



Greater Yellowstone Network Amphibian Monitoring

2010-2011 Annual Status Report

Natural Resource Data Series NPS/GRYN/NRDS—2012/332



ON THE COVER

Amphibian survey on the Northern Range, Yellowstone National Park, June 2011
Photograph by: Janene Colby, NRCC

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June 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Please cite this publication as:

Patla, D. and K. Legg. 2012. Greater Yellowstone Network amphibian monitoring: 2010-2011 annual status report. Natural Resource Data Series NPS/GRYN/NRDS—2012/332. National Park Service, Fort Collins, Colorado.

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Executive Summary

The national parks within the Greater Yellowstone Ecosystem (GYE) provide an opportunity to monitor amphibians within a relatively intact ecosystem, and at spatial and temporal scales that can provide important insights about the status of regional amphibian populations and global declines of amphibians. The Greater Yellowstone Network (GRYN) amphibian monitoring program is the only long-term amphibian monitoring program in the GYE that consistently looks at multiple sites across the ecosystem. The goal of this program is to estimate occupancy rates for the reproductive component of native amphibian species, incorporating the dynamics of wetland sites that provide potential breeding habitat. Annual measures of amphibian occurrence and wetland suitability allow trends in amphibian populations to be considered in context of the available habitat. This work, when combined with historical data, will provide managers and the public with information on a class of native fauna and on wetland characteristics that are important for understanding long-term trends or changes in the GYE wetland resources.

This report describes amphibian monitoring efforts and results from the years 2010 and 2011. In 2010, we conducted surveys in all 40 catchments (sampling units) selected for long-term monitoring. In 2011, the effort was scaled back to a target of 30 catchments; of which we completed surveys in 29. All species targeted for monitoring were found. There were no northern leopard frogs (*Lithobates pipiens*) and no non-native American bullfrog (*Lithobates catesbeianus*) detected at any sites.

Occupancy rates for the subset of the catchments with high and medium quality habitat were summarized from 2006-2011 and indicate annual changes; further analysis is needed to interpret how amphibian species occupancy may be changing over time. The combination of a greater snowpack and spring precipitation in 2011 compared to 2010 led to an increase in the number of potentially suitable breeding sites, with a smaller percentage of sites made unavailable due to a lack of surface water. Amphibian reproduction probably increased or remained stable between 2010 and 2011, based on the descriptive data and preliminary analyses contained in this report.

Research on amphibian disease indicates that the parasitic fungus causing chytridiomycosis is widespread in the GYE, but no die-offs attributed to the disease were found in 2010 or 2011. Monitoring will continue in 2012 at a level similar to 2011. GRYN is collaborating with U.S. Geological Survey (USGS) to conduct a comprehensive analysis of amphibian status and trends between 2000 and 2011 in Grand Teton, Yellowstone, Glacier, and Rocky Mountain national parks.

Acknowledgments

Funding for this program was provided by the National Park Service Greater Yellowstone Inventory and Monitoring Network (GRYN) and the U.S. Geological Survey (USGS). Field work was administered through the Northern Rockies Conservation Cooperative (NRCC), Jackson, Wyoming in 2010 and 2011. We welcomed and appreciated the partnership with NRCC, and thank Jason Wilmot for the smooth transition. In 2010 we collaborated with Sophie St-Hilaire at Idaho State University on disease investigations; we thank Dr. St-Hilaire for contributing funds for our program costs and for the training she provided to field crews. At GRYN, Rob Daley provided database management and technical support, and Cathie Jean accomplished budgeting and program planning. USGS provided technical support for data collection and the database; thanks to Dr. Blake Hossack, Chris Brown, and Donn Holms. A warm thank you to the valiant field crews of 2010 and 2011: Janene Colby, Mary Greenblatt, Erin Hannelly, Eric King, and Scot Martin in 2011; Mary Greenblatt, Kyna Hogg, Dennis Kaleta, Art Schaub, and Dan Schrimsher in 2010. USGS lent field crew support from Glacier National Park in 2010 and 2011; thanks to Brett Addis, Paul Scarr, Christine Doman, and Ken Honeycutt. Char and Dave Corkran traveled from Portland, Oregon to assist with monitoring as they have for nearly every year since 1996; we are grateful for their expertise and support. The GRYN whitebark pine monitoring coordinator, Erin Shanahan, assisted by lending field biologists, John Fothergill and David Brodhead, who accomplished amphibian monitoring in the most remote and challenging catchment in 2010. We thank Dr. Andrew Ray for his review of the this report; and Dr. William Gould for his continuing efforts of analyzing data and advising. At Grand Teton National Park, we thank Cindy O'Neill and Christine Tabacchi for permits, and Sue Wolff for assistance and for lending an SCA volunteer, Will Sherrer, in 2010 to help with monitoring. At Yellowstone National Park, we thank Christie Hendrix and Stacey Gunther for permit and logistics assistance, the backcountry office for camping permits and advice, Resource Management (especially Eric Reinertson), and district rangers for their cooperation.

Introduction

Concerns about amphibians have escalated over the past three decades and since population declines became apparent in diverse areas around the world (Collins and Storfer 2003, Wake and Vredenburg 2008). 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 becoming more pronounced 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 declines in global biodiversity, amphibian population losses are particularly alarming because they are occurring not only where habitat has been lost, but also in protected areas that are relatively free from anthropogenic impacts. The major causes of amphibian decline include land use changes that result in habitat loss and degradation, diseases (particularly the fungal disease chytridiomycosis), climate change, environmental pollution, commercial exploitation, increases in ultraviolet-B irradiation due to ozone pollution, and invasive species (Collins and Storfer 2003, Hof et al. 2011). These threats may act singularly or interact at local and regional scales (Hof et al. 2011 and sources therein). In the Greater Yellowstone Ecosystem (GYE), several of these threats are known to be present. Amphibian declines on the Northern Range in Yellowstone National Park have been attributed to decreasing annual precipitation and increasing summer temperatures. Combined, these conditions led to a loss of surface water and critical wetland breeding habitat (McMenamin et al. 2008). Lethal outbreaks of amphibian disease have also been detected within Yellowstone and Grand Teton national parks, including ranavirus and chytridiomycosis (Corn 2007). Invasive species of potential concern include non-native fish, New Zealand mud snails (*Potamopyrgus antipodarum*), and American bullfrogs (*Lithobates catesbeianus*, formerly *Rana catesbeiana*).

Yellowstone and Grand Teton national parks have relatively few amphibian species compared to more temperate regions in the U.S. Three amphibian species are considered common in these parks (Koch and Peterson 1995): tiger salamanders (*Ambystoma mavortium*, formerly *Ambystoma tigrinum*), boreal chorus frog (*Pseudacris maculata*), and Columbia spotted frog (*Rana luteiventris*). Boreal toads (*Anaxyrus boreas boreas*, formerly *Bufo boreas boreas*) are thought to be less widespread and less common than in the 1950s (Koch and Peterson 1995). Northern leopard frogs (*Lithobates pipiens*, formerly *Rana pipiens*) vanished from Grand Teton National Park in the 1950s (Koch and Peterson 1995). One non-native species, the American bullfrog, was introduced in the 1950s or earlier and still occurs in Grand Teton National Park at Kelly Warm Springs.

The Greater Yellowstone Network (GRYN), as part of the National Park Service's Inventory and Monitoring Program, has identified amphibians in Yellowstone and Grand Teton national parks as a vital sign for long-term monitoring (Jean et al. 2005). Long-term monitoring of amphibian populations provides an opportunity to observe trends that may not be apparent at local scales or in areas with more direct human influences on habitat quality. Starting in 2001, and building on efforts to assess amphibians in the GYE since the 1980s (Koch and Peterson 1995), the NPS collaborated with the United States Geologic Survey (USGS) and Idaho State University (ISU) to develop this amphibian monitoring program. The USGS Amphibian Research Monitoring Initiative (ARMI, <http://armi.usgs.gov/>) designated Yellowstone and Grand Teton national parks as part of the Great Divide Transect, a system of amphibian monitoring and research projects extending from Glacier National Park to Rocky Mountain National Park (Corn et al. 2005a,

2005b). GRYN adopted the ARMI conceptual approach for long-term monitoring. A draft protocol was prepared (Amphibian Monitoring Working Group [AMWG] 2008) which details the approach, rationale, and methods of using repeated surveys of wetlands within small watersheds (referred to as catchments) to monitor amphibian occupancy. This protocol is scheduled to be finalized in 2012.

The current objectives of this monitoring are to:

1. Estimate the proportion of catchments and sites used for breeding by each native amphibian species annually, and estimate the rate at which their use is changing over time.
2. Determine the number of sites within catchments that are potentially suitable for amphibian breeding annually (i.e., have standing water during the breeding season).
3. For boreal toads, estimate the proportion of previously identified breeding areas that are used annually, and estimate the rate at which their use is changing over time.

The third objective is intended to supplement objective 1; occupancy rates are presumed to be too low to enable reliable estimation of rates of change with inference to the entire study area, given the rarity of boreal toads relative to other amphibian species. Objective 3 is not currently being implemented due to inadequate development of analytic and sampling methods needed to detect trends in boreal toad populations. This is not attainable with the available funding.

Since the first year of fully implementing the protocol in 2006, adaptive changes have occurred due to funding reductions as well as evolution in our thinking about the effort needed with regard to different kinds of habitat. In addition, events occasionally prevent surveys of some catchments; for example, in 2011 two catchments were inaccessible during the field season. Catchments that become unavailable due to administrative closures can be replaced with others to maintain the desired sampling effort, but only if we have foreknowledge and adequate time to plan field work in the replacements.

The primary purpose of this report is to summarize the monitoring activities that occurred in 2010 and 2011.

Methods

Study Area

Our study area is Yellowstone and Grand Teton national parks. The sample frame consists of the portions of these parks containing shallow semi-permanent, permanent, or seasonally flooded emergent wetlands. The primary sampling unit—catchments—are small watershed units that were defined by topography as they relate to the flow and collection of water (AMWG 2008).

Sampling Scheme

Catchment boundaries are represented in a Geographic Information System (GIS) layer created at USGS Earth Resource Observation Systems (EROS) Data Center. We used a stratified random sampling scheme to ensure spatial distribution of sampling units among the major drainage basins of Yellowstone and Grand Teton (Figure 1) national parks. 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 (“close” or ≤ 4 km from roads and “far” or > 4 km from roads) in our allocation scheme (Table 1). Since the highest quality habitat within Yellowstone and Grand Teton national parks is limited to a small amount of the area, we sought to ensure sampling this habitat by stratifying on amphibian breeding habitat probability or quality (high, medium, and low) based on National Wetland Inventory (NWI) types and amounts within the catchment (AMWG 2008). We defined high, medium, and low as:

- High quality: > 4 ha of semi-permanent and permanent wetlands (NWI water regime F, G, or H), AND > 2 ha of seasonally flooded wetlands (NWI water regime C). There are 135 catchments in the sample frame, of which 92 are close access.
- Medium quality: > 0 ha (any amount) of semi-permanent and permanent wetlands (NWI water regime F-G-H), AND > 1 ha of seasonally flooded wetlands (NWI water regime C). There are 990 catchments in the sample frame, of which 565 are close access.
- Low quality: > 0 ha (any amount) of semi-permanent and permanent wetlands (NWI water regime F, G, or H); OR > 0 ha (any amount) of seasonally flooded wetlands (NWI water regime C) (i.e., all remaining catchments with potential surface water). There are 2,245 catchments in the sample frame, of which 1,009 are close access.

In 2010 and consistent with the sampling design described in Table 1, we sampled all 40 catchments. In 2011, we scaled back the effort and targeted the 30 catchments in the high and medium habitat classes (Figure 1). This reduction in 2011 resulted from reduced funding available for monitoring and also followed recommendations to forego monitoring in the low habitat quality stratum unless sampling efforts of low quality catchments could be significantly increased (Gould et al. 2012). The downside of dropping the low quality habitat stratum is that inferences about amphibian populations cannot be made to the entire study area (the combined area of both parks containing wetlands). Despite this limitation, our focus on high and medium quality catchments (a third of all catchments), still provides an ability to document the status and trend of amphibians in occupying higher quality catchments within our focal parks (Gould et al. 2012).

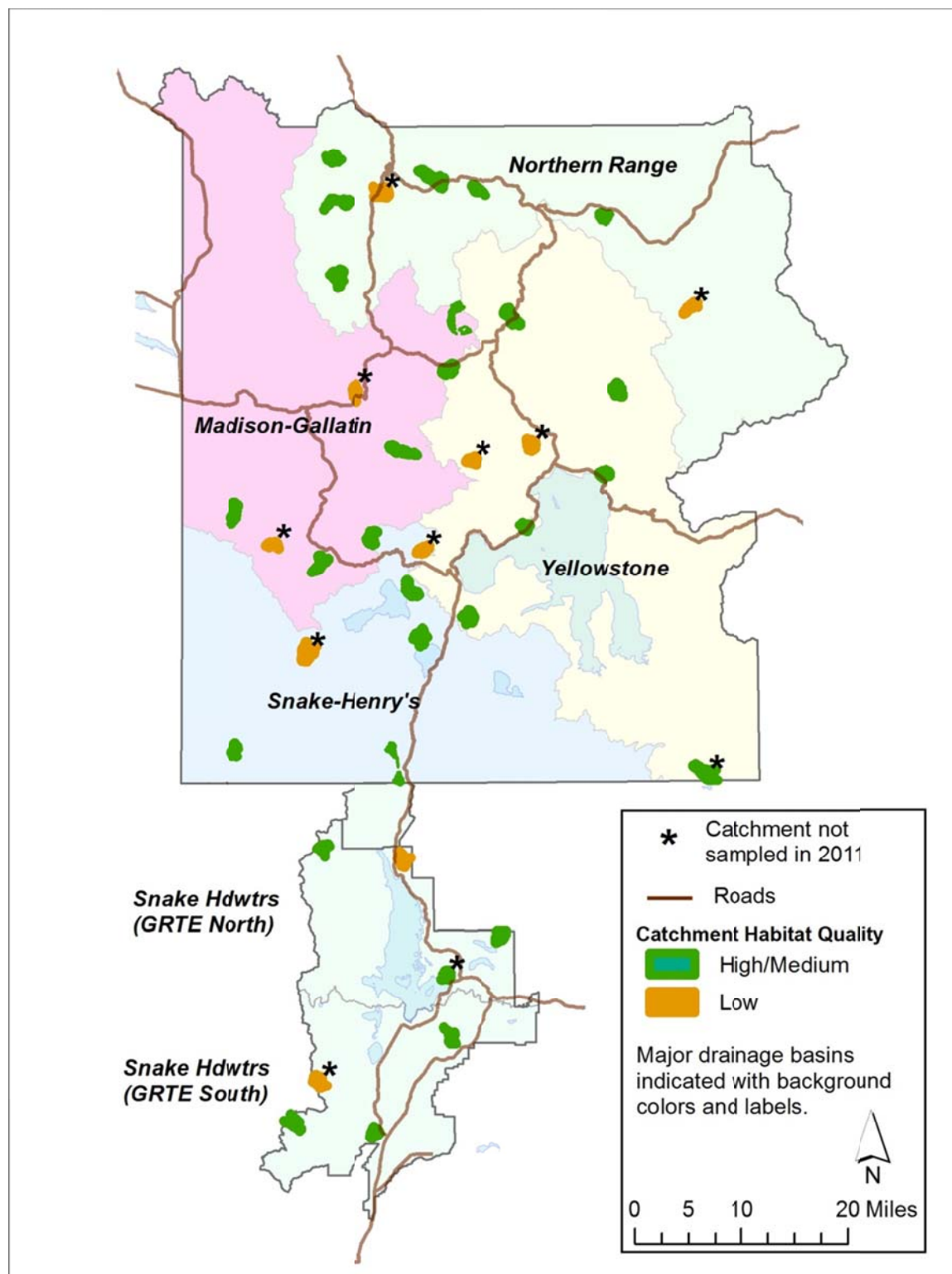


Figure 1. Map of the high, medium, and low quality habitat catchments. All catchments were sampled in 2010 and only high and medium quality catchments were sampled in 2011 unless otherwise indicated on the map.

Table 1. Number of catchments per access class, habitat class, and basin selected for long-term monitoring. All 40 catchments were sampled in 2010. Only high and medium quality catchments were sampled in 2011. Two catchments, one in Yellowstone and one in Grand Teton national parks north basins were not sampled due to flooding and grizzly bear closures, respectively.

Access Class ¹	Habitat Class ²	Basins						Total Catchments
		Northern Range	Yellow-stone	Madison-Gallatin	Snake-Henry's Fork	Grand Teton-North ³	Grand Teton-South	
Close	High	2	2	2	2	1	1	10
Far	High	1	1	1	1	-	1	5
Close	Medium	2	2	2	2	1	1	10
Far	Medium	1	1	1	1	1	-	5
Close	Low	1	1	1	1	1	-	5
Far	Low	1	1	1	1	-	1	5
Total		8	8	8	8	4	4	40

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

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

³Grand Teton is in the Snake Basin; it was divided into north and south zones to achieve better spatial representation.

Amphibian Surveys

Procedures for surveys are detailed in the draft protocol (AMWG 2008). 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 wetlands, following standard amphibian visual encounter methodology (Thoms et al. 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. To determine the presence of breeding populations, we searched for life stages that indicate breeding has occurred: eggs, larvae, or recent metamorphs. Each field crew member surveyed the site independently (dual observer method), to provide data on species detectability. Catchments are visited once per season. We attempt to time the surveys to occur within the optimal period for finding the larvae of all four species. The timing, however, is constrained by a variety of factors including administrative closures by the parks for human safety or wildlife protection, river crossings, and field crew availability.

Data collected in the field included location (initially recorded with Global Positioning System (GPS)) receivers, time spent searching, species observed (life stages, number of adult and juveniles, and categorical estimates of larvae and metamorph numbers), weather, water temperatures, and habitat descriptors (AMWG 2008). Sites were documented with drawings on the initial visits and updated as necessary. Photo points were established on the initial visit and photos were re-taken each year. Data were recorded with personal digital assistants (PDAs), backed up with abbreviated field log sheets including the site identifier, date, and time of visit, observers, species/life stages observed, photo number, and an updated site drawing (if needed). The PDAs were programmed using forms software (Pendragon Forms), and uploaded directly into a Microsoft Access database provided by USGS-ARMI and slightly modified for our use by

the GRYN Data Manager. The relational database, containing multiple tables, is standardized for use in the Rocky Mountain Region by USGS-ARMI.

In 2010, surveys of catchments began on 14 June and ended by 11 August. In 2011, surveys began on 27 June and ended by 7 August. Three two-person field crews worked through the season each year. In addition, the USGS-ARMI provided two people for six work days in both 2010 and 2011. In 2010 and 2011, trained volunteers also assisted regular crew members. In 2010, the GRYN whitebark pine field crew, trained for amphibian monitoring, completed one large catchment in a remote area of Yellowstone National Park. In 2011, the crew was again available, but the catchment was deemed unsafe for work due to high stream levels.

Potential Breeding Sites Within Catchments

To address objective 2, we annually track the number of sites within the target catchments that are potentially suitable for amphibian breeding based on previous years' surveys and following the guidelines outlined in the draft protocol (AMWG 2008). Snowpack of the preceding winter and weather conditions of spring and early summer strongly influence the amount and persistence of surface water in seasonal wetlands and thus the number of suitable breeding sites. By tracking the number of suitable and dry sites annually, we can attempt to identify to what extent habitat loss due to drought or climate change affects amphibian occurrence.

Data Analysis

Catchment and Site Occupancy

Occupancy modeling, also known as proportion of area occupied (PAO), provides a statistical framework for assessing changes in species occurrence (MacKenzie et al. 2002, Royle and Nichols 2003, MacKenzie et al. 2006). The approach has become widely accepted for reliable estimates of species occupancy (MacKenzie et al. 2006). 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 also allow for analysis of covariates potentially affecting occupancy (e.g., habitat class), and covariates affecting detectability (e.g., overcast sky).

Occupancy in this monitoring program is assessed at two levels: catchments (small watershed units containing multiple potential amphibian breeding sites) and sites (individual ponds or wetlands within the catchments). The catchment level approximates the "breeding population" identified by ARMI as the feasible target for monitoring amphibian population trends in national parks. Occupancy at this level was selected as the major vehicle for meeting the goal of determining if amphibians are declining, stable, or increasing in Grand Teton and Yellowstone national parks. Occupancy at the site level is a finer-scale measure that allows one to investigate the importance of site-specific and survey-specific variables affecting occupancy and detection probability. Site occupancy is more challenging to interpret than catchment occupancy since the number of suitable sites within each catchment varies annually and the total number of sites (unlike catchments) in the study area is unknown.

For occupancy rates at the catchment level, we combined the results of surveys in all wetland sites within the catchment boundaries. This is a coarse scale; occurrence of the species in a qualifying life stage (egg, tadpole, or recent metamorph) at one wetland site is sufficient to indicate that the catchment is occupied. The "observed rate" is the proportion of catchments in

which the species was observed; it assumes that non-detection is the same as absence. The “occupancy” rate entails an estimate of the rate at which non-detections of a species are due to failure to find it rather than true absence. Thus, estimated occupancy rates are higher than the observed (naïve) rates, in all cases where detection is less than 100%.

Site occupancy depicts the proportion of sites surveyed (suitable breeding sites) in which reproductive live stages (eggs, larvae, or recent metamorphs) of the species occurred. This is a finer-scale measure than catchment occupancy, and offers a larger sample size. A substantial reduction in wetland sites containing breeding occurrence within catchments could occur but this loss would not be noticed if only catchment-level occupancy was considered (Gould et al. 2012).

For this report, we conducted a provisional analysis of occupancy at the catchment and site levels for each species using the software program Presence (Hines 2006). To extract data from the amphibian database for the analysis, we used an interface tool provided by USGS-ARMI. In Presence, we used the basic single-season model, and we did not attempt to model covariates potentially affecting occupancy and detectability. Analysis of occupancy at the catchment and site levels in the GYE for the years 2006–2009 has been conducted and published, using extinction and colonization rates and covariates to estimate changes in occupancy (Gould et al. 2012). Assessment of changes in amphibian occupancy over time requires a more intensive analytical investigation than is presented in this annual report.

Potential Breeding Site Data Analysis

Central to understanding amphibian occupancy dynamics is the assessment of how wetlands change from year to year. Methods for combining occupancy and habitat data to determine how amphibian occupancy changes as a function of available wetlands are under development (McKenzie et al. 2006, Gould 2010). Currently, we simply track and report on the number and percentage of sites that are potentially suitable for amphibian breeding each year. The GRYN prepares annual reports on climate for the Greater Yellowstone Area following the Rocky Mountain Climate Protocol (RMCWG 2010). These reports provide general information about annual climate in Yellowstone and Grand Teton national parks.

Results

Catchments Sampled and Potentially Suitable Breeding Sites Surveyed

In 2010, we sampled a total of 40 catchments; 32 in Yellowstone National Park and 8 in Grand Teton National Park (Table 2). Thirty catchments were sampled in the high and medium quality habitat strata and 10 catchments in the low quality habitat stratum (Table 1 and Figure 1). Within these catchments, we visited 371 sites. Of these, 292 sites were potentially suitable and thus were surveyed for amphibian presence (Table 2). It took approximately 82 field days to accomplish the work (2 people working about 10 hours per day = 1 field day), not including training.

In 2011, we sampled 29 catchments; 23 in Yellowstone National Park and 6 in Grand Teton National Park (Table 2). All catchments except one were in the high and medium quality habitat strata (Table 1 and Figure 1). Two catchments that we planned to survey in 2011 were not surveyed due to grizzly bear presence and high water (in Grand Teton and Yellowstone basins). Within the 29 catchments, we visited 290 sites. Of these, 255 sites were potentially suitable and surveyed for amphibian presence (Table 2). It took approximately 70 field days to accomplish the work (2 people working about 10 hours per day = 1 field day), not including training.

We found active breeding sites (identified by the presence of eggs, larvae, or recent metamorphs) of all four species in both parks (Table 2) each year. No northern leopard frogs or American bullfrogs were found.

Note that effort levels and the set of targeted catchments varied over the years for the data depicted in Table 2, which affects the number of sites surveyed and breeding sites found.

Table 2. Results of amphibian monitoring in 2010–2011. Total numbers of catchments and sites surveyed per basin, and the number of catchments and sites containing active breeding for each amphibian species and for all species combined.

	Catchments Surveyed		Tiger Salamander		Boreal Toad		B. Chorus Frog		C. Spotted Frog		All Species Combined	
			Catchmts	Sites	Catchmts	Sites	Catchmts	Sites	Catchmts	Sites	Catchmts	Sites
2010												
Northern Range	8	33	3	4	2	2	5	16	3	6	5	17
Yellowstone	8	68	2	2	2	4	4	22	5	9	6	26
Madison-Gallatin	8	66	1	1	0	0	6	27	5	12	7	31
Snake-Henry's Fork	8	57	1	1	0	0	7	15	5	9	7	24
Grand Teton	8	68	2	2	2	2	4	16	4	7	7	22
TOTAL	40	292	9	10	6	8	26	96	22	43	32	120
2011												
Northern Range	6	36	4	7	2	2	6	18	4	6	6	21
Yellowstone	5	48	1	1	1	1	4	25	4	8	5	29
Madison-Gallatin	6	66	2	5	1	1	5	29	4	15	6	36
Snake-Henry's Fork	6	56	0	0	0	0	6	23	4	6	6	24
Grand Teton	6	49	3	7	0	0	4	19	3	13	5	26
TOTAL	29	255	10	20	4	4	25	114	19	48	28	136

Amphibian Occupancy and Detectability

Catchment Occupancy

Catchment-level estimated occupancy rates in 2010 ranged from 0.15 (15%) for boreal toads to 0.67 (67%) for boreal chorus frogs (Table 3). Detection rates were relatively low for tiger salamanders 0.50 (50%), because salamander larvae were seen by only one observer in five of the nine catchments where salamanders were detected. Detection rates were high for the other species ($\geq 90\%$) (Table 3).

Table 3. Catchment observation (naïve), occupancy (adjusted), and detection rates with standard errors from 2010. Estimates for all catchments surveyed, N = 40 catchments.

Species	Observed Rate	Occupancy Rate	Standard Error, Occupancy	Detection Rate	Standard Error, Detection
Tiger salamander	0.23	0.30	0.12	0.50	0.18
Boreal chorus frog	0.65	0.67	0.08	0.94	0.04
C. spotted frog	0.55	0.57	0.08	0.90	0.05
Boreal toad	0.15	0.15	0.06	0.91	0.09

In 2011, catchment occupancy rates ranged from 0.16 (16%) for boreal toads to 0.87 (87%) for boreal chorus frogs (Table 4). Detectability rates were low for boreal toads (67%), because boreal toad tadpoles were seen by only one observer at two of the four catchments in which toads were detected in 2011. Detection rates were high for the other species ($\geq 89\%$) (Table 4).

Table 4. Catchment observed (naïve), occupancy (adjusted), and detection rates with standard errors from 2011. Estimates for all catchments surveyed, N = 29 catchments

Species	Observed Rate	Occupancy Rate	Standard Error, Occupancy	Detection Rate	Standard Error, Detection
Tiger salamander	0.34	0.35	0.09	0.89	0.08
Boreal chorus frog	0.86	0.87	0.06	0.94	0.04
C. spotted frog	0.66	0.66	0.09	0.91	0.05
Boreal toad	0.14	0.16	0.08	0.67	0.22

The catchment occupancy estimates in Table 3 and 4 are not suitable for comparisons between years because the number and type of catchments sampled per year has been variable; however, sampling in the high and medium quality habitat strata within our stratified sample (wetland-rich catchments) has been fairly consistent. Figure 2 displays catchment occupancy rates in high and medium quality catchments surveyed since 2006 (Patla and Jean 2010). At this time there has been no attempt to rigorously analyze longer term trends for species occupancy at the catchment level using 2006-2011 data.

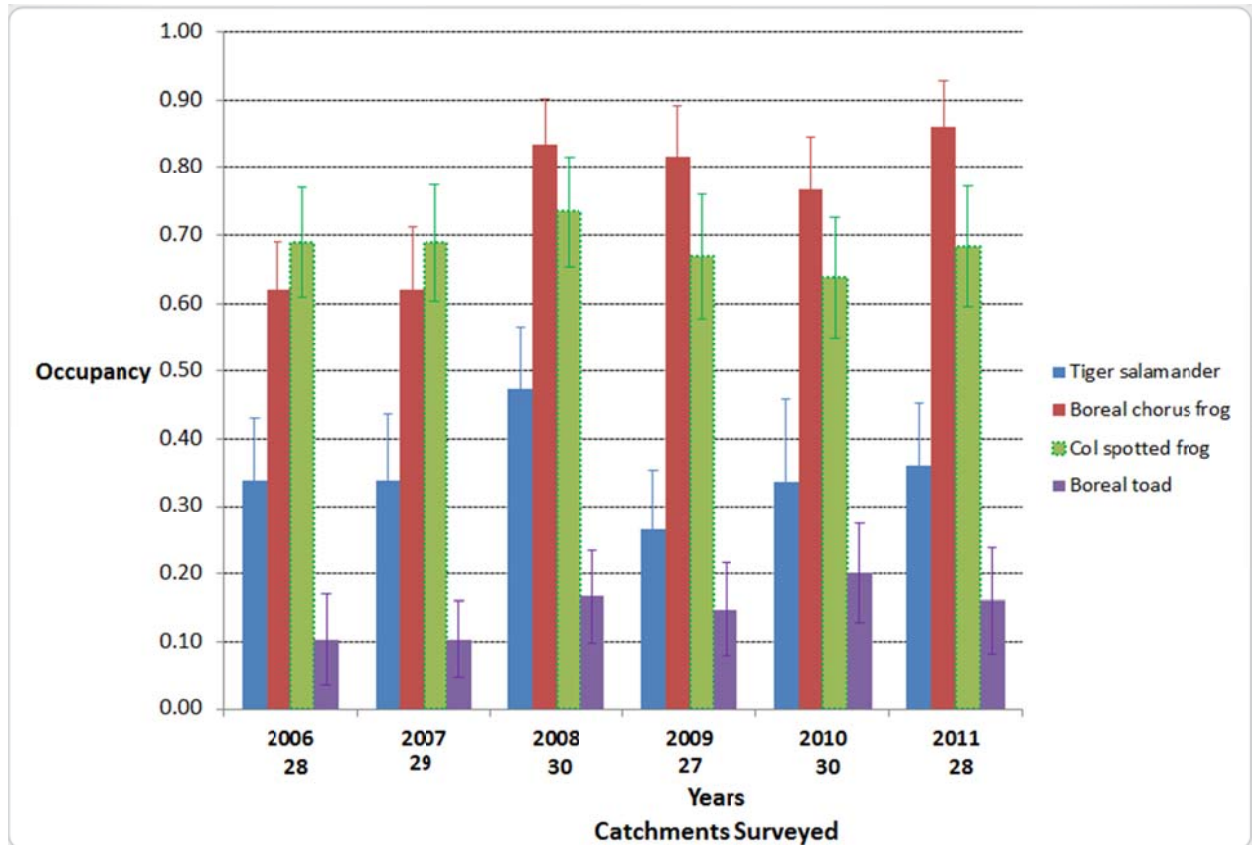


Figure 2. Occupancy rates estimated for high and medium quality habitat catchments by species, 2006–2011, with standard error. The number of catchments surveyed per year is shown beneath the year labels. This graph is not a trend analysis across years.

Site Occupancy

In 2010, one or more species of breeding amphibians (eggs, larvae, or recent metamorphs) were detected at 41% of the sites surveyed (120 active breeding sites within the set of 292 sites surveyed; Table 2). In 2011, there was a substantial increase in the proportion of sites where we detected breeding amphibians; 53% of the sites surveyed (136 of 255 sites) were observed to host one or more species.

Site occupancy in 2010 ranged from 0.03 (3%) for boreal toads, to 0.36 (36%) for chorus frogs (Table 5). Site detection rates for tiger salamanders were low (33%), and $\geq 72\%$ for the other three species. In 2011, site occupancy estimates ranged from 0.02 (2%) for boreal toads, to 0.45 (45%) for chorus frogs (Table 6). Site detection rates were lowest for boreal toads in 2010 (67%), and $\geq 75\%$ for the other three species. For all species except boreal toad, site occupancy and detection rates were higher in 2011 than in 2010, particularly for boreal chorus frogs.

Table 5. Site observation (naïve), occupancy (adjusted), and detection rates with standard errors for 2010.

Species	Observed Rate	Site Occupancy Rate	Standard Error, Occupancy	Site Detection Rate	Standard Error, Detection
Tiger salamander	0.03	0.06	0.02	0.33	0.07
Boreal chorus frog	0.33	0.36	0.03	0.72	0.04
C. spotted frog	0.15	0.15	0.02	0.79	0.05
Boreal toad	0.03	0.03	0.01	0.77	0.17

Table 6. Site observed (naïve), occupancy (adjusted), and detection rates with standard errors for 2011.

Species	Observed Rate	Site Occupancy Rate	Standard Error, Occupancy	Site Detection Rate	Standard Error, Detection
Tiger salamander	0.08	0.08	0.02	0.75	0.09
Boreal chorus frog	0.45	0.45	0.03	0.92	0.02
Col spotted frog	0.19	0.19	0.02	0.88	0.04
Boreal toad	0.02	0.02	0.01	0.67	0.22

Potential Breeding Sites

In 2010, we visited 371 sites and conducted surveys at 292 sites for amphibian breeding. In 2011, we visited 290 sites and conducted surveys at 255 sites (Tables 2 and 7). The reduced number of sites in 2011 is due to sampling a smaller number of catchments (see methods for more details).

Table 7. The number of sites with standing water that would likely support breeding and surveyed by year and not surveyed due to being dry or too shallow or for another other reason such as high water. The percentage of sites that were dry or too shallow is provided (calculated as the Number of sites that are dry or too shallow in any given year/(sites that are surveyed + sites dry or too shallow + sites not surveyed for other reasons)).

Year	Sites Surveyed	Not Surveyed (dry or too shallow)	Not Surveyed (other reasons)	Percent Sites Dry or Too Shallow
2006	262	73	11	21%
2007	221	157	6	41%
2008	356	29	8	7%
2009	307	22	6	7%
2010	292	48	12	14%
2011	255	11	3	4%

The percent of potentially suitable sites that were dry or too shallow varies per year (Table 7), and likely reflects the influence of antecedent weather patterns. In 2010, snow water equivalent

(SWE) for October 2009 through April 2010 was well below the long-term 30 year average (1971-2000), but spring precipitation May through June 2010 was above the long-term average (Jean et al. 2011). It is likely that this spring moisture helped maintain surface water at some seasonal wetland sites, and explain why the percent of dry and shallow wetlands in 2010 was lower than previous dry years, 2006 and 2007 (Table 7). In 2011, SWE was above average and spring precipitation was also high (Yellowstone Center for Resources 2011). This coincided with the lowest percentage of dry or shallow sites since 2006 when the monitoring protocol was implemented (4% in 2011, Table 7). Examples of sites that change their availability for amphibian breeding due to changes in hydrological conditions are shown in Figure 3.

Amphibian Disease Surveillance

In 2010 and 2011, we collaborated with the Yellowstone National Park Disease Surveillance Program (Sophie St-Hilaire at Idaho State University) and the Yellowstone Wildlife Health Program (YWHP, Program Coordinator John Treanor), by reporting observations of dead or abnormal amphibians and by providing location information for amphibian breeding sites and previous disease outbreaks to the disease researchers. In 2010, two outbreaks of an infectious disease causing mass mortality of tiger salamander larvae were documented, including one in a monitored catchment on the Northern Range in Yellowstone. Histological tests showed symptoms consistent with ranavirus infections, but tests for tiger salamander virus DNA using Polymerase Chain Reaction (PCR) techniques were negative (St-Hilaire 2011). Results from the other salamander larval die-off, at a pond near the Nez Perce picnic area, were inconclusive.

In 2011, we encountered numerous tiger salamander larvae at another catchment on the Northern Range, showing clinical signs of ranavirus infection (red flushing and hemorrhaging). Live specimens were collected by YWHP staff, euthanized and sent to the USGS National Wildlife Health Center (Madison, WI). Cultural assays were inconclusive for ranaviruses, suggesting another cause for the observed abnormalities (J. Treanor, pers comm, February 2, 2012). Revisits later in summer (three follow-up surveys by YWHP and one by our crew) revealed no amphibian mortalities. In addition, our field crews collected ten dead amphibians (tiger salamanders and Columbia spotted frogs) at various sites during surveys in 2011. These specimens were sent to the USGS National Wildlife Health Center; results are pending.

The YWHP conducted surveillance in 2010 and 2011 for the *Batrachochytrium dendrobatidis* (Bd) fungus, by collecting skin swabs from Columbia spotted frogs and boreal toads. Bd is the causative agent for chytridiomycosis disease, which has been identified as a global threat to amphibians. During the two years, 549 samples were collected from 22 amphibian survey sites. Bd was identified in amphibians at 68% of sampled sites (J. Treanor, pers comm, February 2, 2012), a finding similar to the reported average for Bd occurrence across the Rocky Mountains (Muths et al. 2008). Further disease monitoring and investigation are needed to determine the severity of the threat posed by Bd to amphibian populations in Yellowstone and Grand Teton national parks.



Site Y1980-17, Nez Perce drainage, July 18, 2010



July 2, 2011



Site Y3272-2, southern Yellowstone, July 22, 2010



July 21, 2011



Site Y4007-3, Northern Range Yellowstone, July 7, 2010



July 1, 2011

Figure 3. A photographic comparison of 3 seasonal wetland sites monitored in 2010 and 2011. Abundant precipitation in 2011 resulted in an increased number of sites available for amphibian breeding within the sampled catchments.

Discussion

Amphibian monitoring efforts differed between 2010 and 2011, due to the decision to focus resources on catchments classified as high and medium quality habitat starting in 2011. This modification to the sampling design limits our ability to compare occupancy results across sampling years but still provides an overview of the distribution of amphibians in high and medium quality catchments. Discerning trends in the amphibian monitoring data requires statistical modeling, such as that presented in the recently completed publication covering the years 2006-2009 (Gould et al. 2012). Despite the aforementioned limitations, there are several indicators that amphibian reproduction increased or remained stable between 2010 and 2011. This report provides a summary of this descriptive data along with preliminary analyses.

1. In high and medium habitat quality catchments, estimated occupancy increased at the catchment level for tiger salamanders, boreal chorus frogs, and Columbia spotted frogs between 2010 and 2011 (Figure 2). The increase was most notable for boreal chorus frogs; it was slight or insignificant for the other two species considering standard error.
2. Amphibian breeding (egg, larvae, or recent metamorphs) by one or more species was detected at a larger proportion of potentially suitable breeding sites in 2011 (53%) compared to 2010 (41%).
3. Site occupancy rates for boreal chorus frog increased sharply between 2010 (0.36) and 2011 (0.45). The other species showed only slight changes. (Small sample sizes for boreal toads limit the quality of information.)
4. Detection rates at the site level increased for all species except boreal toads between 2010 and 2011. We think this may be due to larger numbers of larvae in 2011 than in 2010 (unpublished data on larval numbers detected by field crews).
5. Meteorological data indicated that 2011 was significantly wetter than 2010. Wetter conditions benefit amphibian reproduction, particularly the boreal chorus frog, which frequently uses seasonal or temporary wetlands for breeding.

This monitoring effort continues to generate interest by the parks and other organizations and agencies. Yellowstone National Park referenced the amphibian monitoring in their 2011 Natural Resource Vital Signs report (Yellowstone Center for Resources 2011). Debra Patla presented a poster during the 10th Biennial scientific conference on the Greater Yellowstone Ecosystem, 2010, *Monitoring amphibians in the GYE: Baseline data for understanding effects of climate change* (Patla et al. 2010). Dr. Bill Gould gave two presentations on the multi-season occupancy estimation of amphibians in Yellowstone and Grand Teton national parks. These were at the 44th Arizona and New Mexico Wildlife Regional meeting (February 2011) and the National Wildlife Society Conference (November 2011). He also gave a seminar, *Applying occupancy modeling to natural resources of the Greater Yellowstone Ecosystem*, to the New Mexico State University, Department of Fisheries, Wildlife, and Conservation ecology.

Amphibian monitoring will continue in 2012 using approaches that are similar to those employed in 2011. In addition, the network will collaborate with the USGS ARMI program on a project to

determine the status and trend of amphibians on a transect on the Continental Divide, integrating an NPS Vital Sign with the USGS Amphibian Research and Monitoring Initiative across networks. This project will utilize amphibian monitoring data from the GYE, Rocky Mountain, and Glacier national parks, collected between 2000 and 2011, and will investigate the roles of climate and important habitat characteristics.

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