

Amphibian Monitoring in the Greater Yellowstone Network

2006 PROJECT REPORT

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Introduction

Concerns about amphibian population declines and disappearances in diverse areas around the world have escalated since the problem became apparent in the 1980s (Collins and Storfer 2003). Systematic examinations have revealed that in some regions, including North America, rapid declines probably began around the middle of the 20th century, with the rate of decline increasing in the 1990s (Houlahan et al. 2000; Alford et al 2001). Worldwide, 32% of amphibian species are now threatened with extinction, while 43% exhibit some form of population decrease (Stuart et al 2004). Amidst the rapid and general decline in global biodiversity, amphibian population extinctions and declines are particularly alarming because they are occurring not only where habitat has been lost, but also in natural, protected areas. The six leading hypotheses for amphibian declines are land use changes, infectious diseases, global change (climate warming and increased ultraviolet radiation), toxic chemicals (e.g., pesticides), alien species, and over-exploitation (Collins and Storfer et al 2003). Many of the rapid amphibian population declines are poorly understood and likely have complex causes involving interacting factors. The single biggest threat recognized currently is the disease chytridiomycosis, caused by an aquatic, parasitic fungus first identified in 1998. The fungus has been detected in amphibian populations of the Greater Yellowstone area and appears to be widespread in western North America.



Photo Credit: Dove Kaznyak

Boreal Chorus Frogs are a small, but vocal member of the GYE amphibian communities.

Background of the Program

In 1991, to assess the status and trends of amphibians in the Greater Yellowstone Ecosystem (GYE), the Herpetology Laboratory at Idaho State University began a collaborative project with the National Park Service and the U.S. Fish and Wildlife Service in Yellowstone and Grand Teton National Parks. Early efforts included comparing the occurrence of species at previously documented sites and monitoring ten sites in the GYE. This work suggested that while some local populations had declined due to habitat alterations (e.g., highway construction), three species were widespread and relatively common: tiger salamanders (*Ambystoma tigrinum*), boreal chorus frogs (*Pseudacris maculata*), and Columbia spotted frogs (*Rana lutieventris*). Boreal toads (*Bufo boreas*) appeared to be less widespread and common than in the 1950's. Northern leopard frogs (*Rana pipiens*) had almost completely disappeared from Grand Teton National Park. One non-native species, the American bullfrog (*Rana catesbeiana*), was thriving in GRTE at Kelly Warm Springs. In the course of population monitoring and graduate student research, we witnessed a great deal of year to year variation in reproductive success in all native species.

Since 2000, survey and monitoring efforts increased considerably due to collaborations among the USGS Amphibian Research Monitoring Initiative (ARMI), Idaho State University (ISU) and the NPS Greater Yellowstone Inventory and Monitoring Network (GRYN). From 2000 through 2003, we conducted herpetological inventory in Yellowstone National Park (YELL) and Grand Teton National Park (GRTE) (Patla and Peterson 2004). The main focus of field work 2000-2003 was the survey of potential amphibian breeding habitat in randomly-selected watershed units across YELL and GRTE. The approach was designed and implemented initially as a pilot study in 2000 under USGS-ARMI (Patla 2001). In 2001, 2002, and 2003, surveys were funded jointly by the NPS-I&M and USGS-ARMI, with the majority of funding supplied by USGS-ARMI.

Amphibian occurrence was selected by the NPS in 2004 as one of the “vital signs” for monitoring ecosystem health in GRYN. Concurrently, USGS-ARMI designated the GYE as the central portion of the Great Divide Transect, a system of amphibian monitoring and research projects which extends from Glacier National Park to Rocky Mountain National Park (Corn et al. 2005b). Through the collaborative efforts of ISU, GRYN, and ARMI, we developed and tested a sampling design for YELL-GRTE modified from the Inventory and initial ARMI projects. Our approach involves comprehensive, repeated amphibian surveys of wetlands within small watersheds (referred to as catchments). The goal is to be able to identify and understand changes or trends in amphibian occupancy in the two national parks, and to understand the factors influencing changes in occupancy patterns. In 2005, we field-tested the new approach with a subset of the catchments. The 2006 field season was the final year of testing, and it approximated full implementation.

Conceptual Model

The conceptual basis for monitoring amphibians was developed in 2004 during the process of evaluating and selecting GRYN vital signs. In general terms (Figure 1), amphibians may serve as useful indicators because they are sensitive to stressors that are of concern to national park managers, including habitat alteration, climate change, pathogens, contaminants, parasites, and introduced species. Amphibian populations may respond in a number of ways to such stressors: occupancy and distribution patterns may change, the abundance of individuals may decline, outbreaks of disease and malformations may occur, the genetic structure of populations may change, and species may disappear regionally or within administrative units. The loss or decline of amphibian populations is of concern not only because of the

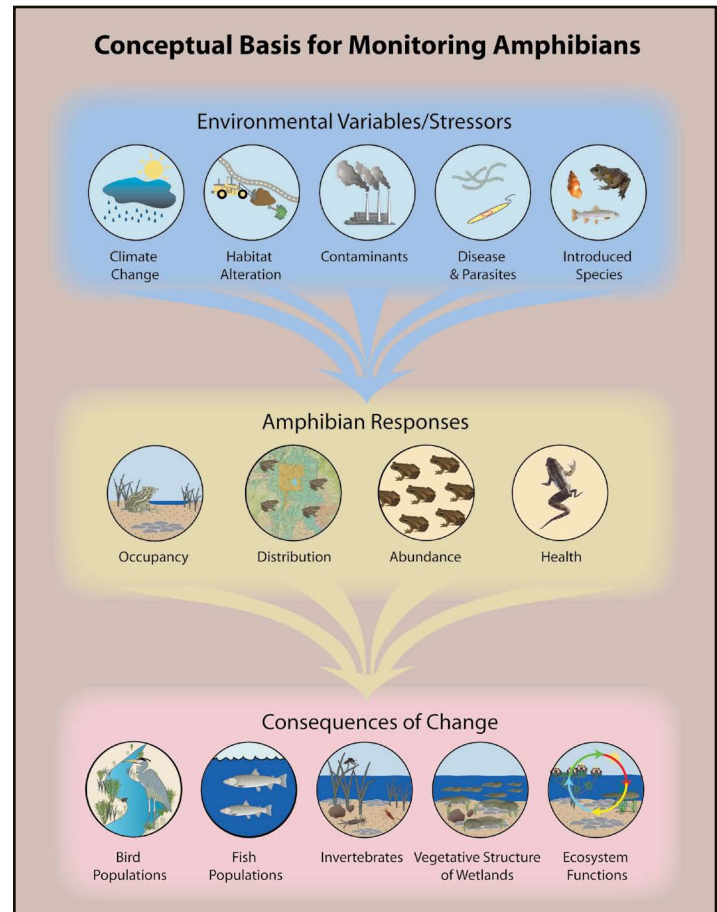


Figure 1. The conceptual basis for monitoring amphibians is that they are sensitive to environmental stressors important to management, and that how they respond may have consequences for aquatic or terrestrial ecosystems including changes in predator/prey populations, vegetative structure of wetlands, or other ecosystem functions (e.g., nutrient cycling).

diminishment in biodiversity, but also because of the potential effects on ecosystems. Amphibians often occur in great local abundance, and declines may alter trophic relationships, given that amphibians serve as predators and prey for many other species. Another example of a potential ecosystem effect relates to changes in the flow of energy, considering the unique role that amphibians play in transporting the high productivity of wetlands to the terrestrial environment, as tadpoles metamorphose and emerge from ponds.

A second, more detailed, conceptual model is more specific to amphibians in the GYE (Figure 2). All amphibian species of the GYE rely on shallow, stagnant water bodies for egg deposition and larval development, thus the distribution and size of these wetlands directly affects amphibian distribution and abundance. In the GYE, major ecosystem drivers and landforms (e.g, geology, climate and land use)

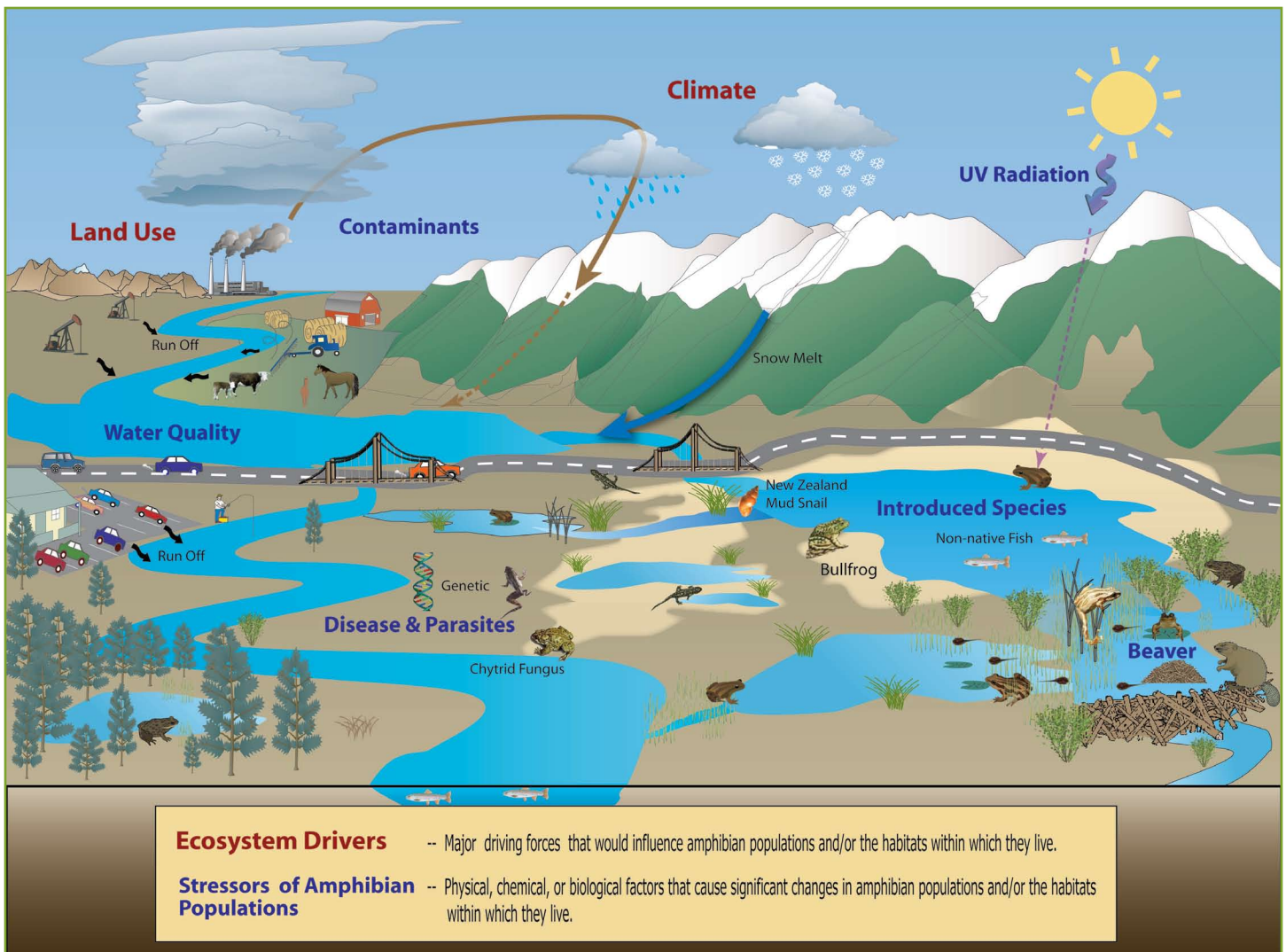


Figure 2. Conceptual model of amphibians in the Greater Yellowstone Ecosystem showing the primary drivers and stressors that influence amphibian populations.

result in a patchy distribution of suitable wetlands. Factors affecting the location and extent of wetlands, such as drought or climate change, land use, and beavers, are likely to substantially affect amphibian populations. Amphibians of the GYE also may be affected by a variety of stressors, including non-native species, pathogens, contaminants from both local and remote sources, and UV radiation. Some environmental factors affect amphibians directly as well as via their impacts on wetland habitats. For example, roads can cause high mortality rates in frogs attempting to reach breeding or wintering habitat, and roads can also cause wetland loss. Details regarding the magnitude and possible importance of these various stressors or environmental factors for amphibians in the GYE can be found in Patla et al. (2007).

Objectives

Our specific monitoring objectives are intended to answer the following questions: Is the occupancy of amphibians changing within the Greater Yellowstone Network of Parks, and is there evidence regarding likely underlying causes of any observed declines that might warrant further directed research or management actions consistent with National Park Service policies?

Occupancy, or the proportion of catchments and/or suitable wetlands occupied by amphibian breeding populations, was selected as the most sensible and feasible approach (biologically, statistically and logistically) for monitoring amphibians across large administrative units (Corn et al. 2005a). This metric allows for the recognition of increases in amphibians as well as declines, and can account for the

problem of bias that arises when animals are present but not detected on every survey.

Objective 1. Proportion Of Breeding Sites Occupied

Objective: To estimate the proportion of sites used for breeding by each species of amphibian and to estimate the rate at which use of sites for breeding is changing over time (supplemented by Objective 2 for boreal toads).

Estimates of occupancy (MacKenzie et al. 2002, 2003, 2006) will be assessed at both the catchment and site levels (catchments contain multiple potential amphibian breeding sites). This will allow for a comprehensive evaluation of variation among and within catchments, as well as to facilitate an assessment of the relative importance of environmental factors (covariates) that may affect occupancy.

Objective 2 – Rate Of Change In Occupancy (Boreal Toads)

Objective: To estimate the rate at which use of known sites for breeding by boreal toads is changing over time.

Boreal toads present a special case in that they are sufficiently rare so as to make estimation of rates of change difficult from a sampling scheme with a targeted scope of inference to the entire parks. Preliminary sampling indicates that the proportion of sites occupied by boreal toads is too low to enable reliable estimation of rates of change. Thus, the major distinction between this objective and Objective #1 is that our sampling frame targets only previously identified breeding locations for this species.

Objective 3 – Wetland Dynamics

Objective: To estimate the occurrence, number, and size of potential sites that are suitable for breeding.

For reliable comparisons of change in occupancy over time, the sampling frame must be the same from year to year. There is also an assumption of the occupancy estimator that sites have a non-zero probability of being occupied at the time that estimates are made. However, during some years, some wetlands have a zero probability that amphibians will be breeding if that site is dry. This objective is intended to account for that possibility by simultaneously estimating the proportion of sites occupied and the proportion of sites that have or do not have standing water. Thus, we can directly observe how occupancy by amphibians changes as a function of the proportion of wetlands that are dry.

Objective 4. Disease

Objective: To identify and record the presence of infectious and emergent amphibian diseases.

Boreal toads are sufficiently rare so as to warrant augmented sampling of known breeding areas.



Photo Credit: Debra Patla

Infectious and emergent amphibian disease is a very active field of investigation among researchers. This objective calls for a flexible, rapid response to information needs, requests for research support, and implementation of new practices or measures in the field.

Methods

Study Area

Our primary study area includes YELL and GRTE, with inference to all portions of the parks containing shallow wetlands. Sampling units for amphibian monitoring are small portions of watersheds, referred to as catchments. Figure 3 shows the catchments that have been selected for long-term monitoring. In 2006, we initiated a pilot effort for an additional study area at BICA, although here we have limited our sampling to a series of 11 ponds within the Yellowtail Wildlife Management Area (Figure 4). This area of BICA has the vast majority of suitable breeding habitat for amphibians and is subject to water management that might influence its quality for amphibians.

Sampling scheme

Catchment boundaries were provided by a GIS layer created at USGS EROS Data Center. Prior to 2005 this project used a catchment size that resulted in up to 54 wetland sites per catchment. The net result was that we were spending too much time sampling per catchment and could not sample enough catchments for statistical analyses. To determine an appropriate scale for catchments, we were aiming for a smaller catchment size that would enable us to sample a greater number of catchments with an average of approximately 5-10 wetland sites per catchment. The resulting catchment size, initiated in 2005, was on average approximately 200 ha, but quite variable in size and amounts of potential amphibian breeding habitat due to the diversity of topography and

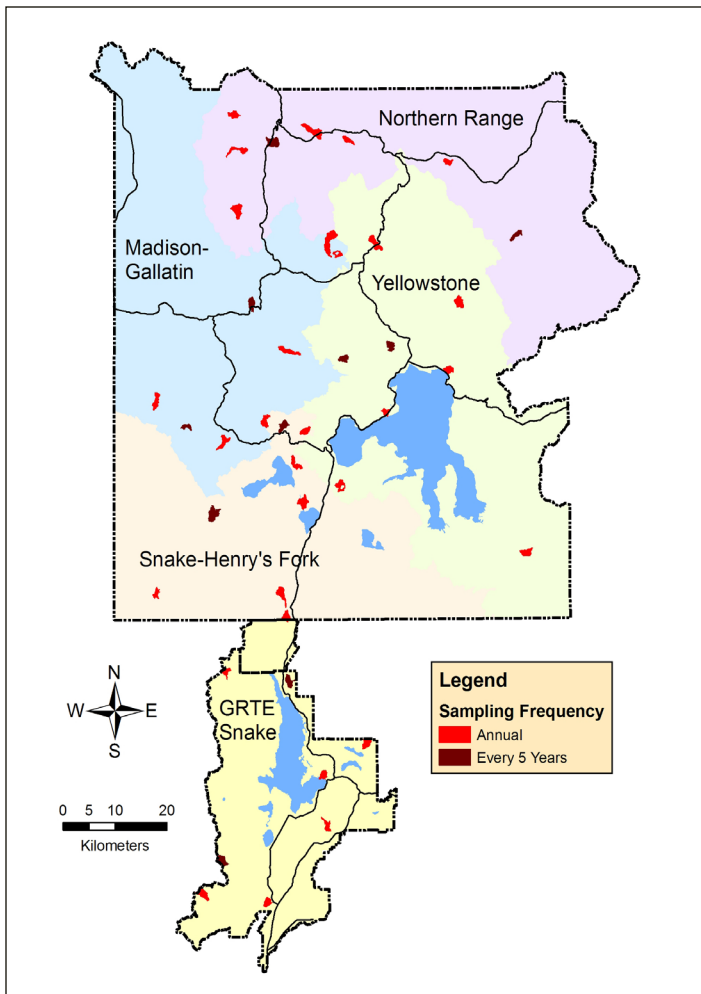


Figure 3. The water catchments at YELL and GRTE that were selected for sampling annually (medium and high quality) and once every five years (low quality)

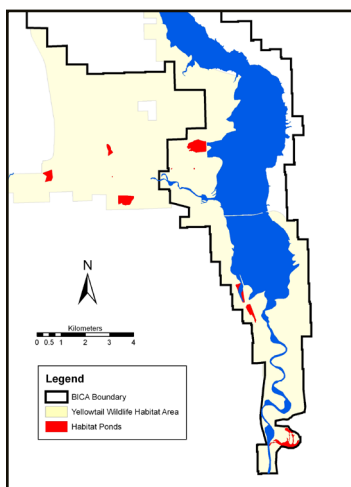


Figure 4. The 11 ponds that will be surveyed at the Yellowstone Wildlife Management Area.

drainages in the GYE.

We used a probabilistic sampling scheme with unequal inclusion probabilities to ensure spatial distribution of sampling units among the major drainage basins in YELL and GRTE. To help ensure that the majority of units could be reached without extraordinary off-trail efforts during the brief field season, we used two accessibility classes (>4 km and <4 km of roads) with an unequal inclusion probability of be-

ing in our sample (Table 1). Since the highest quality habitat within YELL and GRTE is limited to a small amount of the area, we also wanted to ensure sampling this habitat by designating amphibian breeding habitat probability (high, medium, and low, based on National Wetland Inventory (NWI) types and amounts within the catchment)(Patla et al. 2007).

Amphibian Surveys

Protocols for surveys are detailed in Patla et al. (2007). In summary, two-person field crews visit all potential amphibian breeding sites within the boundaries of the selected catchments. Surveys are conducted at all sites with suitable water, following standard amphibian visual encounter methodology (Thoms and Olson 1997). This entails walking the perimeters of water bodies and transects through shallow ponds and wetlands, and using long-handled dip-nets to sweep the water for amphibian larvae. The main target of surveys are life stages indicating reproduction at the site—eggs, larvae, or recent metamorphs. Each field crew member surveys the site independently (dual observer method), to provide data on species detectability. In 2005, 3 catchments received two rounds of visits, in June and again in July. In 2006, catchments were visited once per season.

Data collected in the field include location (recorded with a GPS receiver), time spent searching, species observed (life stages and numbers of each), weather, habitat descriptors, water temperature, pH and conductivity (Patla et al. 2007). Sites are documented with drawings and photos, and species larvae are documented with photographs. Data are recorded on field sheets and personal digital assistants (PDAs). The PDAs are programmed using forms software (Pendragon Forms), and downloaded directly into a Microsoft Access database provided by USGS-ARMI. The relational database, containing multiple tables, is standardized for use in the Rocky Mountain Region by USGS-ARMI.

In 2006, surveys at monitoring sites began on June 19 and ended by July 26. Three two-person field crews were employed, supplemented by a USGS crew working in GRTE, July 5-11. In 2005, surveys were conducted by two field crews and the field supervisor, working between June 14 and August 2.

Boreal Toad Monitoring

Due to the relative scarcity of boreal toads, monitoring for this species is supplemented by visits to previously identified toad breeding areas in the GYE. Based on a comprehensive list of locations compiled from all existing amphibian databases and spreadsheets, a total of 42 toad breeding areas (some containing multiple breeding sites) have been found in the GYE (including GRTE, YELL, and the National

Table 1. Catchment selection for long-term amphibian monitoring.

Access Class ¹	Habitat Quality ²	Survey frequency	Basins						Total catchments
			Northern Range	Yellowstone	Madison-Gallatin	Snake-Henrys Fk	GRTE-North*	GRTE-South*	
Close	High	annual	2	2	2	2	1	1	10
Far	High	annual	1	1	1	1	0	1	5
Close	Medium	annual	2	2	2	2	1	1	10
Far	Medium	annual	1	1	1	1	1	0	5
Close	Low	5 years	1	1	1	1	1	0	5
Far	Low	5 years	1	1	1	1	0	1	5
Close	Low	annual	0	0	0	1	0	0	1
Total			8	8	8	8	4	4	41

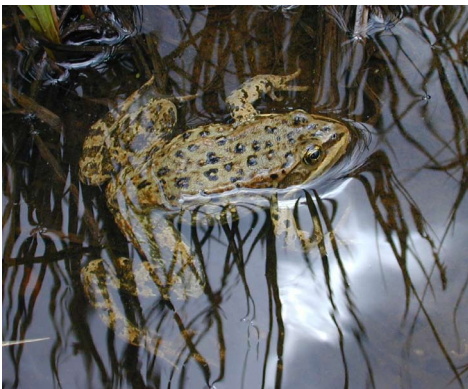
¹ Based on whether catchment is > or < 4km from a road.

² Based on the amount and type of wetlands in each catchment identified by the National Wetlands Inventory and verified on the ground.

Elk Refuge). Monitoring consists of conducting time-constrained visual encounter surveys at the known breeding sites and in the vicinity up to about 500 m, with time limited to 3 hours.

Data analysis

Occupancy modeling provides a statistical framework for assessing changes in species occurrence (MacKenzie et al. 2002; Royle & Nichols 2003). Information from repeated observations at sample units is used to estimate detectability and adjust occupancy rates for imperfect detection (failure to observe a species that is actually present). Occupancy models allow for analysis of covariates potentially affecting detectability (e.g., observer, weather conditions) and covariates affecting occupancy (e.g., water depth, vegetation type). For occupancy modeling, we are using the program PRESENCE, developed by USGS for occupancy modeling (<http://www.mbr-pwrc.usgs.gov/software/>), and MARK (White & Burnham 1999).



Columbia Spotted Frogs are seldom seen far from water

Preliminary Results

In 2005, we sampled a total of 15 catchments, 12 of which were in YELL and 3 in GRTE (Table 2). In 2006, we extended that effort to 32 catchments, 25 of which were in YELL and 7 in GRTE. Breeding sites (identified by the presence of eggs, larvae, or recent metamorphs) of four species were found. Boreal chorus frogs and Columbia spotted frogs were found in all basins and at many sites. Tiger salamanders were clustered mostly in the northern range of YELL and in GRTE. Boreal toads showed a similar pattern but with fewer total occupied catchments and breeding sites than salamanders. No leopard frogs or bullfrogs were found.

Occupancy and detection rates based on catchments and sites are shown in Table 3. Detection rates using the dual-observer method were generally high, varying from 75% to 97% for estimates at the catchment scale, and from 63% to 93% for estimates at the site scale. The high detection rates resulted in only small discrepancies between observed (naïve) and adjusted, estimated occupancy. Species varied in their relative occupancy depending on whether it was estimated at the catchment or site scale, and depending on year. An exception is that boreal toads had the lowest occupancy at both scales and during both years.

Field effort to complete monitoring in 2006 was 85 field crew-days. Field time per catchment varied from 1 day to 6 days, with a mean of approximately 2.7 days spent per catchment. A field crew-day includes driving, hiking, survey time, and data entry, by a two-person crew. This computa-

Table 2. Total number of catchments and sites surveyed per basin, and the number of catchments and sites containing breeding sites for each amphibian species.

	Catchments Surveyed	Sites Surveyed	Tiger Salamander		Boreal Toad		Chorus Frog		Spotted Frog	
			Catch	Sites	Catch	Sites	Catch	Sites	Catch	Sites
2005										
Northern Range	4	10	2	2	1	1	3	5	1	3
Yellowstone	2	26	0	0	0	0	1	3	2	6
Madison-Gallatin	2	16	0	0	0	0	2	2	1	2
Snake-Henrys Fk	4	31	1	1	0	0	4	9	3	9
GRTE	3	38	1	2	1	3	1	3	2	3
TOTAL	15	121	4	5	2	4	11	22	9	23
2006										
Northern Range	6	24	5	10	3	3	4	9	5	7
Yellowstone	5	40	0	0	1	1	2	11	4	6
Madison-Gallatin	6	71	1	1	0	0	5	30	4	13
Snake-Henrys Fk	8	65	0	0	0	0	4	16	5	15
GRTE	7	62	3	8	1	4	4	16	4	13
TOTAL	32	262	9	19	5	8	19	82	22	54

tion does not include training, equipment care, supervisor's assistance on surveys in several of the catchments, and data management tasks. The number of sites surveyed per catchment varied from 1 site to 26 sites, with a mean of 8.2 sites per catchment. On average, 3 sites were surveyed per field crew-day in 2006. This does not include time spent on potential sites that were visited but not surveyed due to lack of surface water, a total of 173 dry or otherwise unsuitable sites in 2006.

Boreal Toads

In 2006, we surveyed 32 of the 42 previously identified breeding areas. Evidence of breeding (eggs, tadpoles, or recent metamorphs) was found at 24 areas. Most of the absences occurred at sites where toads have been observed only rarely or intermittently over the past decade.

Discussion

In 2006, we attempted to survey all catchments selected for annual, long-term monitoring. Problems were encountered with two catchments, which will need replacement selections: (1) Trail access to a catchment in YELL was closed by park managers in July to protect wolves, just prior to our planned survey. It appears likely the closure will be necessary in the future, blocking our access to this catchment. (2) A catchment in GRTE was found to lack suitable amphibian breeding habitat and should be replaced.

A major challenge to accomplishing monitoring is the short field season, which is constricted in June by area closures and high water from snowmelt, and in late July by the rapid desiccation of seasonal water bodies. This problem is exacerbated by extended drought and high summer temperatures. Pilot work in 2005 provided insights on how to schedule field visits in 2006, but even so several of the new

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Table 3. Estimates of occupancy (Ψ) and and detection probability (p) for each species during 2005 and 2006.

Species	Catchments			Sites		
	p	Ψ	SE	p	Ψ	SE
2005						
Tiger salamander	0.90	0.27	0.12	0.86	0.06	0.02
Boreal toad	0.77	0.14	0.09	0.88	0.03	0.01
Boreal chorus frog	0.80	0.76	0.12	0.89	0.21	0.04
Col spotted frog	0.90	0.60	0.13	0.63	0.23	0.05
2006						
Tiger salamander	0.88	0.29	0.08	0.85	0.07	0.02
Boreal toad	0.75	0.17	0.16	0.86	0.03	0.03
Boreal chorus frog	0.97	0.59	0.08	0.93	0.32	0.03
Col spotted frog	0.96	0.72	0.08	0.84	0.22	0.03

catchments were surveyed too early or too late, and further adjustments are needed in scheduling. Visiting catchments too early or too late can result in missing the period when amphibian eggs, larvae, or metamorphs are present. This violates a major assumption of the occupancy models used to analyze the data.

Occupancy modeling makes it possible to test the relative strength of hypotheses about factors influencing detectability and occupancy. For example, we think that tiger salamanders may be less detectable in June than in July, and that the abilities of observers could also affect detectability. In terms of occupancy, salamander larvae probably do not occur in habitats where fish are present, and they could also be affected by a scarcity of deep (>50 cm) pools with shallow edges. Using the program PRESENCE, it is possible to determine which model(s) best fits the data patterns. Modeling will help us understand trends. If salamanders decline, for example, we can look for drought effects in terms of the increased scarcity of fish-less water bodies with sufficient deep water pools. Because this study is designed to provide inference to YELL and GRTE, such a finding would provide evidence about salamander declines and their causes throughout both parks.

We intend to conduct thorough data analysis every 5 years, with basic occupancy and detectability computed an-

nually. The 5-year synthesis period will make it easier to determine if trends are present, with less danger of inflating the importance of annual fluctuations.

Given widespread and rapid decline of amphibians around the world, we are frequently asked how amphibians are doing in the Greater Yellowstone area. Our current view is clouded by the fact that until 2006, we have lacked a means of assessing the entire area. Although many years of surveys and research preceded implementation of this monitoring program, sampling effort and locations varied from year to year, making any assessment of trends highly qualitative. Our current view, based on previous surveys and the initial monitoring effort is that Columbia spotted frogs and boreal chorus frogs are widespread and common in both parks where suitable habitat is present. Tiger salamanders are common in fishless lakes and wetlands in the lower elevation areas, such as the Northern Range and Jackson Hole, with rarer occurrence in central and southern Yellowstone. Boreal toads, which may have declined from their former abundance mid-20th century, are widespread but spotty in occurrence, and absent above 2500 meters elevation (8200 feet). Boreal toads are persisting at most of the large or major breeding sites we have been monitoring since the early 1990s. Our main concerns for amphibians are disease, drought and the yet unknown effects of climate change, and

Photo Credit: Dave Kazyak



Tiger salamanders are common in ponds and fishless lakes of the Northern Range and Jackson Hole.

the potential for anthropogenic influences such as increased nitrogen deposition (Corn et al. 2005b). We hypothesize that local declines could be occurring due to development within the parks, with the gradual erosion of populations around developed areas and roads. Our prominent current concern is the potential effect of two amphibian diseases known to be present and possibly widespread in the region, chytridiomycosis and ranavirus. Chytridiomycosis is strongly implicated as a driver of rapid, widespread declines of amphibians in the Rocky Mountains of Colorado and the Sierra Nevada of California (Muths et al. 2003; Rachowicz et al. 2006). On-going research may help us understand the nature of this threat in the Greater Yellowstone, while monitoring may reveal if population declines occur.

Acknowledgments

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Surveying Amphibians in the Greater Yellowstone Ecosystem

COOPERATING ORGANIZATIONS

U.S.GEOLOGICAL SURVEY

AMPHIBIAN RESEARCH AND MONITORING INITIATIVE (ARMI)
NORTHERN ROCKY MOUNTAIN SCIENCE CENTER

USDI NATIONAL PARK SERVICE

GREATER YELLOWSTONE NETWORK OF PARKS
BIGHORN CANYON NATIONAL RECREATION AREA
GRAND TETON NATIONAL PARK
YELLOWSTONE NATIONAL PARK

IDAHO STATE UNIVERSITY

DEPARTMENT OF BIOLOGICAL SCIENCES

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