Amphibian Diversity, Distribution, and Habitat Use in the Yellowstone Lake Basin

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Abstract

Global amphibian population declines are being investigated through four interdependent fields of study: distribution and status, ecology, causes of declines, and environmental contexts. In Yellowstone National Park, work on amphibians has proceeded in all four of these fields. This paper describes amphibian species occurrence, distribution, and habitat-use patterns in the Yellowstone Lake area; summarizes the findings of a field study on habitat use by spotted frogs; and describes the directions and goals of continued amphibian investigations. Tiger salamanders, western toads, boreal chorus frogs, and Columbia spotted frogs all occur in the subwatersheds surrounding Yellowstone Lake. Chorus frogs and spotted frogs are the most common species. Salamanders are uncommon. Toads are rare, and we are concerned about their status in Yellowstone and in the Greater Yellowstone Ecosystem. A large variety of wetlands in the Yellowstone Lake basin provide breeding sites. Foraging and overwintering sites are also crucial to amphibian persistence. A case study of spotted frogs in the Lake Lodge area exemplifies this and underscores the need to understand habitat requirements, movement capabilities, and the effects of human activities. Amphibian investigations in Yellowstone over the next several years will probably focus on completing distribution surveys for inventory and monitoring purposes, research into habitat use and amphibian movements, and habitat mapping and modeling. The practical goal is an integrated information system that Yellowstone National Park can use for environmental analysis, project planning, monitoring, research, evaluation of ecosystem health, and education.

Introduction

At the end of the 1980s, biologists began discussing the possibility that many amphibian populations were rapidly declining and disappearing worldwide. By the end of the 1990s, there was general consensus that alarming declines had in fact occurred (Alford and Richards 1999). Within the context of the global reduction of wildlife and biological diversity, amphibian declines stood out for several reasons: the evolutionary durability of amphibians (survivors of at least three mass extinction events), the ubiquity of amphibians in terms of geography and habitat, the rapidity of the reported declines, and the occurrence of declines in protected and relatively pristine areas (Mattoon 2001).

During the last decade, there has been a large effort to understand the phenomenon of amphibian declines. Four main fields of investigation support and draw on each other:

1. Investigation of amphibian distribution and status is necessary to understand where species occur and to determine if declines have taken place or are in progress. Investigators compile historical and recent records for comparisons, and engage in extensive surveys and monitoring.
2. Natural history and ecology studies of populations in the wild teach us about population dynamics and habitat use, and help explain why populations are vulnerable to certain human-caused changes in the environment.
3. Investigation of the causes of declines is taking place in the field and in the lab. Multiple causes of declines have been identified, including habitat loss and modification, air and water pollution, damaging ultraviolet-B radiation exposure due to stratospheric ozone depletion, climate change, disease, introduction of non-native species, and complex interactions among factors.
4. Analysis of the environmental context using recent advances in geographic information systems (GIS), landscape component analysis, and other technologies allow investigators to map and model habitat and environmental change.

The ultimate goal of these investigations is to conserve and restore amphibian populations, which are important components of natural ecosystems. Investigators seek to provide information to land managers and to society that will stimulate and guide actions needed to maintain amphibian biodiversity and abundance.

In Yellowstone National Park, work has proceeded in all four of these fields of investigation. The effort to understand current amphibian species distributions in Yellowstone began at Idaho State University in 1988. By the mid-1990s, researchers from the Herpetology Laboratory at Idaho State University compiled historical, museum, and recent observation records and published a field guide (Koch and Peterson 1995). We have continued compiling observation and survey records in a Greater Yellowstone Ecosystem amphibian database (Van Kirk et al. 2000). Studies of distribution and occurrence have proceeded through a variety of survey projects, including surveys of roadsides and other areas targeted for development (e.g., Peterson et al. 1995; Patla and Peterson 1997; Patla 1997a), the northern range (Hill and Moore 1994), backcountry wetlands (e.g., Corkran 1997, 1998), and native fish restoration study areas (Patla 1998, 2000). Annual monitoring continues at six sites in the park (Peterson et al. 1992). In 2000, we began park-wide surveys through a joint effort with the U.S. Geological Survey (USGS) and its national Amphibian Research and Monitoring Initiative (Corn 2000) and the Vertebrate Inventory and Monitoring Project of the National Park Service (NPS). Investigators have engaged in studies of the causes of declines (Hawk and Peterson 1999; Hawk 2000) and field ecology studies of local populations (Hill 1995a, 1995b; Patla 1997; Patla and Peterson 1999). Finally, researchers from various institutions are designing habitat mapping and modeling projects. While the state of knowledge about amphibians in the park has advanced considerably over the past decade, we look forward to achieving a more precise understanding in the future about status, trends, ecology, and conservation of amphibians.

With respect to amphibians of the Yellowstone Lake area, this paper will describe what is currently known about species occurrence, distribution, and general habitat-use patterns. We will summarize the findings of a field study in the Lake Lodge area illustrating amphibian vulnerability to human-caused habitat changes. Finally, we will describe current and future directions and goals of amphibian investigations in Yellowstone.

Amphibian Occurrence and Distribution

To assess amphibian occurrence around Yellowstone Lake, we employed subwatershed units known as 7th-level Hydrological Units (HUs). Boundaries of these units were defined by a GIS coverage prepared by Yellowstone's GIS department. There are 48 subwatershed units around the lake. When we plotted locations of all known historical and recent records, we found that 27 units, or 56%, are known to have hosted, or currently host, amphibians (Figure 1).

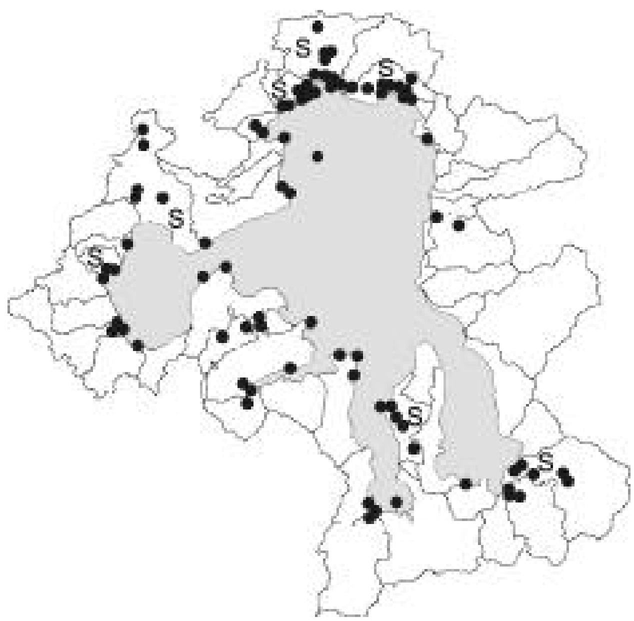

Figure 1. Yellowstone Lake with its 48 surrounding subwatershed units; dots show locations of historical and recent amphibian observations. Twenty-seven of the 48 units (56%) have amphibian records. The letter "S" indicates subwatershed units where formal amphibian surveys have been conducted in at least a portion of the unit within the past 10 years.

Formal amphibian surveys, following accepted protocols for detecting amphibian presence, have been conducted in only eight of the subwatershed units (Figure 1). One subwatershed (Arnica Creek) has been surveyed to identify amphibian breeding sites. Small portions of several other subwatershed units were surveyed during road improvement project analyses for the Arnica-to-West Thumb and Fishing Bridge-to-Canyon road sections. Portions of two subwatersheds, in the Promontory and Thorofare areas, were surveyed by volunteers in the late 1990s.

Knowledge about amphibian distribution in the Yellowstone Lake basin relies largely on incidental sighting reports. Incidental observations were provided by aquatic resources personnel doing fishery work, park rangers and other employees, exploratory surveys and observations by Idaho State University Herpetology Lab personnel, and other visitors. We regard distribution information for amphibians around Yellowstone Lake as incomplete, particularly for the east side of the lake and for roadless, remote areas.

The Yellowstone Lake area has a full complement of amphibian species: all those that one would expect to be present, based on their geographic range and occurrence elsewhere in the park, have been observed. While only four species occur, they are biologically diverse, representing two orders and four different families of amphibians. The tiger salamander *(Ambystoma tigrinum)* is from the order Urodela, the family of mole salamanders. In the order Anura, there is the western toad *(Bufo boreas)* from the family of true toads, the boreal chorus frog *(Pseudacris maculata)* of the tree frog family, and the Columbia spotted frog *(Rana luteiventris)* from the family of true frogs.

To judge from available data, the tiger salamander is surprisingly uncommon in the Yellowstone Lake area (Figure 2) given the abundance of this species in some other portions of Yellowstone, e.g., the northern range (Hill and Moore 1994) and Hayden Valley (Patla 2001). Some of this apparent rarity may be due to the fact that adult salamanders spend much of their time underground and are infrequently encountered by people except during periods of mass migration. Our Yellowstone Lake area dataset's reliance on incidental observation is thus likely to be biased against this species. However, the lack of observations of salamanders on the well-traveled roads north and west of Yellowstone Lake suggests that this species is in fact uncommon, or that salamander populations are much smaller than those of Yellowstone's northern range.

The western toad appears to be rare (Figure 3). We know of only two current breeding sites in the vicinity of Yellowstone Lake. There is much concern about this species because of dramatic declines elsewhere; in Colorado and southern Wyoming the western (boreal) toad *(Bufo boreas boreas)* is a candidate for listing under the Endangered Species Act. Toads and their tadpoles are conspicuous in comparison with salamanders. Adult toads disperse widely from breeding sites and may be seen basking in open areas on sunny days or crossing roads at night. Toad tadpoles and newly metamorphosed toadlets form large conspicuous congregations.

The boreal chorus frog is widespread (Figure 4), and probably common around Yellowstone Lake if the complete picture were known. Although adults are tiny and visually inconspicuous, the males call loudly in May and June, making this an easy species to detect at that time. Wetlands on the north side of Yellowstone Lake ring with the chorus of these frogs on spring evenings. Large

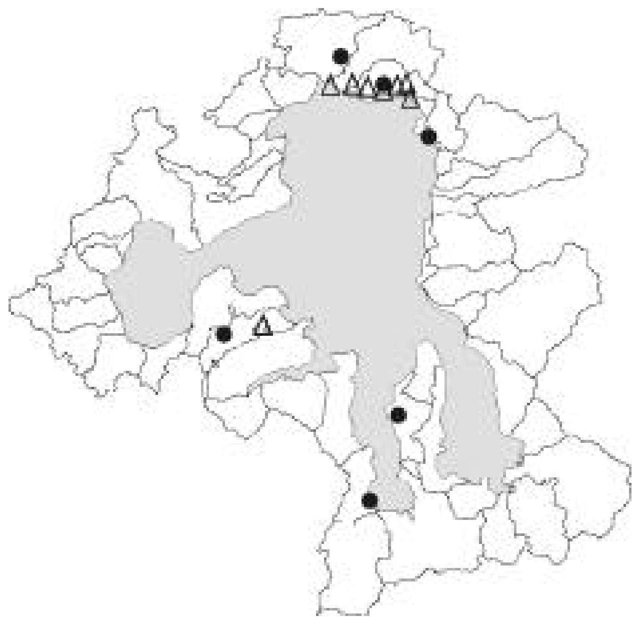

Figure 2. Locations of tiger salamanders, with triangles representing records prior to 1986, and dots indicating more recent records. Salamanders have been observed in a total of 7 subwatershed units (3 prior to 1986; 6 since 1986).

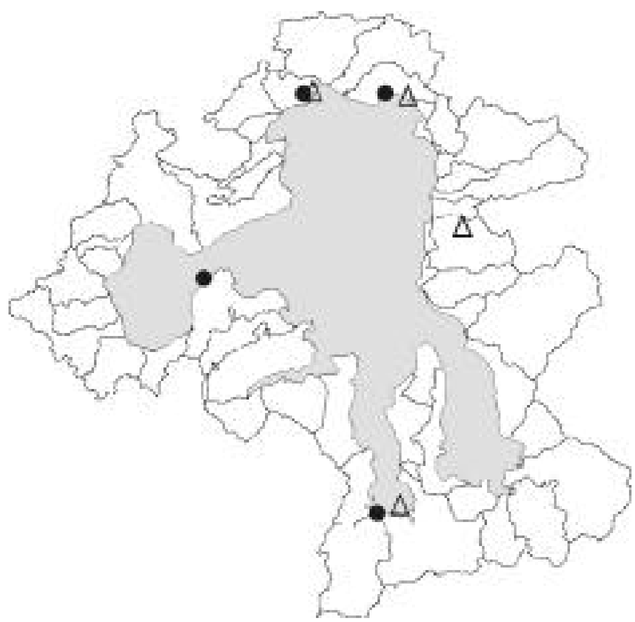

Figure 3. Locations of western toads, with triangles representing records prior to 1986, and dots indicating more recent records. This species has been observed in a total of 6 units (4 prior to 1986; 4 units since 1986).

numbers of metamorphs have been observed in lakeside wetlands on the south shore of Yellowstone Lake (Koch and Peterson 1995).

The Columbia spotted frog is also widespread (Figure 5). It is the most frequently seen amphibian in the Yellowstone Lake area and across much of the Greater Yellowstone Ecosystem. This is a visually conspicuous species: spotted frogs often bask on the edges of ponds and streams, producing a loud splash as

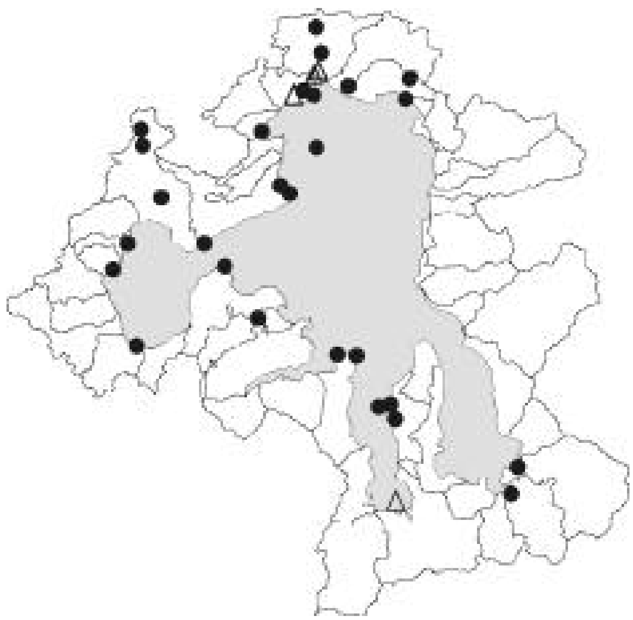

Figure 4. Locations of boreal chorus frogs, with triangles representing records prior to 1986, and dots indicating more recent records. This species has been observed in a total of 17 units (3 prior to 1986; 17 since 1986).

they hop into the water. Tadpoles of spotted frogs grow to a larger size than the other anuran species and are often easily visible in shallow water. Newly metamorphosed spotted frogs may be abundant as they emerge from breeding pools, although they tend to be more dispersed than toadlets.

In summary, based on the number of subwatershed units in which they have been observed, salamanders and toads are relatively rare around Yellowstone Lake, while chorus and spotted frogs are more common and widespread (Figure 6). Historical or pre-1986 information is so scant for most of the area that it does not reveal much about possible trends. For most amphibian species in Yellowstone, the more effort that is expended in searching for them and keeping track of observations, the more locations are recorded. However, this is only marginally true for toads, as is indicated by the relatively small difference between historical and recent records shown in Figure 6. We think it is likely that western toads have declined in the Greater Yellowstone Ecosystem, based on the records

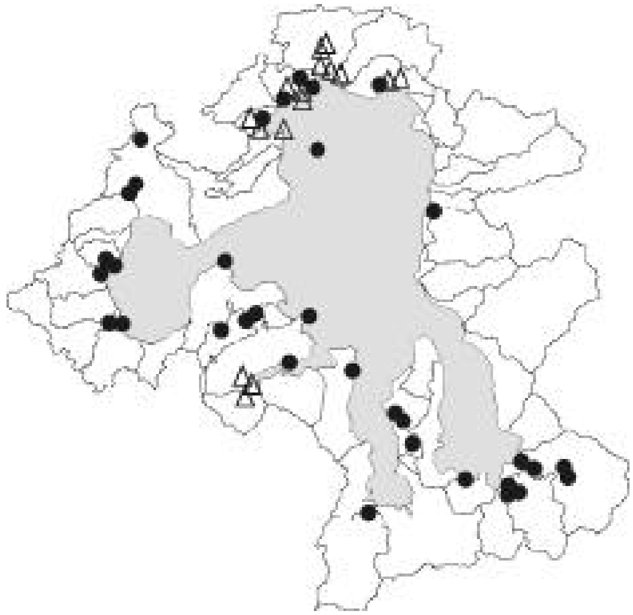

Figure 5. Locations of Columbia spotted frogs, with triangles representing records prior to 1986, and dots indicating more recent records. This species has been observed in a total of 22 units (8 prior to 1986; 18 since 1986).

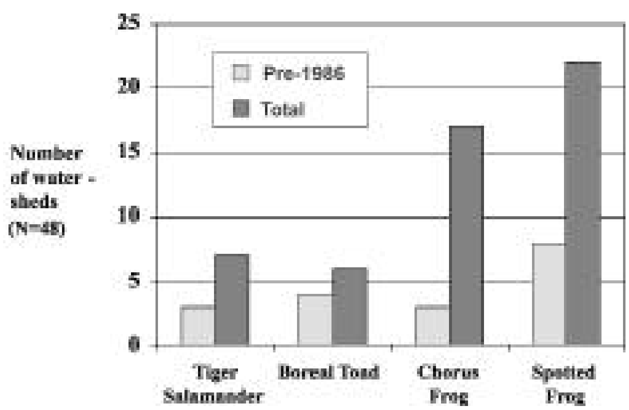

Figure 6. Number of subwatershed units around Yellowstone Lake where amphibian species were observed prior to 1986, and total number of watersheds (including all records, historical and recent) where species were observed.

and notes of earlier researchers and their current scarcity (Koch and Peterson 1995; Van Kirk et al. 2000).

Habitat Use

All amphibian species of Yellowstone rely on ponded or very-low-gradient water for reproduction. Eggs and larvae are aquatic obligates and will perish if breeding sites dry up before development is complete. The Yellowstone Lake area offers a variety of breeding sites for amphibians. Western toads in the Greater Yellowstone Ecosystem breed predominantly in water with high conductivity, often geothermally influenced (Hawk and Peterson 1999; Hawk 2000). These generalizations hold true for the two known toad breeding sites around Yellowstone Lake; toads breed on the west side of Indian Pond where conductivity often ranges above 1,000 FS (Patla and Peterson, unpublished data) and in a thermal pool at Breeze Point (reported by fisheries crew, 1999). The other amphibian species breed in a variety of temporary and permanent ponds in forests and meadows, generally with emergent vegetation. Acidic waters (< pH 6.0) are apparently not used as breeding sites (Patla and Peterson 1997), although this hypothesis needs more investigation. Lagoons and shallow-water marshes at the mouths of creeks draining into Yellowstone Lake, e.g., the mouths of Lodge and Pelican creeks, are known to provide breeding sites that produce large numbers of chorus frogs and spotted frogs.

Finding and documenting breeding sites is the focus of amphibian surveys. Amphibians have a very strong fidelity to breeding sites: some that were known to be used 50 years ago in the Yellowstone Lake area are still active. To monitor amphibians across the Greater Yellowstone Ecosystem and determine if statistically significant declines are occurring, investigators plan to track changes in the number of active breeding sites per species over time.

Breeding sites, however, are obviously only part of the habitat picture. It is quite common to find ponds inhabited by thousands of tadpoles, but with few or no adults in sight following the brief season of mating and egg deposition. The reason for this is very significant in the ecology of amphibians of the temperate zone. In many cases, habitat units that are necessary for amphibians to carry out their lives are spatially separated. Amphibians leave the breeding site to go to prey-rich areas for summer range, and then move on to places where they can safely winter. Biologists are just beginning to get an appreciation for how far amphibians can and do migrate to access breeding, foraging, and over-wintering sites (Pilliod 2001). Maximum migration distances range from 3 to 15 km for some populations (Sinsch 1990). Understanding of amphibian distribution will advance as researchers gain more knowledge about the spatial relationships of habitat components, natural history and habitat requirements that are unique to each species, and habitat-use and movement patterns in a variety of environmental settings.

Case Study at Lodge Creek

Habitat-use patterns of a spotted frog population in the Lake Lodge area have been the subject of historical and recent field studies. In the 1950s, Frederick Turner, a graduate student at the University of California–Berkeley, studied population dynamics and spatial relationships of the spotted frogs inhabiting a 28-ha area around the headwaters of Lodge Creek, between Fishing Bridge and Lake Village (Turner 1960). In the 1990s we repeated Turner's mark–recapture study of the population to compile comparable datasets. We found that the population had sharply declined and that habitat-use patterns had changed (Patla 1997b; Patla and Peterson 1999). Between the two study periods, the frogs' habitat was altered by several development projects, including reconstruction and relocation of the Grand Loop Road in the 1970s, increased residential development, horse-pasture use and maintenance, and increased development and use of Lodge Creek springs for the water needs of Lake Village. In addition to direct habitat losses, habitat fragmentation occurred. A migration corridor linking breeding and over-wintering habitat was interrupted by the path of the new section of the Grand Loop road. Breeding in the affected pool dwindled and finally ceased completely by 1995, and frog numbers in that portion of the study area have declined most severely (Patla 1997b; Patla and Peterson 1999).

This case study exemplifies how important it is for amphibians to have access to all habitat components. It also underscores the need to understand what habitats each species relies on to complete its life cycle, what constitutes constraints to amphibian movements, and how human activities and development projects may adversely affect amphibian populations. In the case of spotted frogs, it is likely that their dependence on non-freezing water (springs or spring-fed water bodies) for winter habitat limits their distribution and persistence in local areas as strongly as the availability of breeding sites (Pilliod 2001; Pilliod and Peterson 2001). Wintering and foraging habitat requirements, and their variability in different environmental contexts (e.g., at different elevations and in different plant communities), are as yet poorly known for Yellowstone amphibians.

Amphibian Studies in Yellowstone

As an overview of current and future amphibian studies in Yellowstone, we envision continued work in three main areas (Figure 7).

Distribution and status. We are conducting amphibian surveys in randomly selected 7th-level hydrological units (HUs) in Yellowstone and Grand Teton national parks. To achieve geographical distribution across Yellowstone, we selected HUs for survey from every third square in a grid placed over the park. As of the end of the 2001 field season, the surveys in Yellowstone are about 30% complete: 11 of the 36 targeted units have been surveyed. Supported by the USGS's Amphibian Research and Monitoring Initiative and NPS's Greater Yellowstone Area Inventory and Monitoring Program, this project will describe the distribution and abundance of breeding populations and considerably extend our current knowledge. The surveys are designed to serve as the basis for monitoring trends and answering questions about potential declines. Depending on funding levels, surveys of the selected units should be completed within three years. The project also includes targeted surveys for species of special concern in Yellowstone and more intensive population monitoring at selected sites.

Environmental context. One of the primary objectives of our amphibian studies is to develop GIS models and maps to indicate the probability of habitat

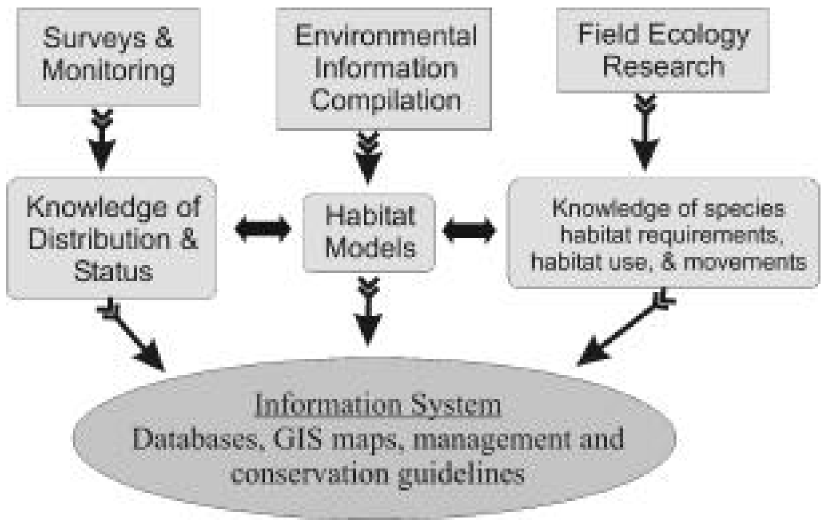

Figure 7. Overview of amphibian investigations. The information system resulting from integrated efforts will have multiple purposes, including amphibian conservation, resource management and protection, interdisciplinary research, and education.

use by amphibians at different times during their life cycle (e.g., breeding, foraging, dispersing, and overwintering). This requires information about environmental conditions (e.g., topography, temperatures, cover types, water quality, and the presence of other species) as well as information about amphibian natural histories (see below). The lack of high-resolution spatial and spectral data is probably the single most important factor limiting the use of GIS to design, analyze, and apply the results of amphibian surveys (Peterson et al., in press). Researchers from Idaho State University, Montana State University, the USGS National Mapping Division, and the Yellowstone Ecological Research Center are taking several approaches to address this issue, including: (1) using high-resolution hyperspectral imagery to identify small wetlands suitable for amphibians; (2) developing GIS and statistical models to predict wetland habitat (based on a variety of information sources, such as digital elevation models, hydrology, and remote sensing), and (3) combining the habitat data with amphibian-use information to develop statistical and GIS amphibian habitat models. These projects seek to integrate advances in landscape analysis with knowledge garnered from amphibian surveys and ecological field studies. With tools provided by these projects, we will be better able to identify and map amphibian habitat, predict amphibian occurrence, and assess potential effects of environmental change and proposed management activities.

Natural history and ecology. Researchers from Idaho State University and other facilities will carry out ecological field studies to elucidate habitat associations and requirements, habitat use, and amphibian movements. Investigations will include population-level studies using mark–recapture techniques, and focal animal studies employing radio-tracking and behavior observation. This labor-intensive field research is vital for the creation and verification of habitat models. Studies are also needed to determine how local populations are connected to each other through dispersal or immigration of individuals, and how important these connections might be for population persistence.

Information integration. These three fields of effort are interactive. Data from amphibian surveys will be used for habitat mapping and modeling, and the models will predict amphibian distribution and occurrence park-wide. Findings of amphibian ecology and movement studies will also contribute to mapping and modeling, which in turn can be used to develop and test hypotheses about habitat associations, ecological relationships, and the causes and patterns of population declines. The products of these investigations will be integrated to form an information system for the park and other agencies interested in amphibian declines and conservation (Figure 7). Uses of this information system could include environmental analysis, project planning and engineering, amphibian conservation at local and regional levels, monitoring, evaluation of ecosystem health and changes, interdisciplinary research, and public education.

Acknowledgments

Surveys and research contributing to this paper have been funded by the Amphibian Research and Monitoring Initiative (USGS Biological Resources Division), Greater Yellowstone Area Vertebrate Inventory Program (NPS), American Natural History Museum, Declining Amphibian Populations Task Force, Greater Yellowstone Coalition, Idaho State University, National Fish & Wildlife Foundation, Northwest Scientific Association, University of Wyoming National Park Service Research Center, and Yellowstone National Park.

We are grateful to the many people in Yellowstone who have helped with amphibian and reptile work over the past 12 years. Our most recent work on park-wide surveys has been greatly facilitated by Lane Cameron, Ann Rodman, and Shannon Savage. We also owe thanks for years of support to Stu Coleman, P. Stephen Corn, Ann Deutch, Merlin Hare, Ted Koch, John Lounsbury, and the Lake ranger district, Dan Mahony and the Yellowstone Aquatics Section, Fred Turner, Jennifer Whipple, John Varley, and the Yellowstone Center for Resources. We greatly appreciate Dan Reinhart's long-term assistance with research and conservation in the Lodge Creek study area. We thank all those who have conducted or assisted with amphibian surveys in the Yellowstone Lake area, including Char and Dave Corkran, Matt Chatfield, Josh Jones, Karen Kitchen, Mike Legler, Brian O'Hearn, Tiffany Potter, Karen Reinhart, and Stephen Sullivan.

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