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National Parks as Scientific Benchmark Standards for the Biosphere; Or, How are You Going to Tell How It Used to Be, When There's Nothing Left to See?

How are you going to tell how it used to be, when there's nothing left to see?

At first, national parks were hard to see because there was so little difference between resource conditions in the parks and in the wild areas around them. Now some parks can be recognized from outer space because humans dominate the land around them so completely. Examples bracket the United States from Olympic National Park on the northwest coast of Washington to Everglades National Park in southeastern Florida. Nevertheless, many national parks are becoming hard to see again because they are small pieces of fragmented landscapes, overrun by invasive alien species, and just as stressed by altered air, water, and soil as the adjacent lands (Grumbine 1990; Vitousek et al. 1997). In the ocean, so-called marine protected areas proclaim "protection" in their titles (e.g., park, refuge, reserve, and sanctuary), but fishing in them is managed virtually the same as it is everywhere else so there are no discernable differences between fish populations in or out of parks (Jackson et al. 2001; Beets and Rogers 2001). Even in the parks, only the ancient hunter-gatherer's strategy of serial depletion based on endless sources of new species and territories sustains ocean fisheries, while exploited populations collapse and ecosystems decay into simplified remnants filled with ghosts (Dayton et al. 1998; Diamond 1997; Jackson et al. 2001). The U.S. National Park System contains special places saved by the American people so that all may experience the nation's heritage—yet even in these most special places unimpaired nature is rapidly disappearing. In this chapter, we will describe potential values of national parks and equivalent protected areas to science and society, discuss forces that threaten those values, and suggest how monitoring ecological vital signs (Figure 1) could help mitigate the effects of those forces.

National parks and equivalent protected areas potentially hold many values for people. An early twentieth-century champion of utilitarian conservation, President Theodore Roosevelt, declared, "There is nothing more practical in the end than the preservation of beauty," upon seeing coastal redwoods for the first time (Morris 2001). Arguably, the most important value of national parks is to provide human happiness. In a utilitarian sense, the persistence of nature in parks administered to "conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations"

Figure 1. Environmental monitoring, such as collecting hydrology and weather data, is part of the management routine at Everglades National Park, Florida. *National Park Service photo*.

should yield the greatest happiness for the greatest number of people. If adequately protected, national parks also have great potential value for scientific investigations of the biosphere—the life support system of Earth. Protected places can serve as environmental benchmark standards for comparisons with more altered parts of nature, and they can help scientists differentiate anthropogenic from other environmental changes. Parks can be reservoirs of wild genetic diversity and refugia that rebuild populations of endangered species and restore the integrity and resiliency of disarticulated ecosystems. They are special places in which scientists can unravel the mysteries of natural and human history, evolutionary adaptation, ecosystem dynamics, and other natural processes (National Research Council 1992).

Parks provide truly unique opportunities. They combine the power of place with the last, best remnants of nature least dominated by humans. Science is a way of knowing, a process for learning (Moore 1993). Personal experience is among the most powerful and enduring ways for most people to learn. Parks provide places to learn from personal experience, thereby rendering the abstract real. By giving multiple examples of reality, parks connect people to abstract concepts emotionally. Such place-based learning offers multiple stimuli that enhance opportunities for diverse learners, clarifies new insights, and strengthens retention. Parks generate passion for learning, with deep, personal, emotional connections born out of experience, and stimulate curiosity that is the bedrock foundation of science.

National parks can be special places for science only if nature is treated differently in them than in other places. In the United States, at first people thought they could protect parks by building virtual walls around them (Sellars 1997). Early park managers based their actions on beliefs of what park visitors wanted and how they thought ecosystems functioned (Davis and Halvorson 1996). They believed that physical environmental factors, not biological interactions, largely determined ecosystem structure and that people came to parks to see the forests and wildlife and to catch fish. Since fires burned the forests, predators ate the elk and deer that visitors came to see, and pelicans ate the trout people sought to catch, it seemed clear that park stewardship called for fire suppression and predator control. So to protect the parks, park stewards killed wolves and coyotes, crushed white pelican eggs, and did their best to put out forest fires (Varley and Schullery 1996). Today these actions seem naive at best. These early perceptions changed as scientists discovered the often counterintuitive ways in which ecosystems function. It is now clear that infrequent, extreme natural events, such as hurricanes, hundred-year freezes, and "catastrophic" forest fires, do not destroy ecosystems but are essential to sustain coral reefs, coniferous forests, and other ecosystems (Dayton and Tegner 1984). Ecologists also found that predators, far from eliminating prey populations, were essential for sustaining diverse communities (Paine 1994). Removing predators from ecosystems, either experimentally or accidentally, triggered cascades of unanticipated consequences in parks that threatened the very resources and values that the stewards sought to preserve.

What changed? Knowledge of place changed. Scientific knowledge and understanding of place are the cornerstones of park stewardship. Effective park stewardship depends on continuing improvements of knowledge and understanding of parks from scientific iterations of monitoring and experimentation (management actions) that frame, test, and falsify myriad hypotheses. Only with this improved understanding of ecosystem structure and functioning can park stewards hope to restore the integrity and resilience of impaired parks, to protect nature unimpaired in parks and to mitigate internal and transboundary threats, or to connect people to their heritage with sufficient impact to engender the public commitment needed to preserve parks unimpaired for the enjoyment of future generations. This knowledge of nature begins with curiosity, exploration, and inventories of the world around us that are the hallmarks of science. Static inventories inevitably lead to monitoring to discover, describe, and understand how nature changes in time and space. Monitoring environmental vital signs of parks is the beginning of scientific stewardship that will determine the success or failure of conservation in the twenty-first century and the survival or demise of nature as the Earth's biodiversity is threatened by human domination.

Changing Management Approaches

As cultural constructs existing within the matrix of their time and place, the purposes and values of national parks and protected areas vary from one place to another and have evolved over time. The perception of what jeopardizes those values has likewise evolved—not only as a consequence of improving scientific knowledge or demonstrably altered circumstances within and surrounding the parks themselves but also because of their evolving context. In the United States, this has been strikingly illustrated by the changes over the past half-century in what are commonly called "threats"—or "stressors" in modern ecosystem vernacular.

During the time when what largely distinguished the classic large western national parks from their landscape matrix was the presence of a recreation infrastructure (i.e., roads, visitor centers, signs, and rangers), those threats were largely identified as the local, particular attributes that interfered with the enjoyment of visitors as they recreated and enjoyed nature on their increasingly civilized terms. As indicated earlier, in the early decades of the twentieth century those might include predators (or poachers) preying on desirable viewing species such as deer, birds consuming catchable fish, or the very absence of infrastructure needed to visit and comfortably enjoy what the parks had to offer.

By the 1950s, those same American parks had begun to differ strikingly from rapidly changing surrounding lands—even those lands as yet undeveloped but dedicated to resource extraction. There was a growing sentiment among conservation writers that national parks should represent some sort of "vignette of primitive America." This was reflected in a commissioned report by a senior committee of wildlife biologists (Leopold et al. 1963) to the U.S. secretary of the interior. Moreover, the science of the time reflected the assumption that natural, wild ecosystems tended to be homeostatic and thus would persist in a relatively constant state over time if they were not compromised. Thus, it would be possible, through intelligent, restrained management, to provide park visitors and society with fragments of a wild, American past that provided not only conservation but the romance of history. Interestingly, the unraveling of this paradigm of natural stability, and its replacement by one of dynamism and even periodic catastrophe, was presaged in one of several scientific reports to the U.S. National Park Service as early as 1963 (NRC 1963). Both of these reports notably emphasized the preeminent value of national parks as preserves of wild nature that retained all of its original parts over their value as "pleasuring grounds" for tourist recreation.

The wilderness movement in America, which began with a small group of scientists in the 1930s and culminated in the passage of the Wilderness Act in 1964 (establishing a new, stringent standard of protection on now more than forty million hectares of public lands, including many national parks, in the United States), was a distinctive cultural thread that was ultimately to have profound and continuing interactions with the perceived values of parks and preserves. The founders of this movement — Robert Marshall, Aldo Leopold, and Olaus Murie—were all trained field scientists who had come to recognize that "untrammeled nature" was fast disappearing from our planet (Leopold 1925, 1949; Marshall 1930), and at great cost—they believed—to the human spirit and the web of living things with which we share the planet. Although in their exhortative and popular writings they emphasized the critical importance of large blocks of completely wild lands, roadless and lacking all mechanized transport, as a sanctuary for the human soul and a place where primitive enjoyment could be pursued, they also believed that the unimpeded interactions of natural ecosystems were of critical scientific value, as well as possessing innate value to and of themselves. There is nothing in the Wilderness Act, however, that acknowledges the possibility of disturbance from outside wilderness that could lead to a compromise or loss of those values.

The scientific reports to the U.S. National Park Service of the 1960s, as well as the changing cultural matrix in which they occurred—which produced Earth Day and far broader (if less personally intimate) interest in nature conservation—ultimately contributed to a significantly greater concern for preserving all "nature" in American national parks. For the first time, this explicitly included nature that did not necessarily offer scenic splendor or recreational opportunities. But the science that supported such conservation was largely autecological and confined within park boundaries. Contemporaneously, values emerging from some of the same springs as the wilderness movement led American parks to seek to eliminate traces of artifice and anthropogenic influence on park landscapes. This has included the removal of structures, the naturalization of camping sites, and regulations to protect fragile features and to reduce crowding and social conflicts in park "backcountry" areas.

The contemporary conservation movement and scientific ecology have interacted in the past two decades to develop a better understanding of and concern for ecosystem-level properties that often function at scales far greater than park or preserve boundaries. The consequence of this has been that even in the largest and oldest national parks, we now understand that most often the serious ecosystem stressors—the anthropogenic forces that lead to a loss of an untrammeled ecosystem retaining all of its parts—are not so much from tourism and the interaction of park visitors with nature but represent forces operating at regional to global scales (Graber 1983, 1995).

For example, in many of the national parks in the American Southwest, these "Four Horsemen of the Apocalypse" typically include:

- *Insularization and habitat fragmentation.* Land use changes outside park boundaries have led to incomplete home ranges for some animal populations, or populations too small to sustain themselves genetically within a park—resulting in genetic impoverishment or extirpations. It has also led to the invasions of alien plants and animals, sometimes outcompeting native organisms or leading to fundamental changes in ecosystem processes.
- *Atmospheric contamination.* Research on the presence and effects of acid precipitation, ozone, nitrates, and sulfates, in particular, has demonstrated that these can significantly alter the competitive balance within an ecosystem, frequently reducing system productivity and often favoring "weedy" species. Air pollution can also have a significant aesthetic effect on visitor enjoyment in national parks.
- *Loss of native fire regimes.* In xeric western shrublands, woodlands, and forests, fire has often been the principal ecosystem architect. Intensive research over the past three decades, especially in the national parks, has demonstrated that the frequency, intensity, and extent of fire has been radically altered by fire suppression, changing land use, the loss of customary aboriginal ignitions, the introduction of alien plant species and consequent changes in system flammability, and sometimes the introduction of new sources of ignition, such as automobiles and cigarettes.
- *Climate change.* Rapid changes in seasonal temperatures, in the timing and extent of precipitation, and even in the chemical composition of the atmosphere are expected to induce profound changes in biological communities over much of the planet within this century. As parks and preserves have come to increasingly resemble islands in an alien sea, they will be less able to function as reservoirs of biodiversity when native biota no longer find appropriate environmental niche, and they introduced cosmopolitan species of broad tolerance arrive to compete with them.

A decision of utmost importance will be facing preserve managers, their scientific advisers, and the public who supports parks in the near future: To what extent will parks and preserves be intentionally managed to mitigate against these grand stressors and to protect native biodiversity to the extent feasible? Or will we apply a wildness standard that accepts change and loss in exchange for a minimum of visible anthropogenic intrusion into these last remaining bits of wild nature (Graber 1985, 1995)?

Monitoring: Species or Ecosystems?

Intact ecosystems are more than the

sum of their parts. Processes and forces that bind the parts into a system produce synergies and properties that the individual parts do not possess when simply collected together. Conservation strategies based on a few parts of systems, such as endangered species, may be effective. As a result, conservation strategies can be tested in national parks that protect whole ecosystems, but they cannot be tested in disarticulated, stressed, or fragmented systems or on isolated individual parts of systems.

Although stewardship goals for federal lands are increasingly focused on the status of entire ecosystems rather than individual species (Noss 1993; Franklin 1995; Woodward et al. 1999), management and monitoring are likely to continue to focus on both individual species and more integrative parameters. Woodward et al. (1999) discuss three types of species often included in monitoring efforts: "target species" of social and/or political significance, "bioassay species" that are responsive to particular types of contamination or other stresses, and "indicator species" that shed light on basic ecological processes. Fleishman et al. (2001) review the utility of "umbrella species" in conservation (i.e., species whose protection is intended to extend to a much broader group of species). They conclude that umbrella species mostly pertain to fairly narrow taxonomic bounds (e.g., a conservation strategy based on an umbrella bird species is not likely to protect many butterfly species). Efforts to develop a conservation strategy for forests of the Pacific Northwest illustrate the point. Although the endangered northern spotted owl (*Strix occidentalis caurina*) occupies large home ranges primarily within old-growth forest, a strategy based on the owl would leave out many key components of biological diversity in the region. Thus, there is a need for a conservation strategy emphasizing a broad array of taxa and habitats (Noss 1993; Franklin 1995). For a variety of political and scientific reasons, monitoring of protected areas may include both high-profile species and basic ecosystem measurements (Woodward et al. 1999). Thus, in addition to the critical role of documenting normal variation of natural systems that are still nearly pristine (Schindler 1987; Noss 1993), monitoring and research in protected areas may help us understand how single species versus ecosystem approaches compare in providing the information needed for stewardship.

Vital Signs Monitoring

The primary applied uses of ecological monitoring are to guide and evaluate stewardship activities, to provide early warnings of abnormal conditions, to identify possible causes of abnormal conditions, and to help frame research questions to resolve conservation issues (Davis 1993). In places such as Channel Islands National Park in California, monitoring demographics of selected species and related physical environmental factors as surrogates for the vital functions of ecosystems over twenty years has helped

- control and eliminate invasive alien species;
- detect and mitigate effects of chemical pollution;
- recognize and change unsustainable uses, including fishery management policies; and
- develop and evaluate population and ecosystem restoration method-

ologies.

Let's consider some specific examples of applications of environmental vital signs monitoring information to park stewardship issues.

Alien species constitute an ever-increasing threat to the park. Stewards of the California Channel Islands have used an environmental "Vital Signs" monitoring program to direct and evaluate removal of several alien species, including burros on San Miguel Island, European hares on Santa Barbara Island, feral pigs on Santa Rosa Island, and South African iceplant on Anacapa Island. Before instituting monitoring programs, eradication efforts were sporadic and ineffective. Numerous efforts were made to remove feral rabbits from Santa Barbara Island in the 1950s and 1960s by hunting and spreading poison bait, but none was successful until the Vital Signs program provided specific information about the effectiveness of various population control methods (trapping vs. hunting), rabbit population trends, and reliable cost and time estimates for complete eradication. By reducing the uncertainly of success through monitoring, the eradication program gained enough support to sustain the effort long enough to succeed.

Even before the Vital Signs program began, monitoring wildlife populations in the park provided an early warning of regional pollution with global consequences. Monitoring reproduction and recruitment in California brown pelican rookeries on Anacapa Island identified pesticide (DDT) pollution in the Southern California Bight and provided sufficient time to ban DDT and restore pelican productivity (Anderson and Gress 1983). Today, the park's Vital Signs program indicates clearly that DDT is still a problem in coastal ecosystems, as evidenced in continuing reproductive difficulties experienced by peregrine falcons and bald eagles (Detrich and Garcelon 1986). The Vital Signs program also indicates that progress is being made, which thereby encourages people (society) to continue abatement activities.

Vital Signs programs also help decide when human intervention in park ecosystem dynamics is appropriate, such as when to suppress forest fires or let them burn. The Channel Islands National Park rocky intertidal monitoring protocol was modified and applied to Cabrillo National Monument, in San Diego, California, in 1989. In 1992, when the San Diego municipal sewage treatment effluent discharge pipe broke and dumped sixteen billion gallons of treated effluent into the sea less than a kilometer from the monument's monitored tide pools over a two-month period, many people were rightfully concerned about marine life in the tide pools and adjacent kelp forests (Tegner et al. 1995). Objective information from prespill monitoring established clearly that the effluent had no immediate negative effect on the fifteen vital sign taxa monitored. Closing the tide pool area to visitation during those two months, in order to protect visitors from potential health hazards in the effluent, actually relieved trampling and other visitor-related disturbances, which was reflected by increased abundance in most vital sign taxa.

The Vital Signs program in this case saved unnecessary expensive litigation that often occurs without actual knowledge and with a belief that damage is self-evident in such situations.

The two-month closure associated with the effluent spill constituted a large environmental experiment unlikely to be conducted intentionally. Since the Vital Signs program was in place, it was possible to measure the effects of the event and separate the longer-term trends in populations associated with regional environmental events, such as El Niño. For example, the chronic loss of California mussels (*Mytilus californicus*) and feather boa kelp (*Egregia menzesii*) that had been recorded for three years before the effluent spill continued at the same rate during and after the spill, while ground cover of ephemeral algae and sea grass (*Phyllospadix* spp.) increased dramatically (Engle and Davis 2001).

Many fisheries are managed and evaluated largely on the basis of fishery-dependent landings data that may not be related to changes in fished populations. Fishery-independent monitoring provides essential corroborative information for fishery managers (Botsford et al. 1997). Serial depletion of five species of abalone (*Haliotis* spp.) and then a sea urchin (*Strongylocentrotus franciscanus*) to support a commercial diving fleet was obscured by ambiguous landings data in southern California before monitoring data were available (Dugan and Davis 1993). As a result, fishing exhausted abalone populations before fishery management policies could be changed and drove at least one species to the verge of extinction (Davis et al. 1996).

Political systems are frequently frozen into inaction by uncertainty (Wurman 1990). Reliable fishery-independent data from Vital Signs allowed the political process to work by reducing uncertainty regarding abalone population status. The California Fish and Game Commission and the state legislature closed five abalone fisheries to prevent loss of critical brood stock and to facilitate and reduce the costs of rebuilding depleted populations statewide only after Vital Signs data confirmed imminent abalone population collapses—collapses that were implied by declining fishery landings but contested by fishing interests.

Vital Signs methodologies are currently being used to test a variety of different abalone population restoration techniques at the California Channel Islands (Davis 2000). Ecological monitoring also provided early warning of a black abalone (*H. cracherodii*) population collapse (Richards and Davis 1995). The ultimate population collapse was apparently caused by infectious disease in small, dense, but fragmented populations. Monitoring provided sufficient information, early enough, to protect disease-resistant individuals from fishery harvest and to ensure survival of another generation.

The Channel Islands National Park Vital Signs program has become a prototype for many other national parks and other agencies, and it catalyzed a national Vital Signs program for the U.S. National Park System. This approach has been used successfully in a wide variety of ecological settings with many Delphi experts, including deserts (Organ Pipe Cactus National Park and Lake Mead National Recreation Area), mountains (Great Basin, Lassen Volcanic, and North Cascades national parks), and the New England coast (Acadia National Park). Other U.S. national park units emulating the Channel Islands model include Virgin Islands

(U.S. Virgin Islands), Dry Tortugas (Florida), Denali (Alaska), Great Smoky Mountains (Tennessee–North Carolina), Shenandoah (Virginia), Olympic (Washington), a cluster of small prairie parks in the Midwest, and a cluster of parks on the Colorado Plateau. Based on the experience gained in prototype park programs, the U.S. National Park Service plans to implement Vital Signs programs in 32 networks covering 270 national park system areas with significant natural resources. Only with the information acquired by Vital Signs programs can national parks be adequately understood, restored, maintained, and protected so that current and future generations can enjoy their wonders, receive their inspiration, and reap the values of their unimpaired ecosystems.

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