



## Using monitoring data to map amphibian breeding hotspots and describe wetland vulnerability in Yellowstone and Grand Teton National Parks

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**T**HE NUMBER OF SPECIES THAT OCCUR IN A location (hereafter species richness) is a basic measure of species or biological diversity (Hamilton 2005). This simple measure of diversity is often used to guide conservation strategies and make inferences about resource condition. Areas with many species (hotspots) are often prioritized for protection, while declines in species richness may indicate environmental change. Monitoring efforts in the National Park System that provide knowledge of patterns of species richness, particularly related to breeding or other vital activities, can therefore assist park administrators with identifying management

actions for sustaining or improving natural resource conditions (Fancy et al. 2009).

Here, we use multiyear monitoring data on amphibian breeding to examine amphibian richness patterns in Yellowstone (Wyoming, Montana, and Idaho) and Grand Teton National Parks (Wyoming) (hereafter “Yellowstone and Grand Teton”). Amphibians have been selected as a “vital sign” by several National Park Service (NPS) Inventory and Monitoring (I&M) networks, including the Greater Yellowstone I&M Network. Selection was based on the understanding that amphibians can be sensitive to environmental and land use change and provide an indicator of



**Figure 1.** The native amphibians of Yellowstone and Grand Teton National Parks comprise (A, facing page) Columbia spotted frog (*Rana luteiventris*), (B) western tiger salamander (*Ambystoma mavortium*), (C) boreal toad (*Anaxyrus boreas*), (D) boreal chorus frog (*Pseudacris maculata*), (E) northern leopard frog (*Lithobates pipiens*), and (F) Plains spadefoot (*Spea bombifrons*).\*

\*Plains spadefoot shown, but the taxonomic species of spadefoot in Yellowstone has not yet been determined.

### Abstract

Amphibians have been selected as a “vital sign” by several National Park Service (NPS) Inventory and Monitoring (I&M) networks. An eight-year amphibian monitoring data set provided opportunities to examine spatial and temporal patterns in amphibian breeding richness and wetland desiccation across Yellowstone and Grand Teton National Parks. Amphibian breeding richness was variable across both parks, and only 4 of 31 permanent monitoring catchments contained all four widely distributed species. Annual breeding richness was also variable through time and fluctuated by as much as 75% in some years and catchments. Wetland desiccation was also documented across the region, but alone did not explain variations in amphibian richness. High annual variability across the region emphasizes the need for multiple years of monitoring to accurately describe amphibian richness and wetland desiccation dynamics.

### Key words

amphibians, wetlands, Grand Teton, Yellowstone

wetland ecosystem and landscape condition (Guzy et al. 2012). A recent analysis documented that North American amphibian populations are declining at a rate of approximately 4% annually and that some of the greatest declines in amphibian occurrence were observed on lands administered by the National Park Service (Adams et al. 2013).

Only six native amphibian species, representing five different families, have been recorded in Yellowstone and Grand Teton: western tiger salamanders, boreal toads, boreal chorus frogs, northern leopard frogs, Columbia spotted frogs, and a spadefoot species (Koch and Peterson 1995; table 1 and fig. 1). This limited species richness is characteristic of montane regions of northern latitudes; consequently, the loss of one amphibian species represents a large proportion of the total species pool. The northern leopard frog has apparently vanished from Grand Teton, with only one confirmed sighting since the 1950s. Boreal toads used to be common in this region, but are now relatively rare. Spadefoots

**Table 1.** Native amphibians of Grand Teton and Yellowstone National Parks

Common Name	Family	Scientific Name
Western tiger salamander	Ambystomatidae	<i>Ambystoma mavortium</i>
Boreal toad	Bufonidae	<i>Anaxyrus boreas</i>
Boreal chorus frog	Hylidae	<i>Pseudacris maculata</i>
Northern leopard frog	Ranidae	<i>Lithobates pipiens</i>
Columbia spotted frog	Ranidae	<i>Rana luteiventris</i>
Spadefoot species	Scaphiopodidae	<i>Spea</i> sp.

have been documented just a few times in Yellowstone’s history (Koch and Peterson 1995), and the taxonomic species of spadefoot remains unclear. Species loss and declines are surprising given that the Greater Yellowstone Area (GYA) is renowned as the largest relatively intact temperate ecosystem in the conterminous 48 states.

While the reason for amphibian declines on protected lands varies, climate-related changes to available wetland breeding habitat have been identified as a potential driver of the decline (McMenamin et al. 2008). Higher air temperatures and decreased precipitation can lead to wetland desiccation, reducing the surface water required for amphibian breeding and larval development. In 2007, a hot and dry year, up to 40% of all monitored wetlands in Yellowstone and Grand Teton lacked surface water by mid-summer (Ray et al. in press). Climate-related declines in available wetland habitat could reduce amphibian distribution and abundance (Matthews et al. 2013) and affect amphibian richness in even the most protected places. Documenting the spatial and temporal patterns of amphibian breeding richness along with patterns of wetland desiccation in Yellowstone and Grand Teton is an important first step in determining amphibian vulnerability.

We used eight years of amphibian monitoring and wetland data from Yellowstone and Grand Teton to explore patterns of amphibian breeding richness and wetland desiccation dynamics. Our primary goals were to describe the spatial and temporal patterns

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## *Climate-related declines in available wetland habitat could reduce amphibian distribution and abundance and affect amphibian richness in even the most protected places.*

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of amphibian breeding richness across both parks. Moreover, we were interested in identifying monitored catchments that are vulnerable to wetland desiccation in relation to catchments with the highest amphibian richness. To that end, we asked the following three questions: Where are hotspots for amphibian breeding richness? Are hotspots constant through time? Do amphibian breeding hotspots exist in regions where a high proportion of wetlands are susceptible to drying?

### Methods

The Greater Yellowstone Network, in collaboration with the U.S. Geological Survey's Amphibian Research and Monitoring Initiative, has organized annual amphibian monitoring in a set of randomly selected catchments distributed across Yellowstone and Grand Teton since 2006 (Gould et al. 2012). Catchments (or watersheds) are defined by topography as it relates to the flow and collection of water sources and averaged approximately 200 hectares (494 acres) in size. On average, 30 catchments are revisited annually; we report results from 31 catchments that have more than five years of monitoring data. All wetlands within the selected catchment are visited in summer, when two independent observers search for evidence that amphibians bred there (i.e., eggs, larvae, or recently metamorphosed individuals). We also describe the presence of surface water observed during the surveys: wetland sites without surface water are described as "dry," while sites with an expanse of surface water greater than 1 m<sup>2</sup> (1.2 yd<sup>2</sup>) in size and exceeding 2 cm (approximately 1 in) in depth are described as "inundated." We used results from annual surveys completed from 2006 to 2013 to examine spatial and temporal variation in amphibian richness and to describe wetland status for monitored catchments. Because elevation is a potentially limiting factor of amphibian richness in montane landscapes (Sergio and Pedrini 2007), we also used correlation analysis (a technique to examine the association between two variables) to examine the relationship between average amphibian breeding richness and average wetland elevation in catchments.

To identify catchments that are amphibian breeding hotspots, we plotted the total number of breeding amphibian species that

were observed at least once from 2006 to 2013 (fig. 2). We did not correct for detection probabilities because detection for breeding amphibians at the catchment scale is high and constant over years (>75%; Gould et al. 2012). Nevertheless, improved methods for identifying rare species like boreal toads, spadefoots, and northern leopard frogs are needed. We are testing DNA-based monitoring tools, which are now being used widely to survey for rare or secretive amphibian species (see the sidebar on page 118 and Pilliod et al. 2013b for more information about environmental DNA).

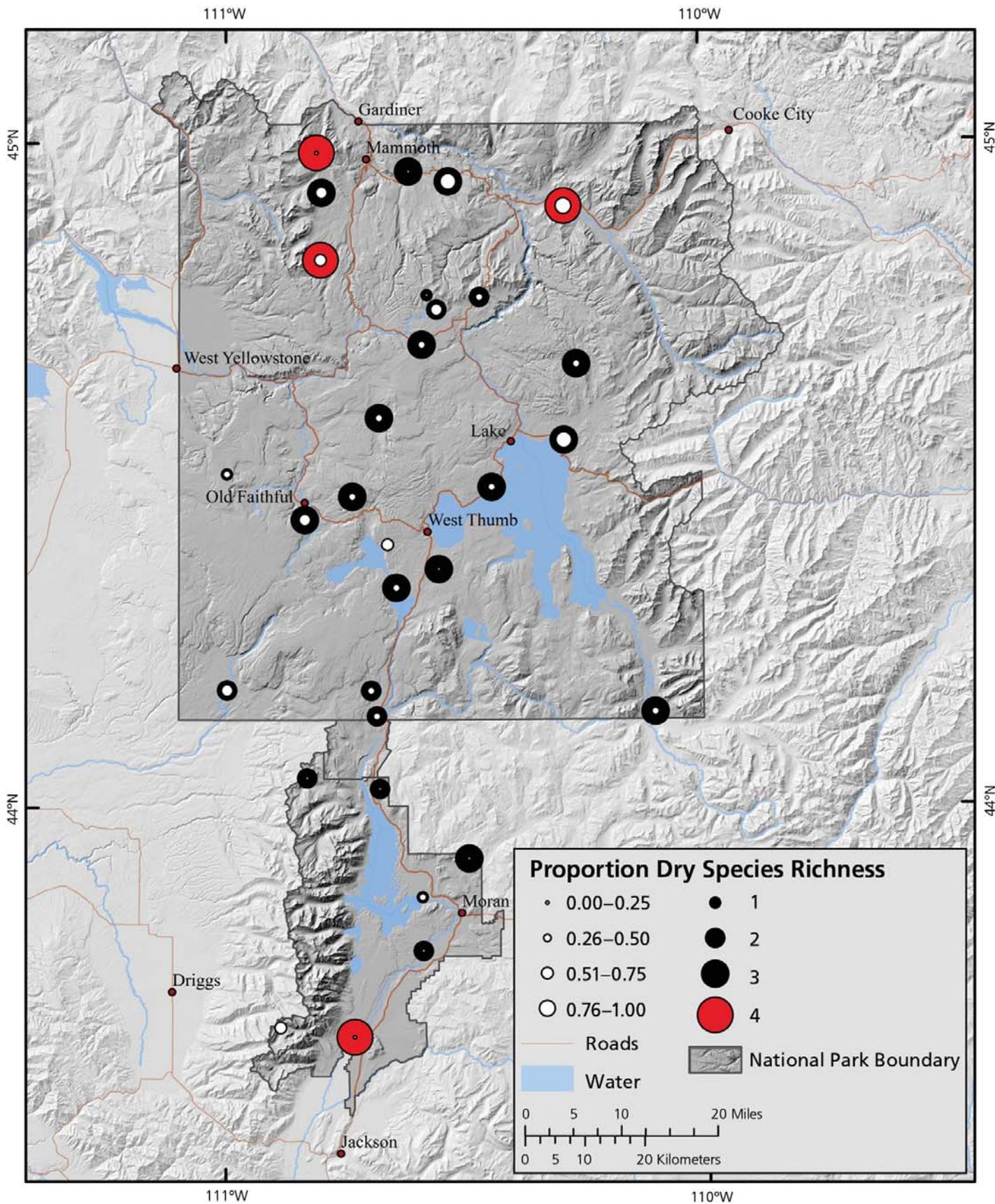
To examine whether amphibian breeding hotspots exist in regions where a high proportion of wetlands are susceptible to drying, we plotted the maximum number of breeding amphibian species observed in a catchment with the proportion of dry wetlands (fig. 2). We calculated the proportion of dry wetlands within a catchment by summing the number of wetlands reported as dry at least once from 2006 to 2013 and dividing by the total number of wetlands visited. Catchments with a high proportion of wetlands susceptible to drying indicate areas where amphibians are vulnerable to climate-related declines in available breeding habitat.

### Results

#### *Species summary*

The boreal chorus frog was the most common species encountered during this eight-year period and breeding was detected in an average of 23 (range 19–26) catchments annually. The Columbia spotted frog was also widely distributed and breeding was detected in 20 (18–22) catchments each year. The western tiger salamander and boreal toad were less widespread and breeding was

**Figure 2 (facing page).** The map shows the locations of catchments (i.e., watersheds) in Yellowstone and Grand Teton national parks that are used for long-term monitoring of amphibians. The maximum number of breeding amphibian species observed in a catchment (species richness) is shown by the outer circles, with the proportion of dry wetlands (proportion dry) indicated by the inner circles. The circles summarize results from surveys conducted from 2006 to 2013. Red circles indicate amphibian "hotspots," where four amphibian species have been documented as breeding in a catchment.



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detected in 10 (7–14) and 4 (3–6) catchments annually, respectively. No northern leopard frogs or spadefoots were observed.

#### ***Amphibian breeding hotspots***

Just less than half (15 of 31) of all catchments surveyed contained three breeding amphibian species for at least one year of monitoring (fig. 2). Surprisingly, all four widely distributed species were documented only in four catchments (fig. 2, shown in red). Three of these catchments were located in Yellowstone's Northern Range and one was in Grand Teton's Snake River Valley. Across all years, higher-elevation regions (>2,500 m or 8,200 ft) had the lowest amphibian richness. In general, we discerned a weak but significant inverse relationship ( $r = -0.373$ ,  $P = 0.030$ ) between elevation and average annual amphibian breeding richness.

#### ***Variations in amphibian breeding richness through time***

Amphibian hotspots (catchments with four species breeding in at least one year) in Yellowstone's Northern Range fluctuated from two to four breeding amphibian species during this eight-year period (fig. 3). A synchronous drop in breeding richness occurred in 2007 at these hotspots; however, the identity of species that did not breed varied by catchment. The 2007 drop was followed by a synchronous increase in 2008. After 2008, breeding species richness varied annually but lacked synchrony among these hotspots. The only hotspot in Grand Teton varied from two to four breeding amphibian species. In this catchment, breeding richness declined to two species in 2007, returned to three species in 2008, and increased to four species in 2012 when boreal toad breeding was detected for the first time (fig. 3).

#### ***Wetland desiccation***

The proportion of dry wetlands ranged from 0 to 1 in monitored catchments. The median proportion of dry wetlands within a catchment was 0.40, indicating 40% of available wetlands within that catchment were dry at least once in the 2006–2013 period. Catchments in the Northern Range contained few wetlands altogether ( $6.0 \pm 0.9$ ; mean  $\pm 1$  SD), and four of six Northern Range catchments had a high proportion of dry wetlands ( $\geq 0.57$ ;

fig. 2). In contrast, catchments in lower-elevation regions (<2,250 m or 7,380 ft) of Grand Teton generally contained more wetlands (five of six catchments contained  $\geq 14$  wetlands) and a much lower proportion of dry wetlands ( $\leq 0.36$ ). Catchment elevation and the proportion of dry wetlands were not correlated ( $r = -0.097$ ,  $P = 0.591$ ).

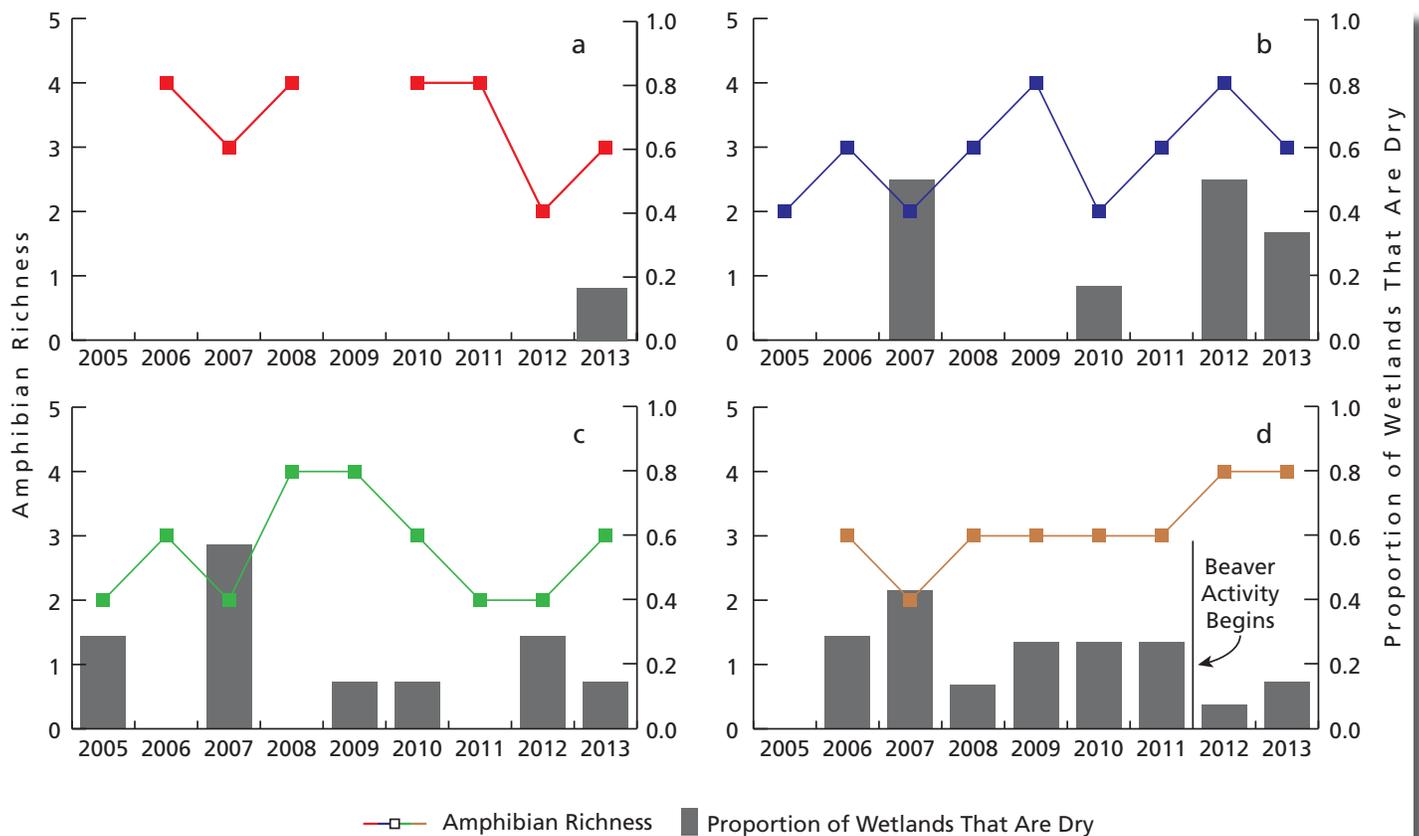
#### ***Amphibian breeding hotspots and wetland desiccation***

The proportion of dry wetlands in documented amphibian hotspots ranged from 0.17 to 0.83. The catchments that had the highest proportion of dry wetlands (0.57 and 0.83) also exhibited the most frequent fluctuations from two to four breeding species (fig. 3b and 3c).

## **Discussion**

We identified amphibian breeding hotspots in Yellowstone's Northern Range and in the Snake River Valley of Grand Teton. These areas supported breeding populations of boreal chorus frogs, Columbia spotted frogs, western tiger salamanders, and boreal toads. The latter two species had the patchiest distributions, suggesting that breeding hotspots may be tied to special habitat conditions or may be associated with particular biogeographic conditions (e.g., proximity to glacial refugia).

Our eight-year data set on amphibians underscores the importance of multiyear monitoring for making inferences about amphibian status. We found that annual breeding richness variability can be very high and fluctuated by as much as 75% in some years and catchments. Importantly, annual fluctuations in the number of species breeding were common among Northern Range catchments, a region where wetland desiccation has been well documented (McMenamin et al. 2008; Schook and Cooper 2014). Basing inferences on amphibian status on only 2007 data, for example, would provide an underestimate and a potentially incorrect interpretation of amphibian breeding richness. The high annual variability across the region emphasizes the need for mul-



**Figure 3.** The graphs show the annual variation in amphibian breeding richness (left vertical axis) for four amphibian hotspots (colored lines). Hotspots are long-term monitoring catchments that contained four breeding amphibian species in at least one year (see fig. 2). Also shown is the proportion of dry wetlands (right vertical axis) in each catchment summarized by year (gray bars). Catchments summarized in panels a, b, and c are located in Yellowstone's Northern Range. The catchment shown in panel d is located in the Snake River Valley of Grand Teton National Park. New beaver activity was documented in this catchment in 2012.

multiple years of sampling to accurately describe amphibian richness and, potentially, overall biodiversity.

Climate-driven wetland desiccation has been implicated in changes to amphibian richness in Yellowstone's Northern Range (McMenamin et al. 2008). In Wyoming, low-elevation wetlands have the greatest desiccation risk because they typically have higher air temperatures and lower precipitation than higher-elevation wetlands (Copeland et al. 2010). We found that wetland desiccation is proportionally high in the Northern Range and is widespread across Yellowstone and Grand Teton (Ray et al. in press), but that elevation alone did not explain differences in the proportion of those that were dry among catchments. This is likely because some wetlands may be connected hydrologically to permanent water sources (e.g., the Snake River) or are made resistant to desiccation by beaver activity, which can impound and store water even during dry years. Interestingly, beaver activity was documented in two catchments since 2012, and in both catchments boreal toad breeding occurred at the newly created or expanded wetlands.

## Conclusion

Our amphibian and wetland monitoring efforts indicate that amphibian breeding hotspots in the Yellowstone Northern Range are vulnerable because they occur in a region with few wetlands and high susceptibility to wetland drying. Breeding hotspots in Grand Teton are less vulnerable to wetland drying because they occur in the Snake River Valley, where there are more wetlands per catchment, where some wetlands have a hydrological connection to permanent waters, and where beavers have been active recently. In the Northern Range and other areas that are susceptible to wetland drying, monitoring and vulnerability modeling can be helpful strategies to increase awareness of the potential for climate effects on amphibians and wetlands. In addition, adaptation strategies, including the removal of other stressors in permanent wetlands (e.g., nonnative fish; Ryan et al. 2014), can help increase amphibian resiliency. Another management option that may increase wetland resiliency is protection of beaver

# Environmental DNA: Can it improve our understanding of biodiversity on NPS lands?

By Andrew Ray, Adam Sepulveda, Blake Hossack, Debra Patla, and Kristin Legg

Traditional biodiversity monitoring approaches require large investments in field time, are based largely on visual observations, and require significant taxonomic expertise. New survey techniques using DNA collected from aquatic habitats may provide a cost-effective, repeatable approach to sampling a large number of sites for many taxonomic groups (Thomsen et al. 2012b; Bohmann et al. in press).

Environmental DNA (eDNA) monitoring enables the detection of organisms from DNA present and collected in water samples (Darling and Blum 2007; Darling and Mahon 2011). Detection of organisms can be confirmed because aquatic and semiaquatic organisms release DNA contained in sloughed, damaged, or partially decomposed tissue, gametes, and waste products into the water. In fact, recent evidence suggests that DNA survey techniques may be considerably more sensitive than traditional surveys for rare species (Jerde et al. 2011; Dejean et al. 2012; Pilliod et al. 2013a) and offer the ability to identify multiple species simultaneously (Minamoto et al. 2012; Thomsen et al. 2012b; Thomsen et al. 2012a) from individual water samples.

For these reasons, the Greater Yellowstone Inventory and Monitoring Network is partnering with university and agency scientists to begin testing whether eDNA monitoring can be integrated with ongoing amphibian monitoring in Grand Teton and Yellowstone National Parks. Our monitoring program is uniquely suited to evaluate the use of eDNA for amphibian richness monitoring across Grand Teton and Yellowstone for multiple reasons. First, visual encounter surveys are completed each year at approximately 250 long-term monitoring wetlands and will provide a means of testing the efficacy (i.e., determine if it is accurate and repeatable) of eDNA monitoring and potentially develop protocols for its incorporation into long-term monitoring. Additionally, these parks had two native species (e.g., spadefoot and northern leopard frog) that have not been detected in eight years of surveying. The ability to detect species at low densities with eDNA monitoring therefore offers greater potential for detecting these secretive, rare, or now-defunct species. Finally, our work and that of others suggest that some of the most biologically rich wetlands in the region occur at lower elevations; these same wetlands may be at risk for changes in climate. Cataloguing the amphibian, mammalian, avian, and invertebrate assemblages or their use of these wet-

lands using eDNA techniques may help to more fully characterize the biodiversity of these threatened habitats (see Bohmann et al. in press).

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*In Wyoming, low-elevation wetlands have the greatest desiccation risk because they typically have higher air temperatures and lower precipitation than higher-elevation wetlands.*

dams and, where possible, beaver establishment (see McKinstry and Anderson 1999 for attitudes regarding beaver management). Increasing resiliency and growing awareness are just two of the primary tenets of adaptation planning (see Heller and Zavaleta 2009) that can help to conserve some of the most biologically rich yet climate change–vulnerable resources.

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