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The United States Geological Survey's Amphibian Research and Monitoring Initiative

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The Amphibian Research and Monitoring Initiative (ARMI) began in 2000 as an attempt by the United States Geological Survey to determine the status and trends of amphibians on federal lands in the United States and its territories. ARMI research focuses on determining causes of declines, if observed, developing new techniques to sample populations and analyze data, and disseminating information to scientists and policy makers. Monitoring is conducted at multiple scales, with an emphasis on an ability to draw conclusions about status in well-defined study areas such as national parks and wildlife refuges. Several papers originally presented at a national symposium in 2004 are published in this special issue of *Alytes*.

INTRODUCTION

Amphibian decline achieved recognition as a global issue after the meeting of the First World Congress of Herpetology in England in 1989. During the ensuing decade, considerable progress was made in documenting the status of populations and in understanding the causes of some of the declines. However, significant gaps in our knowledge remained, including basic information on status and life history. Additionally, the occurrence of large numbers of malformations in some locations in North America in the mid-1990s increased the urgency to

critically examine the status of anuran populations. To address these needs, the United States Congress authorized and funded the Amphibian Research and Monitoring Initiative (ARMI) beginning in October 2000. ARMI is a national program coordinated by the United States Geological Survey (USGS) and the science and research bureau for the Department of the Interior (DOI). The goal of ARMI is to better understand the dynamics of amphibian populations, including causes of declines, so that DOI agencies and other land managers have the most accurate information from which to develop effective ways to manage and conserve amphibian populations.

A symposium presenting ARMI monitoring and research results, co-sponsored by the American Society of Ichthyologists and Herpetologists (ASIH) and the International Society for the Study and Conservation of Amphibians (ISSCA), was held at the 2004 joint annual meeting of the three North American herpetological Societies (ASIH, Herpetologists' League and Society for the Study of Amphibians and Reptiles) in Norman, Oklahoma. This issue of *Alytes* presents a sample (6 of 24 papers presented at the symposium) of this work. Prior to introducing these papers, we briefly describe the history, objectives, and basic methods employed by ARMI researchers.

History of ARMI

Herpetology in the USGS came into being when the National Biological Service (NBS) was incorporated into the USGS in 1996. The NBS was a short-lived agency, created only three years before by combining research scientists from the various DOI agencies with land-management responsibilities (primarily the United States Fish and Wildlife Service, National Park Service, and Bureau of Land Management). Several scientists who were employed by these agencies and who now are involved in ARMI have long histories of research on amphibian ecology and conservation. For example, Bury et al. (1980) described the status and conservation issues for a number of amphibians that were either listed as threatened or endangered or were thought to be in need of conservation research. Other examples of studies conducted prior to the First World Congress include Bury (1983), Corn et al. (1989) and Dodd (1991, 1992). In the early 1990s, BRD herpetologists submitted several proposals for broad national or regional surveys, but these were not funded, and there was no coordinated effort among DOI scientists to determine the status and trends of amphibians nationally.

In 1998, the escalating concern over the status of amphibians and the recent discovery of high incidence of developmental malformations in some populations of ranid frogs in the upper Midwest (Meteyer , 2000; Souder, 2000) prompted Bruce Babbitt, then Secretary of the Interior, to request USGS to prepare a budget request for a national amphibian monitoring and research program. This task was performed by a small group of scientists and managers from USGS, the National Park Service, Bureau of Land Management, and US Forest Service during a meeting at Point Reyes National Seashore in June 1998, and funding for amphibian research and monitoring was included in the USGS budget beginning in Fiscal Year 2000. Three USGS Disciplines, Biology, Water and Geography, receive funding through ARMI.

ARMI objectives and methods

The goals and methods of ARMI were developed in a series of meetings and workshops by USGS scientists, including an "Amphibian Leadership Team" composed of scientists and managers from USGS and other agencies, largely external to ARMI, which conducted a workshop in Gainesville, Florida in February 2001. The overall goals of ARMI, derived from these meetings (Corn et al., 2005), are to: (1) establish a network designed to monitor the status and changes in the distribution and abundance of amphibian species and communities in the United States; (2) identify environmental conditions known to affect amphibians and document their differences across the Nation; (3) conduct research that identifies causes of amphibian population change and malformations; and (4) provide information to managers, policy makers and the general public in support of amphibian conservation.

The Leadership Team recommended that ARMI adopt a hierarchical approach to monitoring described by the Committee on the Environment and Natural Resources (Anonymous, 1997; Bricker & Ruggiero, 1998). This hierarchy can be visualized as a pyramid (fig. 1). At the base, extensive but necessarily coarse measurements are made at many sites across the country. At the apex of the pyramid, intensive research and population monitoring is conducted at a relatively small number of sites throughout the country. At the middle level of the pyramid, monitoring directed toward detecting change in occurrence and abundance of species across the landscape is conducted at a moderate number of sites.

Ideally, the ARMI approach would provide unbiased, base of the pyramid estimates of the status of most amphibians in most habitats across the United States. Realistically, several constraints prevent this approach. Primary among these constraints is the mandate of USGS to provide science support for the other DOI agencies, which for ARMI means devoting the majority of our efforts on lands managed by DOI agencies. Other important constraints are that there are few species distributed widely across the US, that species richness and habitat diversity vary widely among geographic regions, and that amphibians display a variety of reproductive modes and habitat associations. This diversity requires that a variety of sampling methods, rather than a single standardized approach, be used to detect and monitor amphibians across the country, even within regions (Heyer et al., 1994; Dodd et al., in press).

For example, the USGS coordinates the North American Amphibian Monitoring Program, an annual volunteer survey of calling frogs in several states in the Midwestern and Eastern United States (Mossman et al., 1998). However, the lack of audible calls by many species, greater aridity of the landscape, sparse road network, and unpredictability of breeding in desert habitats prevents calling surveys from being widely applicable in most of the western United States. Even with standardization, the use of frog call surveys has many limitations associated with sampling representative areas and species detection.

The constraints on collecting base-level data mean that middle-level surveys are the core of ARMI monitoring efforts and are conducted mainly on large protected areas (national parks and wildlife refuges) managed by DOI (Hall & Langtimm, 2001). At the middle level of monitoring, ARMI has taken the approach of defining a trend as the change in site

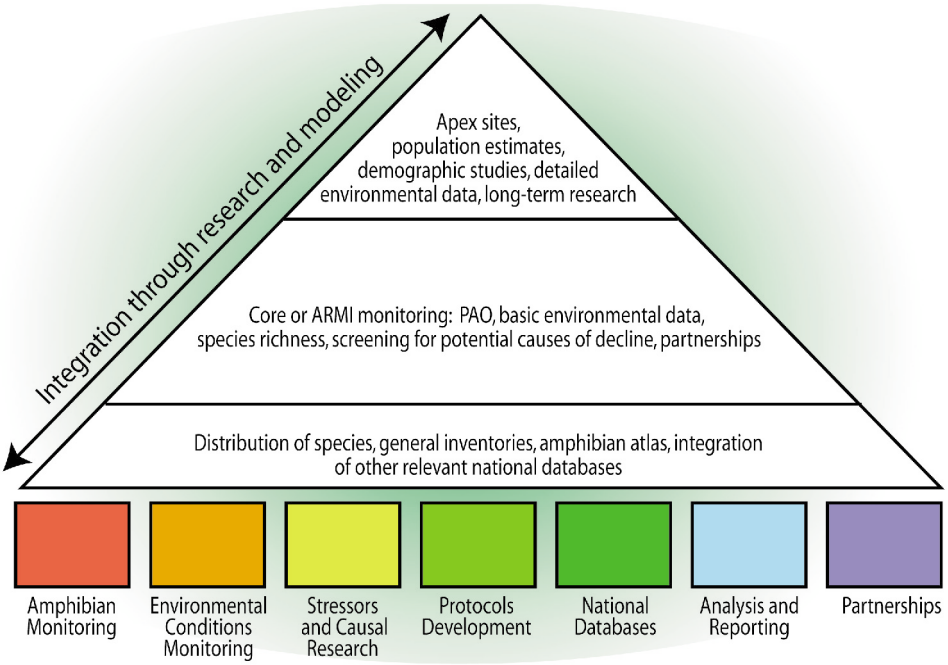

Fig. 1. – The conceptual framework of the United States Amphibian Research and Monitoring Initiative envisioned as a pyramid with three levels. Research and monitoring are integrated across scales, and the pillars across the bottom indicate what is necessary to support a national assessment of amphibian status. See text and Hall & Langtimm (2001) and Corn et al. (2005) for additional details.

occupancy by a given species, as recommended by Green (1997). For example, ARMI researchers in the mountainous west monitor many lentic-breeding species by documenting change in the proportion of ponds occupied. Other commonly used methods of trend analysis are either impossible to implement on a large scale (direct population estimates) or are unlikely to provide unbiased estimates of change (for example, counts intended to provide an index to true abundance: Anderson, 2001; MacKenzie & Kendall, 2002; Schmidt, 2003). Moreover, changes in occupancy are likely to better reflect amphibian status than changes in abundance for many lentic-breeding species with erratic population dynamics (Green, 1997).

Sites are selected for sampling based on a probabilistic scheme to allow inference about status and trend for the defined study area. Because absence in a survey may also indicate failure to detect a species that is actually present, multiple surveys are conducted at sites so that detection probabilities can be calculated and occupancy adjusted to account for errors in detection (MacKenzie et al., 2002). The approach of monitoring changes in site occupancy of species based on presence/non detection data allows for the estimation of several parameters that can be used to study population and community dynamics, estimate extinction and colonization probabilities, and test hypotheses concerning how environmental factors affect population dynamics. This approach also allows for comparable data to be obtained despite a wide variety of sampling designs. The actual occupancy estimates can only be compared among middle-level monitoring areas to the extent that sites are defined consistently, but

ARMI researchers can compare unbiased estimates of trends in occupancy across the country. Whereas inference is limited to the boundaries of the middle-level monitoring areas, the ARMI approach allows trends to be scaled up to provide regional and national summaries.

Detailed population data are collected by ARMI researchers on a number of species at relatively few locations (apex sites). Unlike middle-level sites, apex sites are not selected randomly, but provide locations for determining demographic and life history characteristics of key species and studying changes in these characteristics over time. Apex monitoring, coupled with controlled manipulations, can sometimes be used for cause and effect hypothesis-testing research.

At all levels of the pyramid, ARMI researchers are encouraged to form partnerships with other agencies, programs and researchers to broaden the scope of investigation beyond DOI. One example is a national amphibian atlas, initiated by Michael Lannoo (LANNOO, 2005) and now hosted by ARMI [http://armi.usgs.gov]. In other cases, middle-level and apex monitoring sites have been established in partnership with other agencies and organizations.

The causes of amphibian declines are varied and can be complex, and ARMI is contributing to understanding both direct and subtle interactions through a number of approaches. Some research is of short-term duration to address a known or suspected problem, but there are still significant gaps in our knowledge of what is causing the declines of many species. A major effort of ARMI includes a multidisciplinary approach to determine environmental factors responsible for the decline or malformation of amphibians.

ARMI SYMPOSIUM

Papers presented at the 2004 symposium and the subset printed in this issue present a sample of work being conducted by USGS scientists and cooperators. For a more complete list of published papers, consult the ARMI web site [http://armi.usgs.gov]. As in the symposium, the papers in this issue reflect a mixture of monitoring and research approaches.

Developing new tools for analysis and refining field methods are ongoing areas of emphasis in ARMI. JUNG et al. compared capture-recapture and removal methods for estimating abundance of stream salamanders in the Appalachian Mountains in Virginia. Removal methods usually resulted in higher capture probabilities for most species, but several sampling episodes are necessary because of high variability among samples.

CORN et al. described a transect of middle-level monitoring sites in the Rocky Mountains along the Continental Divide that includes several of the premier national parks in the United States. Status of amphibians in Colorado at the southern end of the transect is apparently worse than at the northern end in Montana. The southern end of the transect is also characterized by much higher human population and use of park lands, suggesting topics for more focused research on causes of declines.

WENTE et al. surveyed known and random localities for two anurans in the Great Basin in Oregon. Both species were absent from a substantial number of locations where they had

been recorded previously, and present at few new sites. Despite caveats about the effects of prolonged drought in the region, they concluded that at least western toads had likely undergone a recent decline.

In a study related to Corn et al., Green & Muths surveyed the health status of amphibians in Colorado in and around Rocky Mountain National Park. They found significant levels of infection by chytrid fungus, suggesting the possibility of further declines in this region.

Bridges & Little extracted naturally-occurring compounds from amphibian habitats in three national parks or wildlife refuges and assessed their toxicity to developing anuran larvae. The extracts did not cause mortality. However, amphibians reared in extracts had a lengthened larval period or reduced mass at metamorphosis in at least some of the areas studied. Extracts from both the air and water at one site lengthened the larval period. These sublethal effects likely influence life history characteristics which in turn affect population persistence.

Finally, Battaglin et al. demonstrated an important use of the national amphibian atlas. They compiled species richness by county and compared the patterns to climate statistics. As expected, precipitation and temperature were significant variables in explaining richness in most regions. Trends in climate may provide insight into areas of greater stress on amphibian populations.

Résumé

L'Amphibian Research and Monitoring Initiative (ARMI) a commencé en 2000. Il s'agit d'une tentative de l'United States Geological Survey de déterminer le statut et l'avenir des amphibiens dans les territoires fédéraux des Etats Unis. Les travaux de l'ARMI sont centrés sur la recherche des causes des déclins, lorsqu'ils existent, la mise au point de nouvelles techniques pour échantillonner les populations et analyser les données, et la diffusion de l'information aux scientifiques et aux décideurs. Les travaux sont conduits à diverses échelles, mais l'accent est particulièrement mis sur la possibilité de tirer des conclusions sur le statut des amphibiens dans des zones d'étude bien définies telles que les parcs nationaux et les réserves naturelles. Plusieurs communications initialement présentées lors d'un symposium aux Etats Unis en 2004 sont publiées dans ce numéro spécial d'*Alytes*.

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