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The U.S. National Amphibian Research and Monitoring Initiative and the Role of Protected Areas

Introduction

In response to concerns about the worldwide status of amphibians (Alford and Richards 1999; Bury 1999; Daszak et al. 1999; Houlahan et al. 2000), Congress in Fiscal Year 2000 provided initial support to agencies of the U.S. Department of the Interior for research and monitoring of amphibians. Most funds came to the U.S. Geological Survey (USGS), but additional funds for the U.S. Fish and Wildlife Service and the National Park Service (NPS) were provided for activities that directly or indirectly support the amphibian research and monitoring effort. The goal of the program is to provide timely and reliable information on the status of U.S. amphibians so that causes of declines can be understood and appropriate management responses initiated.

The Interior Department was fortunate to have a cadre of scientists who had already conducted pioneering work to document and understand declines of amphibians, primarily in the western states. These scientists were enlisted along with hydrologists, geospatial analysts, database managers, and others to plan a comprehensive national effort. After several rounds of planning that ultimately involved scientists from a number of disciplines, representing both federal and state agencies, a comprehensive framework was developed to guide the program, now known as the U.S. Amphibian Research and Monitoring Initiative (ARMI).

The difficulty of the task and the limitations posed by available staffing and funding soon became clear. The roughly 200 species of amphibians dispersed across the vast land area of the USA encompass a diverse range of life histories, habits, and habitats, and share few common characteristics. Even if the scientists and technicians in the ARMI had the resources of an actual army, it seemed doubtful that they could effectively determine the status and monitor the well-being of the U.S. amphibian fauna without major innovations in methodology and organization. The realization that it would be impossible to simply build the new program on the model of past efforts led to a strategy that seeks the active involvement of biologists and resource managers in all sectors of the public and private conservation community and that identifies a clear but highly restricted role for the federal science agencies. Paralleling this specified role for federal research scientists is a special role for protected areas. We believe that protected areas should play a vital role in all or most large environmental monitoring networks, and below we advance that argument from the point of view of the ARMI.

The Framework for Amphibian Research and Monitoring

The framework for the national ARMI is modeled on the l997 Committee on Environment and Natural Resources (CENR) report *Integrating the Nation's Environmental Monitoring and Research Networks and Programs: A Proposed Framework* (CENR 1997). This report presents a pyramid model (modified in Figure 1) of research defined by different levels of geographic scope and intensity. At the base of the pyramid, planners envisioned a network of geographically extensive surveys, such as the development of state-based amphibian atlases, and broad-based activities, such as the amphibian call surveys coordinated by USGS as the North American Amphibian Monitoring Program (NAAMP). In the apex of the pyramid, intensive monitoring, research to develop and improve monitoring protocols, and development of baseline data useful at all levels would occur at a few "index sites." Occupying the broad middle range of the pyramid would be more extensive operational resource surveys conducted by state and federal agency personnel responsible for managing land units or tracking the status of species of special concern. Integration of these components would be achieved by agreement among participants to adopt certain protocols and share data, and through development of models that present a coherent view of the regional status of amphibians.

The role of the USGS scientists in the framework includes the following activities:

- ***Field protocols.*** Working at index sites, USGS scientists, in cooperation with others, will develop methods and protocols for inventory and monitoring, and will conduct research to test and improve the effectiveness of available protocols.
- ***Disease and malformities.*** The USGS National Wildlife Health Center will investigate disease and malformation problems and help to develop biosecurity plans to avoid inadvertent transmission of disease.
- ***Species indentification.*** The USGS will collect and maintain specimens, tissue samples, and genetic materials necessary to document species found in inventories, and attempt to ascertain the species of specimens not easily identified.

- ***Monitoring at index sites***. Through intensive monitoring at index sites, USGS scientists will provide data to managers and others that may help in the interpretation of data collected at other sites.
- ***Design and analysis strategy***. The USGS will develop sampling designs and strategies to implement the ARMI program nationwide, involving biometricians, statisticians, hydrologists, cartographers, geospatial analysts, and modelers, as needed.
- ***Database management***. A national database at the USGS Patuxent Wildlife Research Center will serve as a repository for ARMI data and will make data available to scientists and the public on the Worldwide Web.

The Role of Protected Areas

Protected areas are a significant and essential component of large and comprehensive research and monitoring programs such as the ARMI. They are invaluable as index sites and often provide the physical and organizational settings for resource surveys (see Figure 1). Their multiple contributions are based on several qualities:

1. They can provide comparative sites for the evaluation of effects in less protected areas because they are insulated from many small-scale direct effects of human activities and thus can help distinguish these effects from large-scale natural and human-related events, such as storm damage, fire, global climate change, acid rain, and changes in regional hydrology patterns resulting from human manipulation or consumption.
2. Because many protected areas are actively managed for their natural resources, they offer the opportunity to study the effects of management practices on amphibian communities and populations.
3. Protection makes it likely that land units will retain their ecological integrity and will be available far into the future for continued monitoring and research on long-term trends.
4. By design or by chance, protected areas often harbor remaining examples of rare or declining species and biotic communities. In general, networks of protected areas include habitats and communities that are broadly representative of the regions in which they occur.
5. Protected areas have frequently served as sites for ecological studies or other kinds of environmental data collection, and when monitoring is co-located with on-going or past studies, it can often benefit from the knowledge developed in them.
6. Managers of protected areas have a vested interest in monitoring the status of resources under their protection and it may be advantageous to them to provide

material support to broadly based research and monitoring initiatives. Also, the management staff of protected areas often include biologists and other experts who can contribute local and regional knowledge that can enhance the quality of large-scale efforts such as the ARMI.

In recognition of the important role of protected areas in the ARMI, the four operational ARMI regions operational in 2000 (all seven will have been initiated by 2002) included surveys of at least 32 protected areas in their FY2000 study plans (Table 1). Specific examples of how a network of protected areas can be used in the ARMI program are discussed below.

Figure 1. Conceptual diagram of the components of a national framework for amphibian monitoring in the United States, with surveys becoming more intensive and less extensive as one moves from the base to the apex of the pyramid. Activities at the different levels are integrated by: common databases and reporting; compatible protocols, analytical tools, training, and planning; research, which at all levels is guided by monitoring results; synthesis across ecological regions (National Atlas; synthesis reports); research on causes of change; and modeling.

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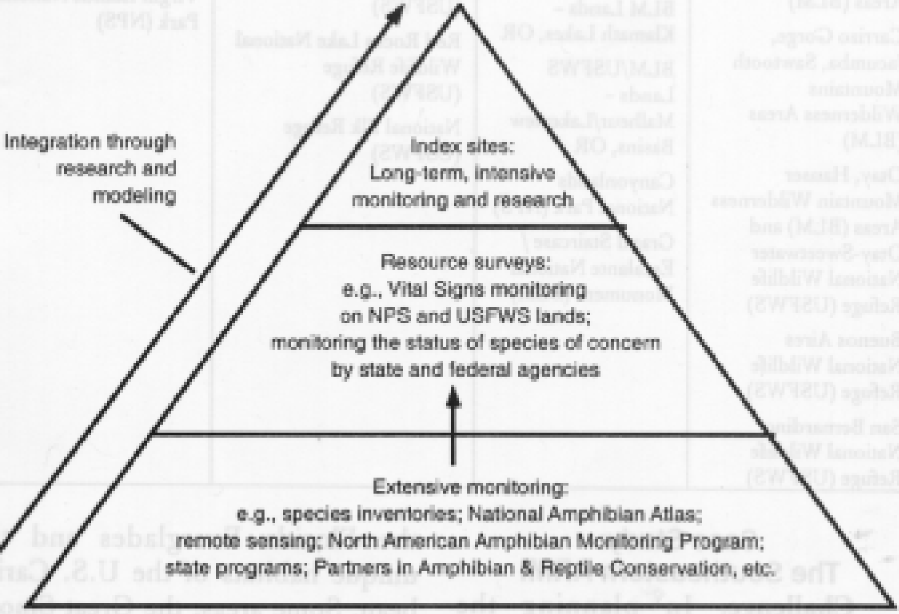

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Table 1. Major protected areas identified in FY2000 ARMI study plans.

ARMI Region			
Southwest	*Pacific Northwest*	*Northern Rocky Mountains*	*Southeast*
Yosemite National Park (NPS) Point Reyes National Seashore (NPS) Santa Monica Mountains National Recreation Area (NPS) San Gorgonio and Bighorn Wilderness Areas (BLM) Carrizo Gorge, Jacumba, Sawtooth Mountains Wilderness Areas (BLM) Otay, Hauser Mountain Wilderness Areas (BLM) and Otay-Sweetwater National Wildlife Refuge (USFWS) Buenos Aires National Wildlife Refuge (USFWS) San Bernardino National Wildlife Refuge (USFWS)	Olympic National Park (NPS) Crater Lake National Park (NPS) National Wildlife Refuges – Willamette Valley, OR (USFWS) Redwood National Park (NPS) BLM Lands – Klamath Lakes, OR BLM/USFWS Lands – Malheur/Lakeview Basins, OR Canyonlands National Park (NPS) Grand Staircase / Escalante National Monument (BLM)	Glacier National Park (NPS) Theodore Roosevelt National Park (NPS) Yellowstone National Park (NPS) Grand Teton National Park (NPS) Grays Lake National Wildlife Refuge (USFWS) Red Rocks Lake National Wildlife Refuge (USFWS) National Elk Refuge (USFWS)	Great Smoky Mountains National Park (NPS) Okefenokee National Wildlife Refuge (USFWS) Everglades National Park; Big Cypress National Preserve (NPS) Virgin Islands National Park (NPS)

Case Study: The Southeastern ARMI

Challenge. In planning the southeastern component of the ARMI, we faced some significant challenges. At least 141 species of amphibians occur in the southeastern USA, not counting putative species identifiable only by genetic analysis.

Landscapes range from the high peaks of the southern Appalachians, to the swamps of the coastal plain, to the Florida Everglades and the unique habitats of the U.S. Caribbean. Some areas, the Great Smoky Mountains and the Okefenokee Swamp for example, may have up to 40 amphibian species each, while sharing fewer than 10 species between them. Species range from those that never leave the water to those that are entirely terrestrial, and include many that undergo dramatic shifts in ecological relationships as they transform from aquatic to terrestrial life stages. A practical consequence of this diversity is difficulty in identification; some amphibian species cannot reliably be distinguished in hand, even by experts. Also problematical is the fact that the places with the greatest diversity of amphibians are often poorly accessible to researchers. The high altitudes of the southern Appalachians and the trackless expanse of the Everglades and Big Cypress are but two examples of places poorly accessible by normal modes of transportation. Yet another problem results from the great differences in abundance seen across the range of southeastern amphibians: rare or isolated species may be restricted to a single mountaintop, whereas other species such as the green and squirrel tree frogs *(Hyla cinerea* and *H. squirella)*, are so abundant and ubiquitous within their broad geographic ranges that measuring abundance is nearly impractical.

These challenges and the limited resources available for the southeastern ARMI made it necessary for us to select broadly representative index sites. The sites selected—Great Smoky Mountains National Park, Okefenokee National Wildlife Refuge, the Everglades National Park–Big Cypress National Preserve complex in South Florida, and Virgin Islands National Park—

A salamander, *Plethodon jordani*, found in Great Smoky Mountains National Park. USGS photo.

encompass much of the diversity of southeastern amphibians. Three of the four are part of the PrimeNet program, a shared NPS–U.S. Environmental Protection Agency effort that measures and monitors air quality in 14 parks nationally. Co-location of PrimeNet and ARMI sites is an opportunistic effort to benefit from environmental data collected for different, although not unrelated, purposes. In FY2000, NPS supported inventories of amphibians in ten of the PrimeNet Parks nationwide, and these have been integrated into the ARMI program. Funding for the southeastern ARMI was sufficient to support major efforts in only four primary sites in any given year, but the availability of NPS funds for inventories in the Great Smokies, Everglades, and Virgin Islands parks permitted the USGS to get an early start on these important areas.

Great Smoky Mountains National Park, a World Heritage Site, is of special importance because it represents a region regarded as a major center of evolution and distribution of lungless salamanders, and it has long attracted the interest of amphibian specialists (Huheey and Stupka 1967). Moreover, in FY2000 the USGS Florida Caribbean Science Center was in the final year of a three-year effort supported by the USGS–NPS Prototype National Park Monitoring Program to develop an amphibian monitoring program for the park. Despite the significant efforts devoted to Smokies amphibians in the past, USGS biologists have recently discovered species formerly not known from the park and rediscovered species that had not been recorded there for as long as 40 years.

Okefenokee National Wildlife Refuge is another site of special importance in that it comprises 80% of one of the world's largest and most significant wetlands. It is being considered for nomination as a World Heritage Site and is a Ramsar Wetland of International Significance. Although its diversity of amphibians approaches that of the Great Smoky Mountains, its dominant amphibians are frogs rather than salamanders. Like the Smokies, the Okefenokee swamp has been the site of surveys and research on amphibians in the past (e.g., Wright 1932), but, as in the Smokies, surveys and research have been neither systematic nor fully representative of habitats present. Much of the swamp is inaccessible, so, aided by past studies that have provided excellent delineation and characterization of habitats, we will use a stratified sampling scheme to adequately sample all amphibian populations likely to occur on the refuge.

The Everglades–Big Cypress complex in South Florida has a lower diversity of amphibians than the Smokies or the Okefenokee, but they represent a unique ecosystem and a biological region subject to unique driving forces. Native species in South Florida are a subset of those found in the more diverse sites, but the area has three or more established nonindigenous species of amphibians and the interaction of these species with native biota is of interest. There is much available data on the ecology of the greater Everglades (which, like the Smokies, is a World Heritage Site). Excellent maps and physical science information are available, and other on-going studies in the physical and biological sciences are likely to add to the value of our findings on amphibians. With the recent approval of plans to restore the Everglades to its natural hydrology, scientists will be studying all aspects of this historic management action.

Virgin Islands National Park on the island of St. John is the smallest of the protected areas chosen for study and has the smallest number of amphibian species, but its combination of native Caribbean and introduced amphibian species is far different than that found anywhere on the mainland. Although less studied than our other index sites, it is better known biologically than most of the U.S. Caribbean.

Conceptual approach. Available methods for inventorying and monitoring amphibians are inadequate to

A southern toad, *Bufo terrestris*, found in the Okefenokee National Wildlife Refuge. USGS photo.

meet needs in the Southeast. Published protocols and manuals developed for conducting inventories and monitoring of amphibians (e.g., Heyer et al. 1994) do not address the problems of scope, scale, and synthesis needed for design of a program intended for implementation across the entire USA, and these methods seem particularly lacking when it comes to addressing the diversity and abundance of amphibians of the Southeast. We need methods that do not require technically sophisticated field surveys; that can be tailored to different kinds and configurations of habitats, landscapes, and amphibian communities; and that are potentially transferable to persons and organizations who are not specialists in amphibian biology.

We in the southeastern ARMI have been fortunate to recruit an outstanding team of biometricians who are working with us to develop protocols that are statistically sound, regionally and nationally comparable, but flexible and relevant at different locales. The approach we are taking eschews attempting to achieve the nearly impossible objective of estimating abundance of amphibians on a species-by-species and population-by-population basis, and relies instead on the more reliably and easily obtained data of presence or absence of species within habitats and communities across the landscape. From this data, the proportion of area occupied by selected species can be estimated and changes can be monitored over time. Communities of amphibians can also be monitored for changes in species richness. This approach will be augmented with focused monitoring of sentinel species or species and populations of special concern, and this is the second area of protocol development. Critical issues in protocol development include how to spatially sample the landscape and how to estimate what proportion of an amphibian community or population may go undetected in sampling. Poor spatial representation and not knowing what fraction of the community or population was missed during sampling can both seriously flaw conclusions drawn from monitoring, and compromise actions taken in response to those findings.

Benefits for managers of protected areas. Our conceptual approach for the southeastern ARMI provides for a series of statistically rigorous inventories that produce lists of documented species, some measure of habitat association, and estimates of species present but not observed. The inventories alone should have value to managers in that they can help to identify species of special concern, habitats important for those species, and areas or types of habitats deserving of special protection because of their importance to amphibians and wildlife in general. Repeating these protocols over intervals of time can provide managers with statistically reliable indications of change in the local distribu-

Weighing a captive frog in the Okefenokee National Wildlife Refuge. USGS photo.

tion and abundance of amphibians, alert them to degradation of habitats or other changes that result in losses of biological diversity, and lead to implementation of management remedies. Repeating such inventories over intervals of space can provide a regional context to observed changes and can serve managers by distinguishing changes occurring locally from those resulting from broad regional or even global trends. Better knowledge of the origins and extent of environmental change may help managers to devise actions that will correct, mitigate, or encourage such change as appropriate to their con--servation goals.

Complementary Objectives of ARMI and the Land Protection Agencies

The framers of the ARMI see themselves as working in concert with land and resource protection agencies in that both rely upon inventory and monitoring to determine the condition of the protected resources and to explain how and why these conditions may change. Information generated in inventory and monitoring programs like the ARMI can lead to regional and national assessments and at the same time to development of management plans specific to protected areas. While scientists and managers participating in the ARMI program may view their short-term goals differently, the information resulting from the program can provide meaningful input and insights on a wide variety of scientific, resource management, and conservation issues. Such information may be essential to land managers in fulfilling their mandates for protection. For example, the National Wildlife Refuge System Improvement Act of 1997 requires the U.S. Fish and Wildlife Service to develop comprehensive conservation plans for all refuges to ensure protection of living resources, based in part on programs to monitor the status and trends of fish, wildlife and plants. If the ARMI achieves its intended role, it will enlist scientists from a variety of academic, governmental, and other research organizations who can also lend their efforts to solving a broad range of problems. Because the ARMI and the agencies responsible for protecting the nation's natural heritage share so many objectives, enlistment of additional land protection agencies into the ARMI effort will produce benefits for all partners.

Ed. note: You can follow the progress of ARMI through the USGS Florida Caribbean Science Center Web site http://www.fcsc.usgs.gov/.

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