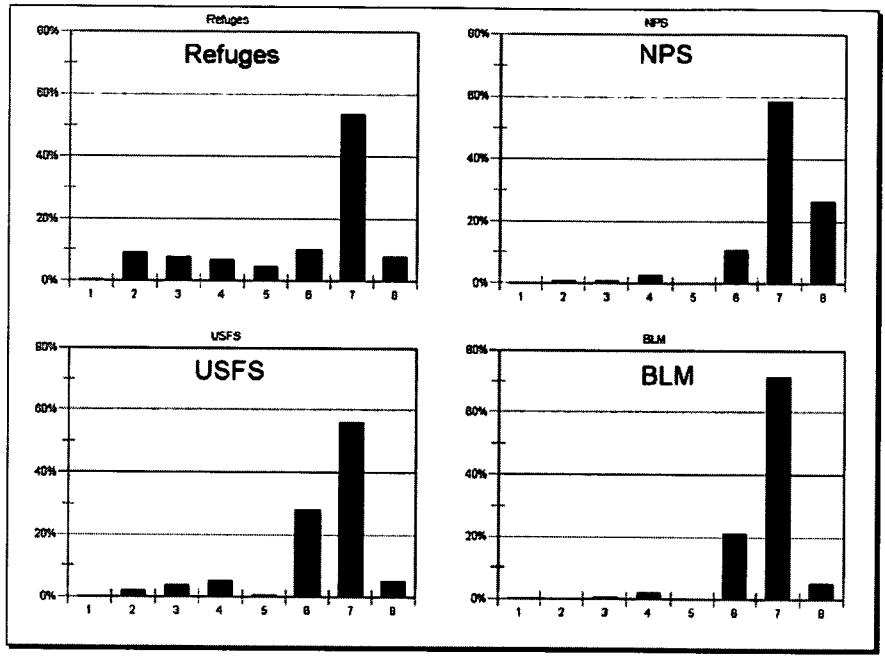

Figure 4: Median Size of National Wildlife Refuges summarized by ecoregion

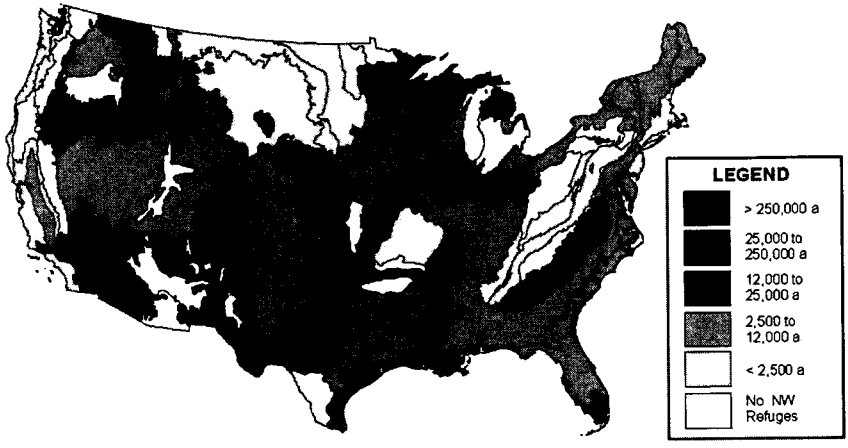

Figure 5: Ecoregions with the smallest median refuges sizes are represented in black and are found in coastal regions. The largest refuges (gray) are primarily in western plains and basins.

Figure 6: Land cover composition within refuges, within 10 km of refuge boundaries, and within 50 km of refuge boundaries

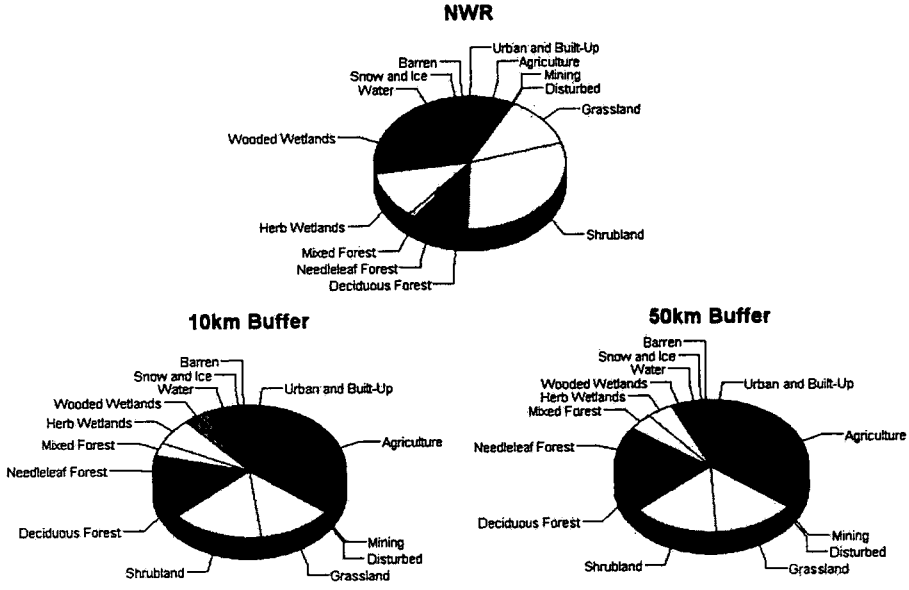

Figure 7: Ecoregions colored black have greater than 70% of the land within 10 km of refuge boundaries cover with agriculture, mining, or urban development. Gray-coded ecoregions have between 50 and 70 percent of the surrounding lands in anthropogenic cover.

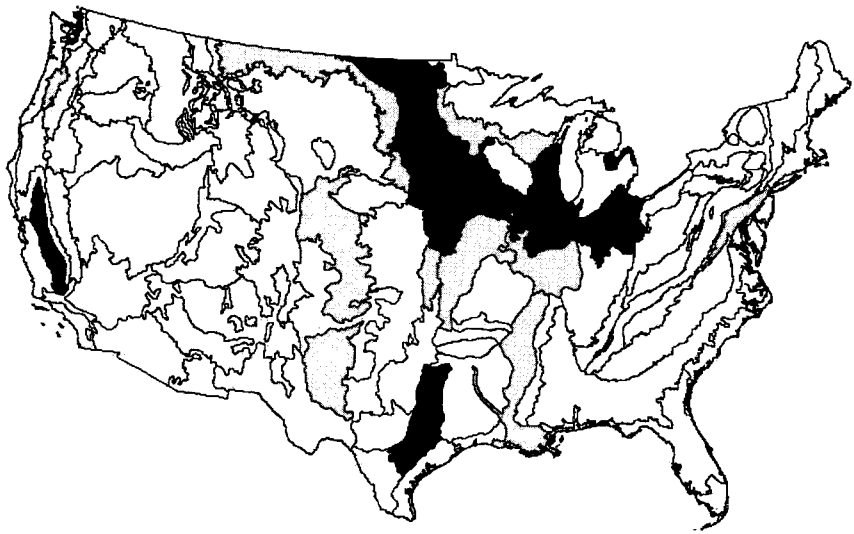

Figure 8: The highlighted ecoregions have high proportions of urban development within 10 km of refuge boundaries. In the black ecoregions, more than 20 percent of the lands within 10 km of ecoregion boundaries are urbanized, and the gray ecoregions have between 10 and 20 percent of the surrounding area urbanized.

Table 1. Refuge area per ecoregion (square miles) ranked by percent representation of each ecoregion. Top 10 ecoregions with the largest NWR are labeled in rank order.

Ecoregion	Ecoregion Area (miles²)	Percent in NWR	NWR Area (miles²)
Southern Florida Coastal Plain	8,703	3.72%	324
(3) Middle Atlantic Coastal Plain	31,288	3.57%	1117
(1) Northern Basin and Range	42,244	3.56%	1502
(6) Western Gulf Coast Plain	25,559	3.41%	872
(4) Mississippi Alluvial Plain	51,520	1.88%	967
Driftless Area	18,260	1.44%	264
Eastern Cascades Slopes and Foothills	21,643	1.43%	310
Atlantic Coastal Pine Barrens	6,144	1.38%	85
(8) Sonoran Basin and Range	45,133	1.19%	538
(7) Southern Coastal Plain	50,242	1.18%	593
Madrean Archipelago	16,100	1.04%	167
Central California Valley	17,758	0.95%	169
(2) Central Basin and Range	131,749	0.87%	1151
Nebraska Sand Hills	24,120	0.85%	204
(9) Mojave Basin and Range	50,467	0.77%	389
Lake Agassiz Plain	15,961	0.68%	109
(5) Northwestern Great Plains	134,443	0.67%	898
Interior River Lowland	35,427	0.65%	230
Arkansas Valley	10,224	0.61%	63
Northern Glaciated Plains	59,251	0.59%	350
Northwestern Glaciated Plains	61,608	0.56%	343
North Central Hardwood Forests	33,944	0.54%	185
(10) Arizona and New Mexico Plateau	74,070	0.49%	364
Cascades	5,729	0.48%	28
South Central Plains	59,705	0.45%	270
Columbia Plateau	34,798	0.43%	149
Cal. Chaparral & Oak Woodlands	38,799	0.41%	157
Chihuahuan Deserts	67,622	0.38%	260
Northern Lakes and Forests	70,803	0.34%	238
Laurentian Plains and Hills	17,468	0.33%	57
Southeastern Wisconsin Till Plains	11,751	0.30%	35
Snake River Basin	25,224	0.29%	73
Eastern Corn Belt Plains	32,270	0.29%	92
Huron and Erie Lake Plains	9,548	0.27%	26
Mississippi Valley Loess Plains	17,648	0.25%	45
Middle Rockies	35,778	0.24%	85
Wyoming Basin	49,380	0.23%	115
Northeastern Coastal Zone	13,398	0.23%	31
Interior Plateau	49,416	0.23%	112
Southeastern Plains	129,496	0.20%	256

Central Great Plains	105,617	0.19%	201
E. Great Lakes and Hudson Lowlands	22,347	0.17%	38
Central Irregular Plains	47,384	0.17%	79
Northern Rockies	65,066	0.16%	106
Coast Range	20,790	0.16%	33
Piedmont	63,342	0.13%	83
Montana Valley and Foothill Prairies	25,067	0.12%	31
Northeastern Highlands	48,924	0.12%	57
Edwards Plateau	22,706	0.11%	25
Erie Drift Plains	11,756	0.11%	13
Southern Texas Plains	20,992	0.10%	21
Northern Piedmont	11,748	0.10%	11
Southern California Mountains	6,914	0.10%	7
East Central Texas Plains	16,914	0.07%	12
Central Oklahoma and Texas Plains	39,625	0.07%	27
Western Corn Belt	78,024	0.07%	51
Texas Blackland Prairie	19,388	0.06%	12
Central Corn Belt Plains	37,875	0.06%	22
Southern Rockies	53,108	0.06%	31
Western High Plains	110,387	0.06%	62
Puget Lowlands	6,315	0.04%	3
Ridge and Valley	44,556	0.03%	13
Southwestern Tablelands	61,530	0.03%	18
Ozark Mountains	41,668	0.03%	12
Colorado Plateau	49,696	0.03%	14
Canadian Rockies	7,568	0.03%	2
Western Allegheny Plateau	32,620	0.03%	8
Southwestern Appalachia	13,768	0.01%	1
Cascades	17,875	0.01%	2
Central Appalachians	23,078	0.00%	1
Sierra Nevada	20,393	0.00%	0
Blue Mountains	24,950	0.00%	0
Wasatch and Uinta Mountains	17,223	0.00%	0
Arizona and New Mexico Mountains	42,083	0.00%	0
Flint Hills	10,605	0.00%	0
Ouachita Mountains	10,168	0.00%	0
Boston Mountains	6,594	0.00%	0
Northern Minnesota Wetlands	9,284	0.00%	0
Michigan and Indiana Drift Plains	27,783	0.00%	0
N. Appalachia Plateau and Uplands	12,018	0.00%	0
North Central Appalachia	11,224	0.00%	0
Blue Ridge	18,134	0.00%	0
North Cascades	11,664	0.00%	0
Klamath Mountains	18,711	0.00%	0

Table 2: Percent composition of National Wildlife Refuges versus the conterminous United States		
Land Cover	**National Wildlife Refuges**	**Conterminous United States**
Urban and Built-Up	0.35%	2.8%
Agricultural	6.7%	26.7%
Mining	0.0%	0.1%
Disturbed	0.3%	0.8%
Grassland	11.1%	9.4%
Shrubland	27.2%	12.26%
Deciduous Forest	3.9%	15.8%
Needleleaf Forest	5.4%	17.0%
Mixed Forest	1.2%	5.8%
Herb Wetlands	13.2%	1.7%
Wooded Wetlands	14.8%	3.8%
Water	13.7%	1.7%
Snow and Ice	0.0%	0.3%
Barren	2.2%	1.9%