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ARMI
Amphibian Research and Monitoring Initiative

The U.S. Geological Survey Amphibian Research and Monitoring Initiative — 2013 Annual Update

Objective

The Amphibian Research and Monitoring Initiative assists Department of Interior (DOI) resource management agencies with information needs related to amphibian conservation. ARMI's work includes research on threats, method development, and monitoring designed to address management needs at multiple spatial scales.

News

Welcome to the 2013 Annual ARMI Update, which provides highlights and significant milestones of this innovative program. This was an especially notable year for ARMI with the release of a landmark publication "Trends in amphibian occupancy in the United States." Our synthesis and scaling up of 9 years of monitoring data produced the first-ever estimate of how fast frogs, toads and salamanders in the United States are disappearing from their habitats. Our findings received international attention and rekindled the discussion about global amphibian declines. This was not the only topic we addressed this year, as ARMI's total publication count rose to 460 papers representing our latest research findings on the effects of climate change, land use, diseases, pesticides, and management on amphibian populations.

ARMI's proposal, "Elucidating mechanisms underlying amphibian declines in North America using hierarchical spatial models," was selected for Powell Center Support for 2014-2015. The Powell Center is a USGS center that facilitates the development of new and innovative processes for understanding significant and complex issues. This project moves us forward from the Adams et al. (2013) paper, and we will examine hypotheses for the mechanisms of the national decline we reported. We hope that our insights will be applicable to other systems and lay the foundation for an assessment of mechanisms behind global amphibian declines.

On December 16, 2013, we participated in the U.S. Fish and Wildlife Service, Office of the Science Advisor Web Conference Series. ARMI and our colleagues in USFWS presented the results of three recent publications on amphibians. The webinar, "Recent Advancements in Amphibian Research: Declines, Pesticides, & Abnormalities," is archived at: http://link.brightcove.com/services/player/.

U.S. Department of the Interior
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Scaling Local ARMI Projects to Larger Areas

ARMI is composed of individual projects that can inform managers at the local level and be combined to make inferences across a larger landscape. Each Mid-level monitoring project (the basis of our yearly status estimates) tracks a primary amphibian metric (occupancy) across the country, but with objectives designed for a specific site. Occupancy is the probability that a site is occupied by a given species, and ARMI considers this to be the most meaningful metric of amphibian status, particularly at larger spatial scales. Though the monitoring projects that produce these metrics each have their own methods and goals, we are able to compare trends among sites and over time because our sampling is probability-based and we correct our naïve estimates for detection probability.

As of 2012, ARMI had accumulated 679 estimates of occupancy for 114 time series (a time series is a temporal sequence of occupancy estimates for a species at a monitoring area). Each of these estimates applies to a defined area of inference that typically covers tens to hundreds of potential amphibian habitat units. Each project requires multiple surveys of a subset of units within the area of inference so that the probability of detecting a species that is present can be incorporated into an estimate of occupancy. ARMI has 34 monitoring areas across the United States that produce occupancy estimates for 50 species of amphibian. Time series range from 2 to 10 years. These data represent the most comprehensive and quantitative data on amphibian trends in the United States.

The species and places monitored were selected for reasons related to local objectives and do not necessarily represent other species and places. In some cases, species were selected for study because of conservation concerns, but ARMI scientists often monitor a suite of species that occur in a particular habitat.

Although the primary objective of ARMI is to provide information for DOI resource managers at a local scale, ARMI data are a unique resource in the ongoing global assessment of amphibian decline.

Project Updates

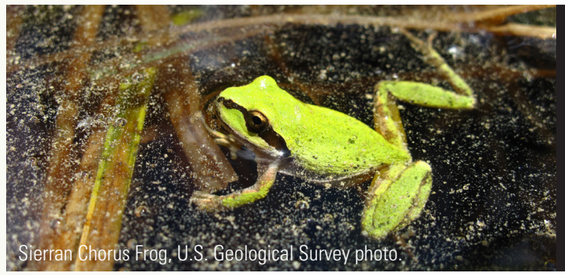
Trends in Amphibian Occupancy in the United States

Amphibian declines have been recognized as a problem since the late 1980s, but no assessment of the rate of population loss at a broad geographic scale has been attempted. ARMI scientists used data from ARMI mid-level (occupancy) monitoring sites to quantify the rate of change in the probability of occurrence of amphibians at study sites throughout the United States from 2002 through 2011. Because these estimates of occupancy account for imperfect detection, they are statistically unbiased. Among-time-series random intercepts and slopes were used to generate overall (nationwide) trend estimates, and uncertainty in occupancy estimates was factored into the analysis using inverse-variance weighting. Mean annual change in estimates of occupancy was -3.7% (SE = 1.5), indicating declines in the proportion of sites occupied by amphibians. All subsets of the data (by International Union for Conservation of Nature [IUCN] category, taxon (frogs vs. salamanders), geographic area, and management agency) also showed declines in the probability of occurrence. Species in the IUCN Least Concern category had a mean annual trend of -2.7% (SE = 1.6), while those in the Near Threatened, Vulnerable, and Endangered categories had a mean annual trend of -11.6% (SE = 4.3). The declines detected are particularly alarming given that 1) even species that were not considered to be of conservation concern were declining, 2) very few ARMI sites are affected by anthropogenic habitat loss, and 3) the first year of occupancy estimates was 2002, which might be after the declines of many species began. Although the results of the study cannot be extrapolated to the rest of the United States, they suggest that amphibian declines might be more common and rapid than suspected.

Adams, M. J., D. A. W. Miller, E. Muths, P. S. Corn, E. H. Campbell Grant, L. L. Bailey, G. M. Fellers, R. N. Fisher, W. J. Sadinski, H. Waddle, and S. C. Walls. 2013. Trends in amphibian occupancy in the United States. PLOS ONE 8: e64347.

Pesticide Accumulation in Sierra Nevada Frogs

Agricultural chemicals are receiving increasing attention as a potential factor contributing to amphibian declines. Even in areas in which pesticides are not directly applied, environmental transport and deposition of pesticides can result in pesticide occurrence and accumulation in food webs. To evaluate the extent to which such transport and deposition occurs in pond-breeding amphibians and their habitats, ARMI scientists examined samples of water, sediment, and frog (Sierran chorus frog, *Pseudacris sierra*) tissues along a north-south transect in the Sierra Nevada of California for more than 90 current-use pesticides and pesticide breakdown products. The Sierra Nevada Mountains are downwind of California's highly agricultural Central Valley, which are a likely source of agricultural chemicals to remote high elevation sites sampled in this study. Three current-use pesticides, including two fungicides (pyraclostrobin and tebuconazole) and an herbicide (simazine), were frequently detected in frog tissues. Interestingly, none of these pesticides were found in water, and only tebuconazole was found in sediment, though at lower frequencies than in frog tissues. Furthermore, concentrations of pesticides in frog tissues were not related to concentrations of pesticides in water or sediment. In remote areas like these, habitat (i.e. water and sediment) sampled during the study period are not good indicators of exposure of native amphibian populations to pesticides. The concentrations of pesticides and the number of pesticides detected varied by location, with samples from the southern, more agricultural end of the transect exhibiting higher pesticide concentrations than those from the northernmost sites. This study indicates that amphibians accumulate current-use pesticides in their tissues, but the biological effects of the detected pesticides on individual amphibians and amphibian populations are unknown.



Sierran Chorus Frog, U.S. Geological Survey photo.

Smalling, K. L., G. M. Fellers, P. M. Kleeman, and K. M. Kuivila. 2013. Accumulation of pesticides in Pacific chorus frogs (*Pseudacris regilla*) from California's Sierra Nevada Mountains, USA. Environmental Toxicology and Chemistry 32: 2026-2034.

Drivers of Long-term Trends of a Widespread Amphibian

Although amphibian declines have received much attention from researchers and the public, few studies have examined the effects of drought and habitat fragmentation on trends in abundance of a single species over a broad geographic area. ARMI researchers examined the effects of drought frequency, wetland restoration, and patch characteristics on the annual abundance of egg masses of the Columbia spotted frog (*Rana luteiventris*) in the northwestern United States using state-space models. Of the three genetic groups studied, abundance increased in the two groups that had the history of the greatest declines, but declined in the group considered stable. Water bodies with short hydroperiods and those occurring in more modified landscapes had more negative population growth rates than sites with more permanent water and those in natural landscapes. Water body type (modified vs. natural) did not affect population growth rates. Drought interacted with the size of water bodies; large water bodies ameliorated the effects of drought and had positive population growth, whereas small water bodies were more affected by drought and experienced population declines. Wetland restoration resulted in rapid population growth, demonstrating the utility of habitat restoration for conservation of Columbia spotted frogs. The results of this study demonstrate the importance of large water bodies for buffering against drought, and the vulnerability of small habitat patches to random events. Pond restoration was an effective tool for increasing population growth rates, and will likely become more important in a changing climate.

Hossack, B. R., M. J. Adams, C. A. Pearl, K. W. Wilson, E. L. Bull, K. Lohr, D. Patla, D. S. Pilliod, J. M. Jones, K. K. Wheeler, S. P. McKay, and P. S. Corn. 2013. Roles of patch characteristics, drought frequency, and restoration in long-term trends of a widespread amphibian. Conservation Biology 27: 1410-1420.

Structured Population Dynamics in Unmarked Populations

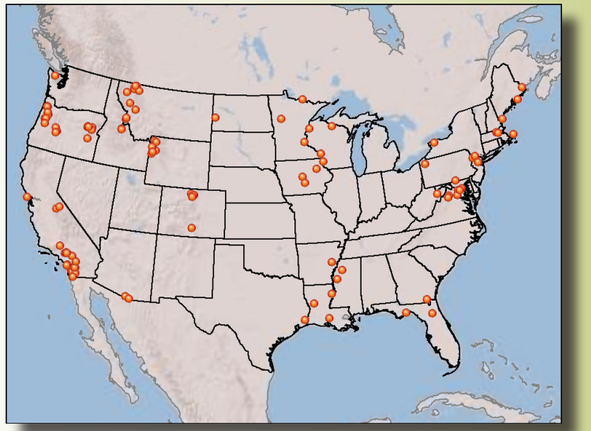
Studies of population dynamics require unbiased and precise estimates of abundance, survival, recruitment, and other vital rates that account for the sex ratios and age or size distributions that characterize plant and wildlife populations. Until now, such detailed analysis has only been possible by intensive capture-mark-recapture studies. ARMI scientists developed a dynamic, stage-based version of existing models that requires only stage-specific count data. Such data can take the form of counts of eggs, larvae, juvenile, and adult amphibians, though the technique is applicable to other taxa as well. These stage-specific counts are replicated across time and space to allow reliable estimation of abundance, recruitment, immigration, stage-specific survival, and detection rates. The method is illustrated using a population of northern dusky salamanders (*Desmognathus fuscus*), which the ARMI scientists found to be declining. Simulations indicated that more precise estimates are achieved by conducting more repeat surveys within periods for which populations can be assumed closed, and by conducting studies with longer time series at as many locations as possible. The approach is valuable because it represents advancement in analytic methods that could make data collection in the field more economical and efficient, and make better use of existing count data.

Zipkin, E. F., J. T. Thorson, K. See, H. J. Lynch, E. H. C. Grant, Y. Kanno, R. B. Chandler, B. H. Letcher, and J. A. Royle. 2014. Modeling structured population dynamics using data from unmarked individuals. Ecology 95:22–29.

ARMI and Collaboration

Much of ARMI's success comes from its collaborations with natural resource partners. We are interested in learning about your management and conservation objectives, and working with you to reach them. If you would like to collaborate with ARMI, please contact HQ or one of the Regional Coordinators. You can find our contact information on our web site.

Columbia Spotted Frog, by K. Honeycutt, U.S. Geological Survey.



ARMI Apex and Mid-Level monitoring sites. Factors related to population dynamics are studied at Apex sites. Factors related to site occupancy dynamics are studied at Mid-Level sites.

Background

The Amphibian Research and Monitoring Initiative (ARMI) resulted from the first multidisciplinary funding request in USGS and remains a leading example of what can be achieved by applying USGS's broad expertise and geographic scope to high priority resource problems. ARMI is a national research and monitoring program that is modular: it is composed of a series of monitoring projects, each designed to meet specific local objectives. These monitoring studies are carried out by 13 ecological centers, distributed across all regions of the lower 48 states. Each project complies with national guidelines, developed collaboratively among ARMI investigators, to facilitate broad synthesis at regional and national scales. This modular framework is novel for a national program and is a key feature that allows ARMI to partner with resource managers and meet their information needs. This modular framework also allows non-standardized methods to produce comparable data that can be examined at multiple spatial scales. Since its initiation in 2000, ARMI has built an unprecedented national data set on amphibian occupancy and abundance. These data provide the only large-scale, quantitative information on amphibian trends in North America and have led to more than 460 peer-reviewed publications.

Although we have learned much since 2000, declines have not abated and interactions among threats to amphibians are complex. Destruction of habitat remains a primary cause of decline, but other factors such as emerging infectious disease and invasive species are also important. Amphibian decline is a problem of local, national, and international scope that can affect ecosystem function, diversity, and commerce. To stem or reverse these declines, DOI managers and other partners need scientifically sound information at local, regional, and national scales. ARMI's modular approach is specifically designed to meet these multi-scale needs. By working with land managers at a local level, ARMI investigators can design projects that address site-specific questions and use methods best suited to local conditions. ARMI's close relationship with on-the-ground managers also ensures that information needs are thoroughly understood, resulting in significant leveraging of funding and resources. By following ARMI guidelines for developing population parameter estimates, these diverse and locally-responsive investigations also support analyses of regional and national trends and other broad-scale questions of importance to conservation partners.

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Back page photographs: Green treefrog, by H. Waddle, U.S. Geological Survey.

ARMI Principles

- Treat monitoring as research.
- Maintain the flexibility to tailor projects to local needs.
- Focus on statistically unbiased metrics that can be scaled up to achieve broader synthesis.

Frequently Asked Questions

Are amphibians really declining?
Yes, a large and growing body of evidence indicates that a significant proportion of the amphibian species are declining at an alarming rate. These declines are occurring in the United States and elsewhere around the world.

What alerted the natural resource community to global amphibian declines?
A combination of direct observations, estimates, and expert opinion were used to recognize and raise awareness of global amphibian declines. ARMI uses estimates of occupancy or abundance to assess continuing changes in the national status of amphibians.

Why are amphibians declining?
There is not one, single cause of amphibian declines. Instead, a combination of habitat loss, disease, invasive species, contaminants, and perhaps other threats have combined to create the current crisis.

Why should we care if amphibians are declining?
Amphibians play important roles in ecosystems, human health, and commerce. They have social value as symbols in some cultures, and they represent an ancient source of biodiversity.

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