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NEEDED: A UNIFIED INFRASTRUCTURE TO SUPPORT LONG-TERM SCIENTIFIC RESEARCH ON PUBLIC LANDS

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We have gone from the early day philosophy that "if national parks were simply left alone they would survive forever" (Botkin 1990, Sellars 1997, Parsons 2004) to the current situation where parks are jeopardized by serious environmental threats both within and outside of their borders (e.g., Pringle 2000). While science alone cannot solve the environmental problems facing public lands, it can lead us to ask the right questions and result in critical information for management and policy needs (e.g., National Research Council [NRC] 1992, Sellars 1997). Unfortunately, we lack a unified infrastructure that supports *long-term* scientific research on public lands and facilitates application of that science to management. We believe that long-term scientific research would provide essential knowledge for management of public lands, a viewpoint expressed by others as well (Callahan 1984, Likens 1989). Our goals in this commentary are to highlight: (1) the scope and magnitude of environmental problems facing U.S. public lands; (2) the lack of long-term scientific information available to identify and address these problems; and finally (3) the value of long-term research, by using a few examples from the National Science Foundation's (NSF) Long-term Ecological Research Program.

U.S. public lands are facing environmental problems of increasing scope and magnitude. The National Parks Conservation Association (NPCA) recently began issuing an annual list of "America's Ten Most Endangered National Parks" to draw public attention to the endangered status of many park units (NPCA 2002*a*). Environmental challenges include air pollution, threats to water resources, and recreational impacts of snowmobiles. NPCA's third annual listing of endangered parks includes Big Bend National Park, Big Cypress National Preserve and Everglades National Park, Glacier National Park, Glacier Bay National Park and Preserve, Great Smoky Mountains National Park, Mojave National Preserve, Ocmulgee National Monument, Valley Forge National Historical Park, and Yellowstone National Park. To highlight the impacts of air pollution, which are evident throughout the national park system, NPCA also established its "Code Red" list of "America's Five Most Polluted National Parks" using an air-pollution index based on haze, ozone, and acid precipitation (NPCA 2002*b*). Regional nitrate deposition in Great Smoky Mountains National Park in the southeastern United States is the highest of any monitored site in North America, with ozone pollution rivaling that of Los Angeles and violating federal health standards more than 175 times since 1998. Similarly, ozone levels surpassed human-health standards on 61 summer days in 2001 in Sequoia and Kings Canyon National Parks in the western United States Other parks making the *list of five* most polluted parks include Mammoth Cave National Park in Kentucky, Shenandoah National Park in Virginia, and Acadia National Park in Maine.

Parks are clearly not the only category of U.S. public lands that face serious environmental problems. National Wildlife Refuges (NWRs) are particularly vulnerable to development pressures from outside of their boundaries because of their small size. Competition for water resources between refuges and adjacent human populations is particularly acute in arid western regions where many refuges report that they do not have enough water in an average year to support wildlife needs (summarized by Pringle [2000]). The Audubon Society (2001) concluded that the NWR system is in a state of crisis and is failing to protect bird species that are federally listed as threatened or endangered. To emphasize this crisis, the Society released its list of "*Ten Wildlife Refuges in Crisis*" (each of which is a major national or international conservation priority) because of imminent threats to their biological integrity. Examples span a wide geographic range and include the Sonny Bono Salton Sea NWR in California's Imperial Valley, the White River NWR in Arkansas, the Blackwater NWR in Maryland, and the Kenai NWR in Alaska. To detail just one example of problems faced by a given NWR: the Sonny Bono Salton Sea NWR is one of the few remaining locations in southern California where many birds can rest and feed during their migration along the Pacific flyway. This refuge is plagued by high mortality of fishes and avifauna resulting from water quality and quantity problems, to the extent that an on-site incinerator is routinely op-

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erated for disposal of dead birds—including endangered species such as brown pelicans.

The lack of long-term scientific information that can be used to identify and address the increasing number of environmental threats to public lands is problematic. How can we systematically assess the biotic integrity of public lands on regional or national levels if data are nonexistent for many land units? All too often, "piece-meal data" are used in local management decisions (see Kaiser 2000) and in attempts at more regional syntheses of environmental problems and trends. As just one example, the NPCA's report "Code Red: America's Five Most Polluted National Parks" is based on data from only 10 national parks (out of 270 major park units)—selected because they had sufficient monitoring data to permit a comparative analyses of data from 1991–2001. In contrast, most of the park units within the National Park System (NPS) lack monitoring programs, precluding systematic assessment at a regional or national level.

The strength of science–management connections is highly variable both within and among different types of public land units. This is a reflection, in part, of the high variability in how natural resources are managed in different regions of the United States, between states, and between different categories of public lands. While detailed discussion of the causal factors behind these disparities is beyond the scope of our commentary, here we emphasize the variability in connections between science and management and the need for a unified infrastructure to promote the gathering and application of long-term scientific information. As just one example provided by Parsons (2004), NPS science-based management in some parks (e.g., Yellowstone, Great Smoky Mountains, Everglades) has been disproportionate relative to others. Research in Yellowstone, Great Smoky Mountains, and Everglades National Parks has benefitted from fairly substantial within-park research centers staffed by NPS research scientists and largely driven by "individual personalities and circumstances rather than a unified, national agenda" (Parsons 2004). Recent attempts to establish an independent research arm within the U.S. Department of the Interior (DoI)—i.e., the National Biological Survey (NBS)—fell prey to a political agenda, regardless of the potential value of the NBS to management of biological integrity on our nation's public lands. Nonetheless, over the past 10 years, the DoI has continued to encourage and support research in some flagship parks, such as Yellowstone National Park. However, the DoI's support of research does not necessarily imply that this research will be directly applied to management in these flagship parks or elsewhere. To do so requires a culture shift in the attitude and training of park managers (Parsons 2004), and the understanding by scientists that policy and management decisions will not be based solely on research data. Instead, scientists must learn to sit at the table as active discussants in order to provide advice and interpretation to managers as they weigh multifaceted policy decisions.

An important mechanism to arm scientists with information for management and policy is integrated, long-term, question-driven ecological research. An example of the prospective utility of this approach is the NSF-sponsored Long-term Ecological Research (LTER) program. The mission of the LTER network is to establish a well-documented legacy of experiments and observations to gain an ecological understanding of a diverse array of ecosystems at multiple spatial and temporal scales. Coupled with this mission is the goal of creating well-designed, well-documented databases that are accessible to the broader scientific community. The LTER network has achieved these goals with varying degrees of success. Certainly, LTER is not the only option, and several non-LTER sites (e.g., Walker Branch Watershed [eastern Tennassee]) have successfully conducted long-term and integrated research of national significance. Nevertheless, a coordinated network of research programs with broadly defined goals would provide invaluable information at multiple spatial and temporal scales to enlighten policy and management decisions on public lands.

As part of the DoI's attempts to foster scientific research, repeated requests were made to NSF to sponsor LTER sites in National Parks. To us, this reflects a favorable directive from the DoI that LTER-like research would benefit park management. Parsons (2004) states that NSF has refused to fund LTER sites in national parks because of a "lack of trust in the NPS's commitment to the long-term protection of study areas"; however, we are unaware of any current policy at NSF to explicitly or implicitly exclude national parks from the LTER Network. In fact, during the last round of competition for Land–Coastal Margin LTER sites, an LTER program managed by scientists at Florida International University was established in Everglades National Park. Moreover, the LTER network has a long history of research partnerships with federal scientists working on federal lands, including USDA Agricultural Research Service stations (Jornada [New Mexico], Shortgrass Steppe [Colorado]), USDA Forest Service Experimental Watersheds (Bonanza Creek [Alaska], H. J. Andrews [Oregon], Baltimore Ecosystem Study [Maryland], Coweeta Hydrological Laboratory [Georgia], Hubbard Brook [New Hampshire], and Luquillo [Puerto Rico]), DoI's Bureau of Land Management property (Toolik Lake [Alaska]) and the DoI's National Wildlife Refuge system (Sevilleta National Wildlife Refuge [New Mexico]). Thus, 11 of the current 24 LTER sites are on public lands where academic and federal scientists conduct integrated research. Indeed, many of these sites are part of the LTER network because they already had long-term research programs in place prior to LTER.

LTER and other long-term research programs have shown repeatedly how question-driven fundamental research yields unbiased knowledge about complex systems that can be applied directly to management issues. Since many ecological processes have high levels of year-to-year variability, long-term research is often essential to separate pattern from noise (Franklin 1989). As a classic example, studies at the Hubbard Brook Experimental Forest in New Hampshire demonstrated the occurrence of acid precipitation (Likens and Bormann 1995), distinguishing relatively subtle changes in the acidity of rainfall through time. These studies led to amendments to the Clear Air Act of 1990, illustrating the importance of long-term studies in identifying and resolving environmental issues from regional to global scales (Blair et al. 2000). Similarly, research at the Sevilleta LTER site in New Mexico provided the background understanding to determine linkages between the 1993 El Niño episode, small-mammal population dynamics, and Hantavirus Pulmonary Syndrome in the southwestern United States. This information was then used to warn the public about a possible Hantavirus outbreak during the 1997–1998 El Niño event (Yates et al. 2002). On a more local level, research on the migratory behavior of riverine shrimps at the Luquillo LTER site (i.e., the Caribbean National Forest) in Puerto Rico was ultimately used to make recommendations for mitigation of negative environmental effects caused by massive water abstraction from streams draining the national forest. Field measurements of the mortality of migratory shrimp larvae, combined with a 30-year discharge record, allowed modeling of the long-term ecological impacts of different water intake management strategies (Benstead et al. 1999) and were instrumental in the Puerto Rican Aqueduct and Sewage Authority's decision to alter the design of two new water withdrawal systems to minimize the mortality of migratory stream biota.

In a visionary evaluation of the LTER network, the "Risser Report" (Risser et al. 1993) recommended an expansion of the LTER network and network activities to include federal lands and federally sponsored research programs. The premise behind these recommendations was that integrated, long- and short-term research would provide the understanding needed to address many management issues on public lands. In addition, presaging NSF's National Ecological Observatory Network (NEON) initiative, the Risser Report recommended that existing LTER sites increase their spatial domain via a sub-network of regional satellite sites, including public landholdings, such as parks and wildlife refuges. The objective of NEON is to build an integrated national network of environmental observatories to address critical questions about changes in ecological systems and to evaluate the impacts of those changes at regional to continental scales. This network would include an intensively instrumented core site and a variety of satellite sites. NEON explicitly includes publicly managed lands as potential core and satellite sites, providing another opportunity to create a legacy of research that will inform land managers.

Without a doubt, long-term research has led to management applications even when that research was not driven initially by management needs (e.g., Krishtalka et al. 2002). We believe that long-term basic research coupled with targeted, problem-based research will go a long way in informing policy decisions on public lands. We strongly recommend that an LTER-like network be established and supported by relevant agencies to promote integrated, regionally based understanding of ecosystems. This network should be linked to existing regional and national programs (e.g., LTER, National Water Quality Assessment Program, AmeriFlux Network, etc.). This would provide a much-needed "network of networks" on a continental scale that would yield a deeper understanding of ecological systems and provide better information to guide management of our endangered public lands.

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PROMOTING ECOLOGICAL RESEARCH IN NATIONAL PARKS—A SOUTH AFRICAN PERSPECTIVE

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BACKGROUND

South African National Parks (SANParks) has its own unique and favorable science dispensation, particularly in its first and biggest holding, the Kruger National Park (KNP). SANParks is a parastatal organization currently administering 20 parks over a wide range of South African biomes. Finances accruing from tourism revenue are recirculated within the organization, but with the central government still subsidizing some mainstream SANParks activities to a level of less than 20% of corporate budget in the last decade. A sustained track record of institutional support for science has been the result of a general desire to link science and management, of some good parks–academic partnerships, and of a legal mandate since a modification introduced into the National Parks Act:[2]

> *The object of the constitution of a park is the establishment, preservation* ***and study therein*** *of wild animal, marine and plant life and objects of geological, archaeological, historical, ethnological, oceanographic, educational and other scientific interest . . . .*
> [emphasis added]

Scientists have been part of the staff at KNP since 1950 and deployed in other parks since the early 1970s, and their work has been expected to inform management through generating relevant basic ecological understanding. Initially, the science emphasis throughout SANParks was more on applied and descriptive topics (especially relating to charismatic fauna), on inventorying, and on setting up what have become long-term monitoring programs. Over time, park scientists have come to act mainly as science facilitators. Since the early 1990s staff scientist numbers in SANParks have stayed more or less constant at around 20 persons, including several veterinarians. They are assisted by technicians, field assistants, secretaries, game guards, and laborers. Apart from a long history of science activity at KNP, some excellent and sustained science initiatives have also been conducted in the Kalahari Gemsbok and Mountain Zebra (both arid savanna parks), Tsitsikamma (mainly marine research), and Wilderness (a freshwater lake system) National Parks (Biggs and Novellie 2003). In an ongoing drive towards biome representivity, much expansion of conservation estate is currently taking place in the unique fynbos (a globally renowned separate floral kingdom) and succulent karoo, and SANParks are increasingly using state-of-the-art structured conservation planning techniques (Margules and Pressey 2000) to select these reserve networks. In particular, science activities in the recently acquired Cape Peninsula National Park, although largely outsourced, include strong elements of what was available through the plethora of organizations that previously controlled the nonresidential parts of the Cape Peninsula. This park also has a strongly developed integrated environmental-management system, making formalized provision for science–management links. Outside of this and the KNP (the two "institutionally large" parks with their own scientific community), a key issue was the clustering of scientists into a few viable centers serving wider areas, rather than placing one scientist at each "smaller" park.

The application of science, and the relationship between science and management is thus uneven across both the existing and the proposed park system (McKinsey and Company, 2002). This is part of a wider challenge, going beyond science and conservation

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[2] First introduced in Act 42 of 1962, Section 4, and carried forward in subsequent revisions.