U.S. National Park Service Inventory and Monitoring: A California Park Perspective

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In the last decade biological diversity has become one of the most intense focal points for thought and research in the ecological sciences since Darwin presented his thesis on organic evolution. One hundred and forty three years after Darwin and Wallace proposed the mechanism for evolutionary change, society is urgently seeking ways to maintain the variety of living species observed on the planet (Wilson 1988, Daily and Ehrlich 1992). In the face of exponential growth in the human population and consequent consumption of natural resources (Daily and Ehrlich 1992), biological diversity is being lost at an alarming rate (Wilson 1988). Concern among scientists for the loss of biological diversity (Harris 1984) sparked the formation of a new scientific society, the Society for Conservation Biology, which is dedicated to understanding processes, developing technologies, and integrating this knowledge for social change (Soulé 1987). It is ironic that as our ability to analyze complex ecological relationships has increased, the biological diversity crisis deepens.

Since MacArthur (1965) first discussed patterns of species diversity, tremendous effort has been focused on the topic. The U.S. National Park Service, with a mandate to maintain biological diversity, will use inventory and monitoring to document biological diversity in managed ecosystems (U.S. National Park Service 1992, Rugh and Peterson 1992). Any monitoring effort must be done with a clear understanding of the intricate assortment of processes that influence an assemblage of species (Cody 1975), such as habitat selection (Rosenzwieg 1985, Thomas et al. 1992). At the population level we must understand (1) that abundance may be misleading as an indicator of habitat quality, and (2) the roles of "sources" and "sinks" (Lidicker 1975, van Horne 1983, Pulliam 1988). We must understand the influence wildlife species have on their habitats (Naiman 1988), such as meadow voles on grassland (Batzli and Pitelka 1970, Lidicker 1975, Batzli 1992). The role of disturbance (which at intermediate levels can promote diversity) and natural patch dynamics are integral to understanding diversity at a landscape scale (Pickett and White 1985, Verner et al. 1986, Urban et al. 1987). The influence of scale on study design cannot be overlooked (Wiens 1981). All of these critical concepts are nested within the hierarchical concept of landscape ecology (Urban et al. 1987).

Golden Gate National Recreation Area (GGNRA) was formed by an act of Congress in 1972 as a unit of the National Park System. The park encompasses 300 km^2 of central coastal California bracketing the Golden Gate and is part of the Central California Coast Biosphere Reserve dedicated in August 1989 (UNESCO 1989). In 1992 it was the most-visited unit in the National Park System, with nearly 20 million visitors. Two centers of endemism are separated by the Golden Gate giving rise to exceptional diversity (Murphy 1988), but because of urban development 11 species are federally classified as threatened or endangered. Park management policies and practices to protect biological diversity remain controversial (Westman 1990).

In the past two decades our society has catapulted into the automated information age of small computers. As computers became smaller, they became more affordable and programming became more sophisticated to the point that an individual can have data storage, retrieval, and analytical capabilities on his/her desk that would have made a scientist on the "Manhattan Project" shudder at the magnitude of their power to process information. Although we are seeing a proliferation of these hardware and software tools, our ability to gather basic wildlife distribution and abundance data to use with these tools lags far behind. Biological diversity will be affected by numerous proximate and global human influences over the coming decades (Wilson 1988). Without empirical information about these relationships, natural resource managers remain blind to the consequences of their decisions, which ultimately affect the biological resources in their care. A case in point is the Park Service's need to have basic biological inventories of each of the 350 park units in the system (Rugh and Peterson 1992).

In 1989 the superintendent of Golden Gate National Recreation Area set two new objectives for natural resource management at the park. First, the park ecologist would begin inventorying wildlife resources. This objective recognized the need to manage dynamic processes and ecosystems for the conservation of biological diversity (Western 1989). Second, the park would establish natural resource monitoring programs similar to more established programs at Channel Islands National Park (Davis and Halvorson 1988, Fellers et al. 1988). The GGNRA monitoring programs were designed to detect changes in important natural resources and potential resource losses as a result of management actions (Howell 1982, Howell 1985, Howell 1987, Thomas 1992), succession (McBride and Heady 1968), animal influences (Naiman 1988), fire (Thomas 1985) or global climate change (Smith and Tarpik 1989, U.S. Department of the Interior 1989, Burke and Kiester 1990). Historically, data collected were project-specific, had little portability to new situations, and were occasionally misplaced.

The California Wildlife Habitat Relationship (WHR) System (Airola 1988) provided a starting point to direct inventory and monitoring efforts. Which species to expect in a given habitat is not always evident. Terrestrial vertebrates exclusive of birds and bats were selected for study because they exhibit characteristics that leave them vulnerable to environmental change. Ehrlich (1986) described three attributes necessary for invading species to be successful: the ability to cross barriers, establish successfully, and expand their range. Terrestrial vertebrates, especially many amphibians, reptiles, and mammals, tend to lack one or more of these characteristics leaving their populations susceptible to environmental change.

My research is designed to bring together the power of new computers, geographic information systems software, and wildlife habitat relationship models to evaluate their ability to assist in conducting a basic resource inventory (Howell 1993). In it, I discuss several themes underlying the process of developing, conducting, and evaluating a basic inventory of terrestrial vertebrates and their habitats and the application of geographic information systems.

For decades federal scientists have struggled with inventorying and monitoring wildlife species, establishing procedures to permit the detection of wildlife distributions and population changes, and predicting the response of wildlife populations to environmental change. Pioneering efforts in the U.S. Forest Service (Thomas 1979, Verner and Boss 1980, Patton 1992) and the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 1981, Hays et al. 1981, Schamberger et al. 1982) responded to the need for better and more accessible wildlife information in the decision-making process. Ralph and Scott (1981) examined the difficulties in our ability to estimate bird numbers. Davis (1982) compiled a handbook of census methods for numerous species. The U.S. Bureau of Land Management joined in the effort with a guide to wildlife inventory and monitoring (Cooperrider et al. 1986). Additional guidance is available from a wide array of sources (Seber 1982, Welsh 1987, Corn and Bury 1990, McCullough and Barrett 1992).

The Park Service has, by U.S. Code, the strongest mandate for wildlife preservation of any federal agency (Coggins and Wilkinson 1987). In 1991, the director of the USNPS Western Region signed a memorandum of understanding with the other federal land management agencies and California state agencies to protect and preserve California's biological diversity (California Resources Agency 1991). In 1992 the Park Service issued guidelines for inventory and monitoring in the National Park System (USNPS 1992). In 1983, USNPS commissioned the American Association for the Advancement of Science to prepare guidelines for resource inventory and baseline study methods (Conant et al. 1983). Ironically, the volume was prepared for developing countries, not the U.S. national parks. In a review by van Riper III et al. (1990) about inventory and monitoring, Conant et al. (1983) was not cited by a single author. It did receive brief mention in the description of Channel Islands National Park's inventory and monitoring program (Davis 1989). A park superintendent thinking of embarking on an inventory and monitoring program would be well advised to review Conant et al. (1983) in some detail. A discussion with resource management and research staff will improve understanding of the nature of commitment necessary to develop and maintain an effective inventory and monitoring program. Miller et al. (1983) stated, "Its [Conant et al. 1983] purpose is to explain, in a single volume, current methodologies for renewable natural resource inventories and environmental baseline surveys that are appropriate for strategic planning and project assessment."

Scientists within the Park Service have begun to address the state of knowledge of inventory databases for national parks. For example, Cook et al. (1990) reported serious inconsistencies in mammal inventory data among parks in California and recommended steps to ensure consistency and quality of data. Similar inconsistencies were reported for vascular plants and amphibians and steps were recommend to close the gaps in knowledge (Stohlgren et al. 1991). Quinn and van Riper III (1990) called for workshops and forums to design and standardize inventory and monitoring studies.

All the above authors called for standardization and uniformity, but in our quest for standard reporting, we can not permit the format to mask the quality of the underlying data. Needs and methodologies will vary across regions and parks. Studies should not be designed by constraints but must "mesh comfortably with space and time scales of organisms, patterns of environmental variation, and content of study objectives" (Wiens 1981). Rigid standardization can lead to studies being limited to the "lowest common denominator," and thereby achieving uniform mediocrity. Wiens' (1981) recommendation was entirely consistent with recommendations for National Park Service's move toward ecosystem management (Agee and Johnson 1989). Adaptive management, first described by Holling (1978), is a process that uses management actions as hypotheses to be evaluated through the scientific process (Walters 1986). Science requires the hypothetico-deductive method of testing hypotheses and documentation of results (Romesburg 1981).

Verner (1986) presented a comprehensive overview of the state of wildlife inventory and monitoring. He recommended alternative strategies for different situations suggesting a focus on high-risk species. High-risk species were de-fined as having low intrinsic rates of increase, limited geographic distributions, low abundances, and limited successful reproduction in single habitats. He thought that habitat suitability models were appropriate for high-risk species, and wildlife–habitat relationship systems were appropriate for low-risk species. A similar approach of selecting species representative of the entire community was recommended for Channel Islands National Park (Davis and Halvorson 1988, Davis 1989). It has been argued, however, that a strategy for high-risk species will not necessarily protect or maintain desired levels of diversity. The validity of using indicator species has been seriously questioned on the grounds that habitat requirements of one species does not sufficiently overlap requirements of another species (Landers et al. 1988). The use of stratified random sampling of taxonomic groups has been suggested, and favorably received, rather than assuming that a particular species reflects environmental conditions suitable for all species in a community (Fry et al. 1986). A balance should be struck between focused censuses for community indicator species (Morrison et al. 1992) and diversity-based monitoring such as illustrated by my research because of the necessity to know which species actually are present.

Sampling to adequately address Type II error, the failure to reject an incorrect hypothesis (e.g., that some species population has not changed when in fact it had), will be an essential consideration when designing a good inventory and monitoring program. Hamilton (1979) warned that levels of precision were often set by: 1) routinely used textbooks, 2) what was satisfactory in the past, 3) what everyone else used, 4) what was attainable with available funds, and 5) what seemed about right. He stated that optimal sample size should be selected to minimize the cost-plus-loss function, that is, losses to resources due to errors in inventory estimates. Guidance is available for selecting appropriate sampling and statistical procedures (Cochran 1977, 1983, Box et al. 1978, Day and Quinn 1989, Chatterjee and Price 1991). Fertile ground for research includes the limits of sample size and power in inventories, the underlying costs, and efficiency of inventories (Verner 1983).

The relationship of survey cost to sample survey methods (Hansen et al. 1962), and to "optimal" precision of resource inventories (Hamilton 1979) has been examined. A central point made by Verner (1986) was the need to show the cost of the inventory effort. A lizard survey at five locations cost $41,000, and a desert tortoise survey with 1,500 line transects cost $100,000 (Marcot et al. 1983). Raphael and Marcot (1986) reported that their multi-year inventory of vertebrates in a mixed-conifer forest cost $600,000. My research cost $35,000 per year to implement, $17,000 of which was received from donations. Earthwatch volunteer labor had an estimated value of $57,600. In this case the implementing agency invested $36,000 over the first two years of inventory and received $91,600 in outside support and labor. Although resource value in national parks will be difficult to assess, inventory and monitoring will remain capital- and labor-intensive. Once a commitment is made to an inventory and monitoring program, it must be carried out in a dedicated and persistent manner—otherwise the program will result in little or no value to all.

Resource inventory is the basis for long-term monitoring of processes that affect biological diversity. The fundamental question of what actually lives in GGNRA has yet to be answered adequately. Through my research I explore some of the processes and problems of gaining information from a "basic" inventory of the diversity of higher plants, amphibians, reptiles, and mammals. This study provided the beginnings of a larger network of integrated inventory and monitoring among biosphere reserves around the world (diCastri et al. 1992). I hope lessons learned will improve efforts to document and monitor the complete range of flora and fauna across all habitats in GGNRA.

Management Recommendations

Conant et al. (1983) recommended that inventory and monitoring should not be project-oriented; that is, focused on or by a specific management problem. They went on to suggest that the methods of study should correspond to the conceptual framework of ecology and ecosystem function. The following recommendations evolved from my research in developing the inventory and monitoring program for Golden Gate National Recreation Area, and should be viewed in that light (Howell 1993):

- ✦ The California WHR System is being used by three California national parks—Golden Gate, Redwood, and Yosemite. The System should be made available to all park units in California with appropriate instruction for proper use.
- ✦ Wildlife habitat relationship models should be used to guide hypothesis development about distribution and community structure when available.
- ✦ Sampling methods, remote sensing, GIS applications, and multivariate modeling should continue to be evaluated by scientists for effectiveness and reliability.
- ✦ The USNPS Western Region should continue to participate in the California Interagency Wildlife Task Group, which is attempting to promote development and adoption of new standardized wildlife assessment and monitoring methods by all state and federal agencies in California.
- ✦ Conant et al. (1983) is a valuable reference for superintendents, natural resource specialists, and research scientists in the national parks. Also the authors might be contacted to elicit updating and revising, and possible republication of this out-of-print book.
- ✦ Adaptive management of natural resources (Holling 1978, Walters 1986) should become the rule in the national parks.
- ✦ Workshops on inventory and monitoring design should be conducted for USNPS resource managers and scientists annually to examine limitation, progress, and opportunities in developing reliable programs (Rugh and Peterson 1992).
- ✦ Data management should become institutionalized under a computer-automated database administrator (Gorentz 1992).
- ✦ Annual inventory and monitoring reports should be produced by each unit with an active program.
- ✦ Cost and efficiency should be an integral factor in the analysis of an inventory and monitoring program (Hamilton 1979).
- ✦ Experimentation in habitat manipulation should be promoted, when feasible, to enhance biodiversity—especially in areas such as GGNRA, where human disturbance has been great.
- ✦ A balanced effort should be conducted between a community-based approach and a species-of-management-concern approach.

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