ASSESSMENT OF A PHASE II MITIGATION SITE: SYNTHESIS OF MULTI-SPECIES PRESENCE DATA AND LONG-TERM AMPHIBIAN DATA

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C. Problem Statement

Evaluating of the success of mitigation projects is typically limited to a description of the topography and physical wetland characteristics of the site. Quantitative data on the use of the mitigation site by aquatic and terrestrial wildlife is frequently lacking but can contribute valuable information for assessing mitigation efforts and for planning for future projects.

Activities designed to mitigate the impacts on U.S. waters from road construction and other activities associated with such large-scale projects are required by federal and state laws (e.g., U.S. Corps of Engineers, compensatory regulations section 404B-1guidelines). Early wetland mitigation efforts were often unsuccessful, but stricter requirements and increased knowledge about wetland function have increased the success of such projects. The aggregate pit associated with the re-construction of the road between Moran Junction and Dubois (Wyoming highway 26/287) is located at the U.S. Forest Service Blackrock Ranger Station work compound (Blackrock) on the south side of the Buffalo Fork River in Teton County, WY. The mitigation site excavated near the aggregate pit was designed to provide woody riparian scrub-shrub wetland habitat as mitigation for area lost in the same watershed due to road construction. The wetland mitigation site was constructed in 2007 and vegetated in 2008. Phase II was completed in summer 2014. Quantitative information on the use of these mitigation sites by wildlife is lacking. Preliminary data (Muths et al. unpublished data) indicate that there were multiple amphibian species breeding in Phase I and that birds and bats were in the area, but there are no data on other taxa. Quantifying the use of these sites by wildlife is an important consideration in determining the success of mitigation sites.

Four species of amphibians native to Wyoming, including the boreal toad, reside on the Blackrock compound. Our research indicates that the toad population at Blackrock is declining at 5-6% per year and that disease due to the amphibian chytrid fungus is contributing to this decline (Muths et al. 2008, Pilliod et al. 2010, Murphy et al. 2009, 2011). This fungal disease is not particular to Wyoming but is having devastating effects on amphibian populations worldwide (Lips et al. 2006, Skerratt et al. 2007, Muths et al. 2003).

As of 2013, 3 of 4 native amphibian species established breeding populations (evidenced by breeding behavior, eggs or tadpoles) at the Phase I wetland mitigation site at Blackrock. The 4th native species, the Columbia spotted frog, bred at the mitigation site for the first time in 2013. These observations suggest that the Phase I wetland mitigation site provides at least adequate, if not preferred, habitat for these species. In addition, the Phase I wetland mitigation site possesses characteristics that are typically “good” for amphibians: adequate shallows to support breeding, aquatic vegetation to provide refuge from predators, and water through the summer to allow metamorphosis. We suspect that food resources (aquatic invertebrates) and hibernation sites are adequate and conducive to the presence of amphibians, and have collected the preliminary data to assess these factors. With the completion of Phase II, characteristics (e.g., connectivity, amount of shallows, margin characteristics) have changed, with a likely effect on amphibian breeding effort. For example, we observed toads at the margins of the Phase II water body.

The primary breeding site for these amphibians was an oxbow of the Buffalo Fork River adjacent to Blackrock. In the spring of 2011, the levee separating the oxbow from the river was breached by late and heavy spring run-off, most likely destroying amphibian reproductive efforts that year. We observed greatly reduced breeding activity in the oxbow in subsequent years (2012-2013), suggesting that breeding habitat provided by the mitigation site may now be even more important to the amphibian populations at Blackrock.

The mitigation site and the surrounding wetland landscape provide an excellent natural laboratory to quantify mitigation efforts at Blackrock. Although long-term efforts are necessary to quantify the ultimate success of the wetland mitigation site, our research over the last 12 years puts us in the unique position of being able to provide quantitative data about the mitigation site in a relatively short time. This proposal builds on that capability. Our proposed work takes advantage of an extraordinary opportunity to compare a newly minted mitigation site (Blackrock Phase II), an established mitigation site ("Snow Oval", eastern side of Togwotee Pass, Shoshone District of the Bridger Teton National Forest), and the reference wetlands at Blackrock and Togwotee Pass. By examining differences in the presence and use (i.e. breeding) of these sites by a variety of taxa, we can draw conclusions about the efficacy of the Blackrock wetland mitigation site, now at Phase II, within the context of the surrounding landscape.

D. Background

Wetlands are one of the world's most endangered environments (Mitch and Goselink, 2007). Approximately 53% of wetlands in the lower 48 United States were lost between 1780 and 1980 (USGS, http://www.npwrc.usgs.gov/resource/wetlands/wetloss/summary.htm), and over 50% of wetlands have been lost in the developed world following European expansion. Recent meta-analyses indicate that created habitats do not fully replace natural wetlands (Ray Benayas 2009, Moreno-Mateos et al. 2012). For example, restored wetlands are 25% less productive than natural wetlands. Communities in small, depressional wetlands in cold temperate forests are especially slow to recover to reference conditions, and restored habitats may provide foraging areas, but not breeding habitat that it is designed to replace (Moreno-Mateos et al. 2012, Queheillalt and Morrison 2006). Furthermore, there is concern that design elements of constructed wetlands may increase disease transmission in amphibians, which could reduce the long-term viability of these habitats (Harp and Petranka 2006, Greer and Collins 2008) by altering food webs (i.e., decline or extirpation of amphibians will cascade up via decreased food supply for birds and snakes and cascade down via decreased predation pressure on invertebrates). If constructed wetlands do not function similarly to those that are lost, the net result is altered ecosystem structure and biological communities. While our primary focus remains the 4-species of native amphibians, by integrating data on invertebrates and the more visible species (birds, bats, and large mammals) we can provide a broader view of the biological communities present in Phase II mitigation site at Blackrock.

Even though mitigation sites typically do not fully compensate for the function and productivity of the wetlands they replace, there is evidence that many (but not all) local amphibians can persist in these sites (Shulse et al. 2010, Petranka et al. 2007, Lesbarreres et al. 2010). Most mitigation sites are constructed to hold water year-round; however, it is becoming more common for mitigation plans to require construction of temporary or semi-permanent wetlands, which poses new challenges to wetland design. Mitigation wetlands with temporary or semi-permanent hydroperiods are also recommended to prevent establishment by fishes, which can strongly alter community structure (Shulse et al. 2013).

The effects of global climate change—including changes in the form, timing, and amount of precipitation (IPCC 2012)—are likely to increase challenges of designing temporary wetlands. Changes in precipitation will likely be compounded by increased summer temperatures that can reduce water availability and stress animals, creating synergies that magnify negative effects

(IPCC 2012, Laurence and Williamson 2001, Wenger et al. 2011). These changes pose especially serious threats to aquatic biodiversity in arid regions like western North America. Drought is shortening wetland hydroperiods, resulting in greater local extinction rates for amphibians (Corn and Fogleman 1984, Hossack et al. 2013, McMenamin et al. 2008). Based on recognition that wetlands are being lost globally, and that climate change is a severe threat to these sensitive habitats, there is a growing need to determine how to engineer replacement habitats to provide appropriate conditions for local species while also providing resistance to drought (Shoo et al. 2011). Unfortunately, quantitative data on differences in vital rates of animals between constructed and natural wetlands, and the mechanisms behind the differences, are lacking. This information is critical if we are to design and construct mitigation wetlands that host communities similar to, and function as, natural wetlands.

E. Study Objectives

Our overall objective is to quantify the success of the mitigation project at Blackrock (now in Phase II). We will also include the Snow Oval mitigation site and mitigation wetlands along Togwotee Pass. Results will provide information for future mitigation efforts in this and similar types of habitat and provide evidence of successful wetland mitigation efforts.

OBJECTIVE 1:

To provide quantitative information on the status of two populations of amphibians (chorus frogs and boreal toads), including estimates of demographic parameters (survival, recruitment and population size) and disease status. The data collection proposed here is a critical addition to our existing data set and will increase the precision of the estimates of demographic parameters. This will occur at 6 focal ponds at Blackrock (3 mitigation, 3 reference).

Approach:

1. We will collect 2 years of demographic data on the amphibian communities using capture-recapture methods at focal ponds in the mitigation sites (Phase I and II), Swan Pond (the older mitigation site) and at 3 naturally occurring wetland areas (n = 6 ponds). Capture-recapture methodology involves capturing animals, giving them a unique mark (the mark depends on the species, all methods used have been approved by the appropriate animal care committees at USGS) and then using program MARK (White and Burnham 1999) to assess the data. We have extensive experience with these statistical methods and program MARK (e.g., Muths et al. 2010, Muths et al. 2011, Muths and Scherer 2011).
2. Disease: The amphibian chytrid fungus (*Batrachochytrium dendrobatidis*, Bd) is a concern, especially for boreal toads. We will sample for Bd in approximately 20 individuals per species, per year. To sample for Bd, the animal's skin is rubbed with a cotton swab that is then preserved in ethanol and sent to a laboratory for molecular analysis (J. Kerby, University of South Dakota). Limited disease testing is currently funded, but additional testing will allow us to explore host-pathogen relationships among the fungus, a susceptible species (boreal toad), and a species that is a putative carrier of the disease, but not significantly affected by it (chorus frog). These data will allow us to determine if constructed wetlands increase disease transmission.

Application:
Results will provide justification for WYDOT and similar agencies to construct wetlands with semi-permanent hydroperiods and a combination of woody riparian scrub-shrub and open water elements, (i.e., Phase I with 1.0 m to 1.5 m maximum depth), rather than focusing exclusively on ephemeral or permanent sites or wetlands that have a uniform plant community, as is currently common in wetland mitigation.

OBJECTIVE 2:

To collect information on a broad array of taxa present at mitigation and reference sites. These data will provide insights into what animals are using the site, and in some cases, the phenology and intensity of use. These data will be collected at 6 wetlands at Blackrock , the "SnowOval" mitigation site, and 9 wetlands on Togwotee Pass. The Togwotee Pass wetlands include 3 wetlands impacted by road construction (e.g., road expansion reduced size of the wetland), 3 created or mitigation wetlands, and 3 wetlands that were not impacted by road construction.

Approach:

1. Visual encounter surveys (Heyer et al. 1994) will be used to determine the presence of amphibians at the sites. Egg mass counts will be used to provide an index to breeding population size of Columbia spotted frogs (1 egg mass = 1 female; Hossack et al. 2013).
2. Disease sampling (as above), ≤ 20 samples collected per species per site.
3. Bird, bat and amphibian call surveys will be assessed using automated recording units (ARU, a technology we have used, e.g., Corn et al. 2011b) placed at 9 wetlands. These data will provide an idea of the intensity of use, the species that are using the areas, and the phenology (timing of when they are present). For example, the ARUs record amphibian breeding choruses (chorus frogs, spotted frogs), indicating when amphibians are breeding, and bird and bat calls that provide information on the species using the site, the timing of use and the intensity of use. These data will help us characterize differences and similarities between mitigation and reference sites.
4. Invertebrates will be sampled during the summer at 16 wetlands. We will use sweep nets to collect invertebrates, preserve them in ethanol and then identify them to family and some to species (sensu Hossack et al. 2010). We will describe the community structure of wetland invertebrates, which can be a key indicator of wetland health (e.g., Wray and Bayley 2006, Sharma and Rawat 2008).
5. Mammal surveys: We will use track surveys and infra-red cameras (Espartosa et al. 2011, Lyra-Jorge et al. 2008, Jennelle et al. 2002) at the sites to determine the presence and activity of medium to large mammals.

Application:
Although an assessment of the presence or density of organisms alone does not prove that the habitat is of adequate quality to support continued use by the observed organisms (Robinson et al. 1995), it is a first step in determining which taxa to focus on for more quantitative research and provides first lines of evidence that mitigation sites are functioning in a similar way to natural sites.

F. Study Benefits

Wetland mitigation efforts are applied to a landscape with the aim of being permanent or at least persisting for a reasonable number of years. The Blackrock project proposed here is invaluable because it already has a jump start on data collection and can provide a defensible quantitative evaluation of amphibian, invertebrate, bird, and bat use of the wetland mitigation site and a well-planned evaluation of large mammal presence.

Mitigation is a required activity. Evidence of the use of a variety of animals at various stages during the project indicates successful mitigation. Results can be used by WYDOT and other agencies to identify wetland designs that simultaneously meet Army Corps of Engineers mitigation requirements and provide the best option for promoting community recovery. Additionally, such information can be used to streamline design decisions for future wetland mitigation projects. Specifically, The Army Corps of Engineers has special conditions requiring shrub wetland creation, a habitat type which is often difficult to establish (B. Bonds, pers. comm.). An important aspect of this project is that it is likely to provide evidence that mitigation wetlands with a combination of woody shrubs and open water increase community richness, compared to wetlands with few shrubs or those that are dominated by shrubs. **Mitigation with this type of wetland as an endpoint rather than the typical endpoint of a shrub monoculture would make the construction of mitigation sites simpler and less expensive. Furthermore, required monitoring could be concluded sooner, saving considerable costs.**

While our efforts focus primarily on amphibians, we assess the presence of a variety of animals that are likely to benefit from "amphibian friendly" habitats, specifically birds, bats, and large mammals. We expect information from this study will have broad applicability to wetland mitigation nationwide. The Blackrock project is an excellent opportunity for collaboration among the Wyoming Department of Transportation, the U.S. Forest Service, and the U.S. Geological Survey. The data gathered will be used not only to inform and support mitigation efforts, but also to inform management decisions about amphibians on the Bridger-Teton National Forest and specifically at Blackrock. This project provides excellent opportunities for public outreach and education.

G. Applicable Question

1. N/A
2. N/A
3. Implementation would begin in the spring of 2015, exact timing contingent on amphibian emergence from hibernation
4. Yes, Wyoming Game and Fish permits are in place (33-350_2014) and will be renewed for 2015 – 2017.
5. Major unknown factors are the timing of snowmelt which determines access to sites and breeding phenology of amphibians.
6. Yes, we make contingency plans each season but they result in low or no cost changes.
7. There are no reasons to segment this study.
8. N/A
9. N/A

H. Statement of Work

Work Plan and Scope:

Initial logistical problems have been solved such that the implementation of this project will be efficient. We plan to be on-site during spring 2015, with field work and analyses following the schedule below. With the inclusion of the Blackrock mitigation site, the Snow Oval, and several mitigation wetlands on Togwotee Pass, we anticipate that the applicability of the results will be broad, extending to mitigation efforts in similar habitats. Furthermore, we plan to recruit a Master's of Science student to summarize and analyze the data collected 2012-2014, providing a solid link between the data collection from the original and the newly proposed aspects of the project. We have already secured part-time Teaching Assistant salary for a graduate student at the University of Montana, which will produce significant cost savings to the project.

Work Schedule:

May 2015–May 2017
--Second phase of data collection as described above for amphibians, invertebrates, birds, bats, and large mammals and initiation of additional work (surveys, camera traps, Snow Oval site).
--Principal Investigators and graduate student will collect data as describe above at all sites.
--Data quality assurance, analysis, writing.

Cost Estimate:
2 years: $69,241.20. Please see budget (below).

I. Change Order Information and Agreements
N/A

J. Implementation Process

The information that we provide from this research may have substantial impact as WYDOT defines alternative actions or alternative endpoints that could be implemented during subsequent mitigation efforts, potentially saving time and costs. Our work underscores the importance of understanding the role of amphibians in this type of wetland and their habitat-specific needs. We expand this species-specific context to include other taxa thereby presenting a more inclusive picture of how the mitigation site is functioning in terms of wildlife. **This information will provide another tool for the mitigation toolbox, perhaps expanding alternatives in the implementation of other wetland mitigation activities**. For example, this project will determine the suitability of the wetland mitigation site for amphibians as it currently presents itself ("a lower functioning wetland"). Typically "higher functioning wetlands" include mature willows of a particular density and size, but such characteristics may not be appropriate for amphibians and may not be critical for other species (e.g., invertebrate communities). A "lower functioning wetland" that reduces cost and effort to WYDOT, but that is providing preferred habitat to species of concern (i.e., amphibians), may be a preferable goal for mitigation. Amphibians are generally present at wetland sites; they eat a variety of invertebrates and may be prey items for birds, snakes, some invertebrates and occasionally mammals. Thus, they are important components of wetland sites and contribute to a healthy wetland ecosystem.

K. Technology Transfer

We will provide updates to WYDOT through presentations at the Wyoming Department of Transportation and Wyoming Contractor's Association Training Conferences, or other venues such as meetings with the Forest Service. We will summarize major findings in a full-color, easily understood fact sheet that can be available for public outreach and communication. We will also present results at 3 or more professional meetings and will publish at least 2 peer-reviewed papers over the course of the project. In addition to WYDOT, other agencies will likely find our results useful, including the US Forest Service, the National Park Service, and various state agencies involved with amphibian conservation such as the Wyoming Game and Fish Department and the Colorado Boreal Toad Recovery Team. We have presented our work on this project at the Forest Service in Jackson, Wyoming, to the Wyoming Department of Transportation and Wyoming Contractor's Association Training Conference in 2012, and as an update to the RAC in January 2014. Earlier data from Blackrock has been incorporated in multiple publications and presentations locally and internationally (see attached investigator CVs). Data from the Blackrock site are currently under analysis for manuscripts in preparation.

L. Special Requirements

1. Staffing
    a. Technicians will be competitively hired.
    b. Graduate student (University of Montana) with 2 years of experience at Blackrock has been competitively selected.
    c. Please see the CVs of each of the collaborating scientists.
    d. Maggie Schilling, The Northern Rockies Conservation Cooperative (NRCC), will administrate the funding, hiring, and purchasing with direction from the collaborating scientists.
2. Equipment
    a. Equipment is either available or listed in the budget below (e.g., cameras for camera traps).
3. Deliverables: quarterly progress reports to WYDOT, draft and final reports and executive summary, copies of any published manuscripts.
4. Responsibilities of parties: Muths, Hossack, Pilliod (scientists) – maintain data, advise and guide student and technicians, oversee project, initiate and complete manuscript preparation; Schilling – administrate funding, hiring and purchasing; Swartz (graduate student) and technician (TBA) – collect data under direction of PIs, enter data into appropriate spreadsheets, maintain adequate field records, communicate with PIs, NRCC, Forest Service and WYDOT on project updates and issues, assist in report writing and manuscript preparation.

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PROJECT TITLE: MULTI-SPECIES ASSESSMENT OF A PHASE II MITIGATION SITE: SYNTHESIS OF MULTI-SPECIES PRESENCE DATA AND LONG-TERM AMPHIBIAN DATA

AGENCY: U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Ave. Bldg. C, Fort Collins, CO 80526, in collaboration with USGS Northern Rockies Science Center, Missoula, MT and USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station, Boise, ID

P.I.: Erin Muths (USGS), Blake Hossack (USGS), David Pilliod (USGS)

BUDGET PERIOD: 1 May 2015 – 30 December 2017

Research Agency: Northern Rockies Conservation Cooperative, Maggie Schilling, 185 Center St., P.O. Box 2705, Jackson, WY 83001, 307-733-6856, FAX: 307-733-6574, nrcc@nrccooperative.org

CONTRACT PERIOD: BUDGET: 2015-2017

Funds Requested

DIRECT COSTS:	Details	2015	3% potential cost increase for inflation	2016
A. Field Personnel				
graduate student summer salary	16 weeks, $15/hr	$9,600.00	$288.00	$9,888.00
technician	16 weeks, $13/hr	$8,320.00	$249.60	$8,569.60
B. Equipment and Analysis				
invertebrate analysis and identification	Montana EcoServices Co.	$5,000.00	$150.00	$5,150.00
contract for bat analysis	USGS contractor, Fort Collins	$2,000.00	$60.00	$2,060.00
wildlife cameras	6 Reconyx HyperFire HC500	$2,700.00		
waders, tagging supplies, batteries, other equipment		$1,000.00		$500.00
disease sampling	200 samples x 15.00	$3,000.00	$90.00	$3,090.00
C. Technology Transfer and Travel				
travel to site: Muths, Hossack, Pilliod		$2,000.00	$60.00	$2,060.00
accommodation for technicians, USFS	$195/month/person	$1,560.00	$46.80	$1,606.80
personal vehicle used for field work	1000 miles at $0.56 per mile	$560.00	$16.80	$576.80
Subtotal		$35,740.00		$33,501.20
D. Indirect Costs	NRCC, 10%	$3,574.00		$3,350.12
ANNUAL TOTALS		**$35,740.00**		**$33,501.20**
E. Matching funds				
Muths and Hossack (2 PP/yr), Pilliod (1 PP/yr)		$26,000.00		$26,780.00
GRAND TOTAL = total cost to WYDOT		**$69,241.20**		

Table 1: Data collected thus far at each of the Blackrock and Togwotee Pass sites.

Wetland Site	Frog & Bat Recorders	Egg Mass Counts[a]	Invertebrate Samples	Visual Encounter Survey (all amphibians)	Capture-recapture			
					AMMA[b]	BUBO	PSMA	RALU
BR[c]-Oxbow	2010–2014	2011–2014	2012–2014	2012–2014	2012–2013	2003–2014	—	2012–2014
BR-Mitigation	2011–2014	2012–2014	2012–2014	2012–2014	2012–2013	2010–2014	2010–2014	2012–2014
BR-Swan	2013-2014	2012–2014	2012–2014	2012–2014	2012–2013	2005–2014	—	2012–2014
BR-Midway	—	2013-2014	2012–2014	2012–2014	2012–2013	2012–2014	—	2012–2014
BR-Heron	2013-2014	2013-2014	2012–2014	2012–2014	2013	2012–2014	—	2012–2014
BR-Marsh	—	2013-2014	2012	2012–2014	2013	2012–2014	—	2012–2014
BR-Chick	—	2013-2014	2012	2012–2014	—	—	—	—
BR-NorthDike	—	2013-2014	2012–2014	2012–2014	—	—	—	—
BR-SouthDike	—	2013-2014	2012	2012–2014	—	—	—	—
BR-Raptor	—	2013-2014	2012	2012–2014	—	—	—	—
BR-Roundworm	—	2013-2014	2012–2014	2012–2014	—	—	—	—
Tog[d]_12AC	—	2014	—	2012–2014	—	—	—	—
Tog_12BI	—	2014	—	2012–2014	—	—	—	—
Tog_12CI	—	2014	2012	2012–2014	—	—	—	—
Tog_12DC	—	2014	—	2012–2014	—	—	—	—
Tog_13AC	—	2014	2013-2014	2012–2014	—	—	—	—
Tog_13BC	—	2014	—	2012–2014	—	—	—	—
Tog_13EC	—	2014	—	2012–2014	—	—	—	—
Tog_14BC	—	2014	—	2012–2014	—	—	—	—
Tog_14CI	—	2014	—	2012–2014	—	—	—	—
Tog_15AI	—	2014	2012–2013	2012–2014	—	—	—	—
Tog_16AC	—	2014	—	2012–2014	—	—	—	—
Tog_16BC	—	2014	2013-2014	2012–2014	—	—	—	—
Tog_16CR	—	2014	2012-2014	2012–2014	—	—	—	—
Tog_17AI	—	2014	—	2012–2014	—	—	—	—
Tog_17BI	—	2014	2013-2014	2012–2014	—	—	—	—
Tog_17CC	—	2014	—	2012–2014	—	—	—	—
Tog_17DR	—	2014	—	2012–2014	—	—	—	—
Tog_17ER	—	2014	2013-2014	2012–2014	—	—	—	—
Tog_19AC	—	2014	—	2012–2014	—	—	—	—
Tog_19BI	—	2014	—	2012–2014	—	—	—	—
Tog_21AR	—	2014	—	2012–2014	—	—	—	—
Tog_21BR	—	2014	—	2012–2014	—	—	—	—
Tog_21CR	—	2014	—	2012–2014	—	—	—	—
Tog_24CC	—	2014	—	2012–2014	—	—	—	—
Tog_25AC	—	2014	—	2012–2014	—	—	—	—
Tog_25BI	—	2014	2012–2014	2012–2014	—	—	—	—
Tog_25CR	—	2014	2012–2014	2012–2014	—	—	—	—
Tog_26AI	—	2014	—	2012–2014	—	—	—	—
Tog_26BC	—	2014	2013-2014	2012–2014	—	—	—	—

[a]For Columbia spotted frogs only.
[b]Trapping for salamanders has been unsuccessful and was terminated in 2014.
[c]BR indicates wetlands near the Blackrock Ranger Staion.
[d]Tog indicates wetlands along Togwotee Pass. The last letter in the site name indicates whether it is an impacted wetland (I), created wetland (C), or reference/unimpacted wetland (R).

Short CVs of Principle investigators follow: Muths, Hossack, and Pilliod

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Curriculum vitae

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ACADEMIC RECORD

Doctor of Philosophy, Zoology
University of Queensland, Department of Zoology, Brisbane, Australia, January 1997. Dissertation title: Reproductive Physiology and Ecology of Female Red Kangaroos (*Macropus rufus*).

Master of Science, Biology-Systematics and Ecology
Kansas State University, Division of Biology, Manhattan, KS, October 1990.

Bachelor of Science, Wildlife Ecology-Natural Sciences
University of Wisconsin, College of Agricultural and Life Sciences, Madison, WI, May 1986.

RECENT GRANTS

John Wesley Powell Center for Analysis and Synthesis: Elucidating mechanisms underlying amphibian declines in North America using hierarchical spatial models; Research Support – E. Muths, E.H.C. Grant and D.A.W. Miller. 2014-2015.

Wyoming Department of Transportation, Research Advisory Committee: Evaluation of a mitigation site: amphibian population dynamics; Research support – E. Muths, S. Corn, B. Hossack and D. Pilliod 2012-2014.

Natural Resources Preservation Program / Park Oriented Biological Support: Investigating the impact of introduced, endangered cutthroat trout on boreal toad breeding success and recruitment; Research Support – E. Muths, L. Bailey, M.K. Watry 2012.

USGS-Rescue Data Program: Capture-recapture and disease data from the 1960: an important addition to boreal chorus frog biology; Research Support – E. Muths and S. Corn 2012.

RESEARCH EXPERIENCE
--U.S. Geological Survey - Biological Resources Division (Zoologist, GS14 - 4) – 1995 – present.
--University of Queensland - PhD research and Tutor, 1991-1995

REFEREED PUBLICATIONS - selected
Muths, E., L.L. Bailey, & M.K. Watry. 2014. Animal reintroductions: an innovative assessment of survival. *Biological Conservation*, 172: 200-208.

Muths, E., R.D. Scherer, & J. Bosch. 2013. Evidence for plasticity in the frequency of skipped breeding opportunities in common toads. *Population Ecology* DOI: 10.1007/s10144-013-0381-6

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Muths, E., D.S. Pilliod, & R.D. Scherer. 2011. Compensatory effects of recruitment & survival on population persistence. *Journal of Applied Ecology* 48: 873 – 879*.*

Woodhams, D.C., J. Bosch, C.J. Briggs, S. Cashins, L.R. Davis, A. Lauer, **E. Muths**, R. Puschendorf, B.R. Schmidt, B. Shaefor & J. Voyles. 2011. Mitigating amphibian disease: Strategies to maintain wild populations. *Frontiers in Zoology 8:8.*

Muths, E., R.D. Scherer, & B.A. Lambert. 2010. Survival Estimates & Evidence for Skipped Breeding Opportunities for a Female Bufonid. *Methods in Ecology & Evolution* 1: 123 – 130.

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Muths, E., & V.J. Dreitz. 2008. Designing monitoring programs to assess reintroduction efforts: a critical component in recovery. *Animal Biodiversity & Conservation* 31: 47–56.

Muths, E., R.D. Scherer, P.S. Corn, & B.A. Lambert. 2006. Estimation of temporary emigration in male toads. *Ecology* 87(4): 1048–1056.

SERVICE / MEMBERSHIPS

Member – Colorado Boreal Toad Recovery Team	1996 – present
Member – Society for the Study of Amphibians and Reptiles	2000 – present
Co-Editor, Journal of Herpetology	2010 – 2014
Member – Herpetologists' League	2007 – present
Executive Council	2007 – 2011
Graduate student committee member (1 PhD, 2 masters)	current

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Education

2011	Ph.D., Fish & Wildlife Biology, University of Montana
1998	M.S., Wildlife Biology, University of Idaho
1996	B.S., Wildlife Biology, University of Montana

Selected Publications

Davenport, J. M., **B. R. Hossack**, and W. H. Lowe. 2014. Partitioning the non-consumptive effects of predators on prey with complex life histories. Oecologia 176:149-155.

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

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Gould, W.R., D.A. Patla, R. Daley, P.S. Corn, **B.R. Hossack**, R. Bennetts, and C. R. Peterson. 2012. Estimating occupancy in large landscapes: evaluation of amphibian monitoring in the Greater Yellowstone ecosystem. Wetlands 32: 379-389.

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Hossack, B. R., M. J. Adams, E. H. Campbell Grant, C. A. Pearl, J. B. Bettaso, W. J. Barichivich, W. H. Lowe, K. True, J. L. Ware, and P. S. Corn. 2010. Low prevalence of chytrid fungus (*Batrachochytrium dendrobatidis*) in U.S. headwater amphibians. Journal of Herpetology 44: 253-260.

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Corn, P. S., **B. R. Hossack**, E. Muths, D. Patla, C. R. Peterson, and A. L. Gallant. 2005. Status of amphibians on the Continental Divide: surveys on a transect from Montana to Colorado, USA. Alytes 22: 85-94.

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RESEARCH BACKGROUND

I have been working on amphibian, wetland, and restoration research since 1995. My research focuses on wildlife ecology, fire ecology, restoration ecology, and conservation biology in both terrestrial and aquatic ecosystems.

EDUCATIONAL HISTORY

1995-2001	Ph.D. Ecology	Idaho State University, Pocatello, ID
1987-1991	B.A. Biology	University of California, Santa Cruz, CA

CURRENT AND RECENT POSITIONS HELD

2006-present	Supervisory Research Ecologist, US Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, ID
2008-present	Adjunct Graduate Faculty, Department of Biological Sciences, Boise State University, Boise, ID
2004-2006	Assistant Professor and Museum Curator of Herpetology, Department of Biological Sciences, College of Science and Mathematics, California Polytechnic State University, San Luis Obispo, CA

SELECT PUBLICATIONS

Arkle, R.S., D.S. Pilliod, S.E. Hanser, M.L. Brooks, J.C. Chambers, J.B. Grace, K.C. Knutson, D.A. Pyke, J.L. Welty, and T.A. Wirth. 2014. Quantifying restoration effectiveness using multi-scale habitat models: implications for sage-grouse in the Great Basin. Ecosphere 5(3):31.

Pilliod, D.S., C.S. Goldberg, R.S. Arkle, and L.P. Waits. 2014. Factors influencing detection of eDNA from a stream-dwelling amphibian. *Molecular Ecology Resources* 9: doi-10.1111/1755-0998.12159.

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Muths, E., R.D. Scherer, and D.S. Pilliod. 2011. Compensatory effects of recruitment and survival when amphibian populations are perturbed by disease. *Journal of Applied Ecology* 48:873-879.

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Murphy, M.A., R. Dezzani, D.S. Pilliod, and A. Storfer. 2010. Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19:3634-3649.

Pilliod, D.S., B.R. Hossack, P.F. Bahls, E.L. Bull, P.S. Corn, G. Hokit, B.A. Maxell, J.C. Munger, and A. Wyrick. 2010. Nonnative salmonids affect amphibian occupancy at multiple spatial scales. *Diversity and Distributions* 16:959-974.

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Shive, J.P., D.S. Pilliod, and C.R. Peterson. 2010. Hyperspectral analysis of Columbia spotted frog habitat. *Journal Wildlife Management* 74:1387-1394.

Stone, K., D.S., Pilliod, K. Dwire, C.C. Rhoades, S.P.Wollrab, and M.K. Young. 2010. Fuel reduction management practices in riparian areas of the western USA. *Environmental Management* 46:91-100.

Muths, E., D.S. Pilliod, and L. Livo. 2008. Distribution and environmental limitations of an amphibian pathogen in the Rocky Mountains, USA. *Biological Conservation* 141:1484-1492.

Petrisko, J.E., C.A. Pearl, D.S. Pilliod, P.P. Sheridan, C.F. Williams, C.R. Peterson, and R.B. Bury. 2008. *Saprolegniaceae* identified on amphibian eggs throughout the Pacific Northwest, USA, by internal transcribed spacer sequences and phylogenetic analysis. *Mycologia* 100:171-180.

Hossack, B.R., P.S. Corn, and D.S. Pilliod. 2005. Lack of significant changes in the herpetofauna of Theodore Roosevelt National Park, North Dakota, since the 1920s. *American Midland Naturalist* 154:423-432.

Funk, W.C., M.S. Blouin, P.S. Corn, B.A. Maxell, D.S. Pilliod, S. Amish, and F.W. Allendorf. 2005. Population structure of Columbia spotted frogs (*Rana luteiventris*) is strongly affected by the landscape. *Molecular Ecology* 14:483-496.

Pilliod, D.S., R.B. Bury, E.J. Hyde, C.A. Pearl, and P.S. Corn. 2003. Fire and amphibians in North America. *Forest Ecology and Management* 178:163-181.

Pilliod, D.S., C.R. Peterson, and P.I. Ritson. 2002. Seasonal migration of Columbia spotted frogs (*Rana luteiventris*) among complementary resources in a high mountain basin. *Canadian Journal of Zoology* 80:1849-1862.

Pilliod, D.S. 2002. Clark's Nutcracker (*Nucifraga columbiana*) predation on tadpoles of the Columbia Spotted Frog (*Rana luteiventris*). *Northwestern Naturalist* 83:59-61.

Pilliod, D.S., and C.R. Peterson. 2001. Local and landscape effects of introduced trout on amphibians in historically fishless watersheds. *Ecosystems* 4:322-333.