Analysis of Landscape and Habitat Variables Associated with Boreal Toad (*Anaxyrus boreas*) Breeding Locations

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Cover: Boreal toad in a beaver-impounded section of stream in the headwaters of a tributary to the Provo River. This individual was documented by Utah Geological Survey staff at a location where boreal toad had not been seen in almost 30 years.

NATURAL RESOURCES GEOLOGICAL SURVEY

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Executive Summary

Boreal toad (*Anaxyrus boreas*) is an amphibian species found in Utah that is under review for federal threatened and endangered listing. In 2015, the Utah Geological Survey, with funding from the Utah Department of Natural Resources' Endangered Species Mitigation Fund, conducted field surveys and a landscape analysis at active and historical breeding locations and randomly selected wetland sites to better understand important boreal toad habitat features. Field data were collected using a boreal toad habitat assessment protocol created for this project and an existing wetland condition assessment protocol which is used to collect quantitative data on wetland plants and ground cover and qualitative data on other wetland attributes. Landscape analysis was conducted to compare land cover, proximity to roads, and wetland abundance among active breeding, historical breeding, and random sites.

Sites with toad breeding (active or historical) were best distinguished from random sites based on the mean value of the boreal toad habitat metrics. Metrics evaluated the type of waterbody present, shore slope and depth of waterbodies, amount of north shore, shallow water temperature, shrub cover, and presence of hibernation features. The top classification tree model, which correctly classified all but one site, indicates that breeding occurs at sites where most of the metrics are scored as B or higher and shrub cover is less than 60%. The toad metrics developed for this project are useful for a coarse evaluation of whether the species is likely to be found at a site. Most other measured parameters did not differ by site type. Active and historical breeding sites exhibited a wide range of conditions in the field, indicating that breeding can occur at sites close to (usually minor) roads and in wetlands with high non-native plant species cover, moderate soil disturbance, moderate hydroperiod alteration, and nuisance algae in the water column.

The presence of water with aquatic vegetation was the strongest and most consistent predictor separating active breeding sites from both historical breeding and random sites. All active breeding sites had at least some cover of floating or submergent vegetation versus only one of the historical breeding sites. Aquatic vegetation may serve as an indicator of other favorable site conditions; many aquatic plant species are sensitive to environmental conditions such as water temperature, turbidity, and nutrient enrichment that may also be important to boreal toads. Direct measures of water temperature, turbidity, total suspended solids, phosphorus, and nitrogen did not differ between active and historical breeding sites, though observers noted a higher potential for contaminants and sediment stress from roads and livestock grazing at historical sites compared to active breeding sites. Aquatic vegetation may be a better measure of overall aquatic conditions than water chemistry parameters collected at a single point in time since the latter parameters may be susceptible to large within-season changes.

Landscape analysis was unsuccessful at differentiating between site types, making it difficult to predict where on the landscape to search for new breeding populations. All sites were surrounded by at least 94% natural land cover, though sites with active or recent breeding were less likely than random sites to be near major roads such as highways. Sites types did not differ based on the abundance of wetland mapped at sites or in surrounding buffers, though wetland mapping was often inaccurate. In the absence of better data, the best survey approach for locating new populations may be focusing on wetlands mapped as aquatic beds that are close to known breeding populations.

Results from this study can be used to plan surveys to locate new boreal toad populations, better understand threats to existing populations, and predict the abundance of suitable boreal toad

habitat in the project areas. We modified the habitat field form based on study results to include only the most appropriate parameters for evaluating potential breeding sites. These parameters include the boreal toad metrics, water temperature, pH, water clarity, and presence of aquatic vegetation. While no unequivocal threats were identified in this study, the link between breeding sites and aquatic vegetation suggests that water chemistry changes may be important. We recommend monitoring pH, turbidity, and the presence of aquatic vegetation at known breeding sites to determine whether changes in breeding status are linked to changes in these other parameters. Only one of thirteen randomly selected sites in the Jordan watershed were suitable for boreal toad, indicating that suitable habitat may be uncommon in this watershed. The Utah Geological Survey will continue to collect boreal toad habitat data during future watershed-based wetland assessments.

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Introduction

Boreal toad (*Anaxyrus boreas*) is a species under review for federal threatened and endangered listing; one of the threats to the species listed in Utah's Wildlife Action Plan is an inadequate understanding of species' ecology (Utah Division of Wildlife Resources, 2015). The Utah Geological Survey, with support from the Utah Department of Natural Resources' Endangered Species Mitigation Fund, conducted field surveys in 2015 at currently and historically occupied boreal toad locations to better understand important boreal toad habitat features. A wetland condition protocol developed by the Utah Geological Survey was used for field surveys, and an additional field form was developed to assess known or hypothesized boreal toad habitat requirements. The Utah Geological Survey concurrently conducted the first year of a two year wetland study in the 6-digit hydrologic unit code (HUC) Jordan watershed, with funding from the U.S. Environmental Protection Agency. This provided the Utah Geological Survey with additional data on randomly selected sites where boreal toad are unlikely to occur.

Several approaches were used to look for differences between breeding, non-breeding (but historically occupied), and randomly selected sites. We analyzed geospatial data on land cover and type and abundance of wetlands at the sites and the surrounding area to evaluate whether landscape features were predictive of boreal toad breeding occupancy. We used the newly created boreal toad assessment metrics to create an overall habitat score for sites. We tested for differences in water quality constituents, vegetation cover, structural features, and stressors between breeding, non-breeding, and random sites. We created classification tree models to predict whether sites were likely to ever have supported breeding and whether sites currently supported breeding. Results from this study can be used to plan surveys to locate new boreal toad populations, better understand threats to existing populations, and predict the abundance of suitable boreal toad habitat in project areas with field data, such as in the Jordan watershed.

Site Selection and Field Methods

Site Selection

Potential survey sites were limited to the Jordan (160202), Lower Green (140600), Upper Bear (160101), and Lower Bear (160102) 6-digit HUC watersheds to decrease natural heterogeneity between sites and decrease drive time for surveyors. We contacted Sam McKay and Chris Crockett, Utah Division of Wildlife Resources' regional native aquatic biologists for the northern and central regions, respectively, and Paul Chase, biologist with the Uinta-Wasatch-Cache National Forest (UWCNF), to obtain data on locations with recent surveys for boreal toad. Three site types were identified of those sites that had been surveyed multiple times within the last five to ten years. *Breeding* sites are sites where boreal toad breeding was documented in 2015 and often in other recent years; these sites had the most consistent breeding populations. *Recent breeding* sites are sites where breeding has been documented within the past 11 years, but has not been documented during the most recent survey(s) at sites. *Historical* sites are sites where boreal toad was historically documented via museum specimens or other historical records that have been surveyed multiple times in the past ten years. For historical sites, the exact location and nature of sightings is less certain than for the breeding and non-breeding sites.

We considered both recent breeding and historical sites *non-breeding* sites. The initial sample frame of potential survey sites was composed of locations provided by McKay, Crockett, and Chase.

We used a combination of logistical necessity and attempt at balancing site characteristics between sites with and without evidence of current breeding. Due to time constraints, we could not obtain permission to visit most privately owned sites, so we removed these from the sample frame, except for a single breeding location that was needed to increase sample size of breeding sites. This left few remaining breeding populations within our proposed study area, so all confirmed breeding sites on state and federal land were selected as survey sites, for a total of seven breeding sites. We removed from the sample frame recent breeding and historical sites that were not surveyed regularly by UDWR or UWCNF and those with inconsistent or unclear survey results. From the few remaining sites, we selected sites that created a sample frame of non-breeding sites that approximately balanced our breeding sites both geographically and by major wetland type.

The final selection of sites included two breeding and two non-breeding sites in the Monte Cristo Range, one breeding and three non-breeding sites in the Bear River Range, one breeding and one non-breeding site in Big and Little Cottonwood Canyons, one breeding and two non-breeding sites in the Uinta Mountains near the Upper Bear River headwaters, and three other sites on either side of the ridge separating headwaters streams in the Lower Green drainage from the headwaters of the Provo River (figure 1). Selected sites included three breeding and six non-breeding sites that were springhead ponds (including one of each that had evidence of beaver activity), three breeding and three non-breeding sites that were streams or ponds with beaver activity (including one non-breeding and one non-breeding site each on the edge of a large lake or reservoir), and one breeding site that was a small montane snowmelt-fed pond. At the non-breeding sites, the most recent documented breeding activity was between 2004 and 2006 at four of the sites, in 2010 at one site, and at 2013 at one site. The site where breeding was documented in 2010 has been surveyed eight times in four years since the 2010 survey with no additional evidence of breeding and only one year with evidence of an adult frog present. The site where breeding was documented in 2013 had been subject to seven other surveys over three years with no adults or evidence of breeding documented.

We used data from some of the Jordan watershed project sites to compare with data from the breeding and non-breeding sites. From the Jordan data, we made a subset of sites between 2000 and 3000 m in elevation to create a set of *random* sites for data analysis. We used this elevation range for the random sites because it was approximately the range of the breeding and non-breeding sites (2000-2950 m) and is similar to the elevation range of sites categorized as good sites according to the Ecological Integrity Table, (2133-3048 m, [Oliver, 2006]). We excluded one Jordan site in this elevation where a single boreal toad individual was found in 2014 because we did not want to introduce a potential breeding or former breeding site to our random sites.

Survey Methods

We surveyed sites using the Utah Rapid Assessment Procedure (URAP), a wetland survey method in draft form developed by the Utah Geological Survey in 2014 (Menuz and others, 2014). Surveys for URAP are conducted in fixed area plots, referred to as assessment areas (AAs), typically 0.5 ha, but plots can be as small as 0.1 ha when smaller wetlands are encountered. As part of URAP, a buffer area extending 100 m from the edge of the AA is also evaluated. The core of URAP consists of metrics

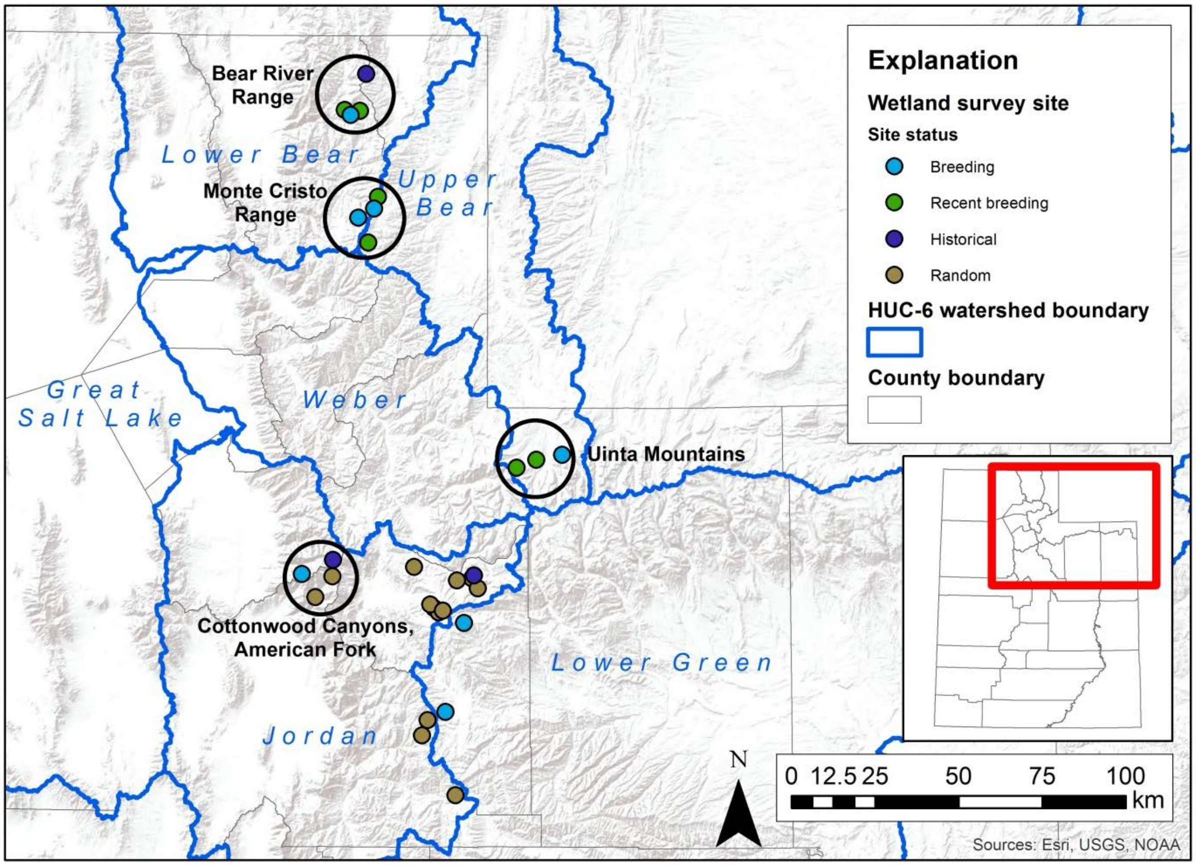


Figure 1. Location of wetland survey sites by site type. Sites located in regions mentioned in the report are labeled and enclosed in black circles.

that allow surveyors to quickly evaluate important and visibly apparent aspects of wetland condition. Each metric is composed of several typically qualitative statements regarding an aspect of wetland condition, such as naturalness of hydroperiod, and each statement is associated with a rank from A to D. The protocol includes a substantial amount of supplementary data collection, including a soil profile, observations of stressors observed at and surrounding the survey site, detailed plant community composition data, and structural (e.g., woody debris, boulders, seeps, etc.) and ground cover (e.g., litter, bare ground, algae) features. Water quality samples were collected at all sites and taken to the Utah Public Health Laboratory Chemical and Environmental Services Laboratory for general chemistry, total metals, and total non-filtered nutrients analysis.

We used information from the boreal toad Ecological Integrity Table (Oliver, 2006) to develop new metrics specific to boreal toad habitat needs. The Ecological Integrity Table consists of a series of indicators to measure key ecological attributes important to boreal toad with a description of very good, good, fair, and poor indicator ratings. We identified six indicators in the Table that were compatible with the existing field sampling methods. We converted each indicator rating into A, B, C, and D categories based on the ratings in the Table. Ratings were modified from the Ecological Integrity Table to increase interpretability of the metrics and to ensure four ratings per metric. We then tested the feasibility and ease of interpretation of each metric in the field at Jordan watershed project sites and modified the metrics accordingly. The final field form used to collect data on boreal toad habitat is shown in appendix A.

The final boreal toad metrics included metrics for waterbody type, slope and water depth, north shore exposure, shallow water temperature, shrub cover, and presence of hibernation features. The first four metrics focused on characteristics of appropriate breeding habitat and were evaluated within or immediately adjacent to the AA. The last two metrics focused on adult habitat and were evaluated in the entire area spanning the AA and the 100 m buffer. To better evaluate the hibernation feature metric, surveyors walked four transects from the edge of the AA to the edge of the 100 m buffer to look for features such as burrows, old beaver lodges, overhanging stream banks, and cavities under tree roots that could potentially be used for hibernation.

In addition to the boreal toad metrics, we collected data on the presence of potential predators and on attributes of potential breeding areas. For the latter, we collected data on waterbody type, shore where measurement was obtained, shore slope, survey time, survey weather, water temperature, pH, electroconductivity, and water depth. We also estimated the percent of the waterbody that was composed of water <10 cm, between 20 and 50 cm, and >50 cm depth. We noted whether submerged aquatic, emergent, or floating leaf vegetation or canopy cover was present at the location where water quality measures were obtained.

Landscape Analysis

We calculated percent land cover in different classes in 500, 1000, and 5000 m buffer surrounding survey sites using the 2011 National Land Cover Dataset (Homer and others, 2015). After preliminary inspection of data using boxplots, we determined that 1000 m buffer data adequately represented trends in the data and continued all further analysis only using data at this scale. We grouped land cover classes into categories including total wetland cover, total wetland and open water cover, total forested cover, total developed land cover, and total natural land cover.

We calculated the area of different wetland classes within 1000 m and directly within the assessment area of each site using National Wetland Inventory (NWI) data, which classified wetlands using the Cowardin classification system (Cowardin and others, 1979). We then created composite values including area of aquatic bed, emergent, scrub-shrub, forested, woody, and unvegetated wetlands and wetland area by water regime, by beaver modification status, and by impoundment status. We created separate values for lacustrine and palustrine wetland area (riverine wetlands were rare in the study area) and also summed total values across wetland systems.

We calculated two types of variables related to roads, the length of road in 1000 m buffers surrounding sites and the distance to the nearest road. For the road length calculation, we used data from Utah Automated Geographic Reference Center (AGRC, [http://gis.utah.gov/data/sgid-transportation/roads-system/]). This data includes the cartocode field which indicates road type. The only road types within 1000 m of sites were unseparated major state highways (cartocode=5), paved major local roads (8), unpaved major local roads (9), other federal aid eligible local roads (10), and other local or rural roads (11). We considered the first three road types "major roads" and calculated both the length of major roads and the length of all roads in the 1000 m buffer. We calculated distance to the nearest road in ArcGIS, but then used aerial imagery to adjust distance measurements because many roads were incorrectly located.

We visually examined sites in ArcGIS with relevant data layers to determine whether they were within 5000 m of abandoned or active mines, point source dischargers, or active oil and gas wells. One non-breeding site was surrounded by a high density of abandoned mines, and one breeding sites was close to a few abandoned mines and had a quarry about 5000 m from the site. No other mine, discharge, or well stressors were identified near sites.

Data Analysis

We conducted extensive exploratory analysis to look for differences in site characteristics between breeding, non-breeding, and random sites. We used field data to calculate variables related to site field classification, vegetation composition, water cover, bryophyte, algae, soil, and litter cover, and field water quality data. When plant species could not be identified in the field, specimens were brought back to the office for later identification, though not all specimens could be identified before data analysis. Species identified only to the genera level were coded as annual or perennial and native or introduced and assigned to a growth habit class whenever possible. All *Carex* spp., *Salix* spp., and *Juncus* spp. were assumed to be native and all *Carex* spp., *Salix* spp., and *Calamagrostis* spp. were assumed to be perennial. We calculated absolute cover, relative cover, and percent cover in dry or wet portions of the AA, depending on the variable. For example, two variables included the absolute cover of water in the AA and the relative cover of introduced plant species in the AA (i.e., cover of introduced species divided by cover of all species). We calculated the cover of macroalgae in the wet portion of the AA and the cover of bare soil in the dry portion of the AA. Stressor data recorded in the field was analyzed based on stressor extent, stressor severity (coded as low=1, moderate=2, and severe=3), and stressor extent multiplied by stressor severity. Tables 1 and 2 list the wetland classification, land cover, and field variables used in the exploratory analysis. Laboratory results for water quality parameters listed in tables 3 and 4 were also used in the exploratory analysis.

We used boxplots to visualize variable means and ranges by site type. We used analysis of variance (ANOVA) to test for differences between variables by site type, using Tukey's honest significant difference test to determine which site types differed from one another when the ANOVA result was significant ($p<0.05$). We used Fisher's exact test to test for differences in metric scoring between site types. For the Fischer's exact test, we converted scores of B and better to "good" and scores of C and below to "poor." We then tested for differences between the two categories. We also used Fisher's exact test to test for differences in the proportion of sites that had each stressor present in 1% or more of the buffer or AA.

We used the exploratory analysis to select variables for classification tree models. An initial set of variables was selected based on their hypothesized relationship with boreal toads and/or trends observed in the exploratory analysis. The sets of variables were then reduced so that no variables used in a model were correlated with one another more than the absolute value of 0.60. Variables were also removed if very few sites had values above zero for the variable. We created four classification tree models. First, we created a landscape model using GIS variables to separate recent breeding and breeding sites (recent/current) from random sites. Second, we created a landscape model to separate breeding sites from recent breeding sites. Third, we created a model using field data to separate

Table 1. Wetland classification and land cover variables used in exploratory data analysis. Wetland classification variables were obtained from National Wetland Inventory data at the assessment area (AA) and 1000 m buffer scale (buffer) and from field observations of assessment areas (field). Land cover data was calculated within 1000 m of sites using National Land Cover Dataset or road data. P-values <0.05 for analysis of variance by site type are shown. The model field indicates variables and their associated scale that were used in development of classificaton tree models for random vs. current/recent sites (1) and for breeding vs. recent breeding sites (2) for either landscape or site data.

Variable	Scale	P-Value	Model
Wetland Classification			
Aquatic bed	AA, buffer, field	p=0.01 (field)	Landscape 1+2 (buffer, AA); Site 1 (field)
Emergent	AA, buffer, field		
Forest	AA, buffer		
Scrub-shrub	AA, buffer, field		Landscape 1 (AA)
Palustrine unconsolidated bottom	AA, buffer, field		
Semi-permanently flooded (f) regime	AA		
Intermittently exposed (g) or permanently flooded (h) regime	AA		
F, g, or h regime	AA, buffer, field[1]		
Seasonally flooded (c) regime	AA, buffer, field[1]	p=0.03 (field)	
C, f, g, or h regime	Buffer[2]		
Saturated (b) regime	AA, buffer, field[3]		
Seasonally flooded/saturated (e) regime	Field		
Temporarily flooded (a) regime	Buffer, field		
Beaver modifier	AA, buffer		Landscape 1+2 (buffer)
Impounded modifier	AA, buffer[1]		Landscape 1+2 (buffer palustrine)
Total wetland	Buffer[2]		Landscape 1+2 (palustrine)
Land Cover and Roads			
Water	Buffer		
Barren	Buffer		
Deciduous forest	Buffer	p<0.01	Landscape 1+2
Evergreen forest	Buffer		
Mixed forest	Buffer		
Total forest (deciduous + evergreen + mixed forest)	Buffer	p=0.03	
Shrub	Buffer		Landscape 1+2
Herbaceous	Buffer		
Woody wetland	Buffer		
Emergent wetland	Buffer		
Total wetland (woody wetland + emergent wetland)	Buffer		
Agriculture	Buffer		
Development	Buffer		Landscape 1+2
Total wetland + water	Buffer		Landscape 1
Length of major roads	Buffer		Landscape 1
Length of all roads	Buffer		Landscape 2
Distance from AA to nearest road	*NA*		

[1]All wetlands in AA; lacustrine, palustrine, and all wetlands in buffer
[2]Palustrine and all wetlands
[3]All wetlands in AA; palustrine in buffer; in field sites classified as new class, seasonal saturation

Table 2. Field ground cover and vegetation data used in exploratory data analysis. Relative cover indicates a cover value obtained by dividing cover of group of species of interest (e.g., introduced plant species) by cover of all species. Significant differences in variables by site type are indicated by analysis of variances p-values of less than 0.05. The model field indicates variables and their associated scale that were used in development of classificaton tree models for random vs. current/recent sites (1) and for breeding vs. recent breeding sites (2) at the site scale.

Variables	P-Value	Model
Vegetation Composition		
Perennial species, relative cover		
Annual species, relative cover		Site 2
Introduced species, relative cover		Site 2
Submerged and floating species, percent cover in wet portion of AA	p<0.01	
Carex, percent cover in dry portion of AA		Site 1+2
Forbs, percent cover in dry portion of AA		
Graminoids, percent cover in dry portion of AA		
Shrubs, percent cover in dry portion of AA		
Woody species (subshrub, shrub, tree), relative cover		
Woody species (subshrub, shrub, tree), percent cover in dry portion of AA		Site 1+2
Water Cover		
Water cover, percent cover	p=0.02	Site 1
Shallow (<20 cm) water cover, percent cover		
Deep (≥20 cm) water cover, percent cover		
Potential shallow water cover, percent cover		
Potential deep water cover, percent cover		
Water cover without vegetation, percent cover		
Water cover with submerged or floating leaf vegetation, percent cover	p<0.01	Site 2
Water cover with emergent vegetation, percent cover	p=0.02	Site 2
Bryophytes, Algae, Soil, and Litter		
Bryophyte, percent cover in dry portion of AA		Site 1
Macroalgae, percent cover in wet portion of AA		Site 1+2
Filamentous algae, percent cover in wet portion of AA		Site 1+2
Dried algae, percent cover in dry portion of AA		
Bare soil (visible), percent cover in dry portion of AA		Site 2
Litter, percent cover in dry portion of AA		
Litter depth, mean from four measurements	p=0.04	Site 1+2
Field Water Quality Data		
pH, all values recorded		
pH, maximum value recorded		Site 2
Temperature, all values recorded		
Temperature, maximum value recorded		Site 1+2
Electroconductivity, maximum value recorded		
Mean Metric Values		
Mean toad metric value, all six metrics	p=0.01	Site 1+2
Mean toad metric value, excluding water temperature and shrub metrics	p<0.01	Site 1+2

Table 3. Standard water quality parameter and major cation and anion data, including minimum, maximum, and quartile values by site type. Number following units for each constituent, when present, indicates the minimum reporting limit—the value below which the constituent cannot be reliably quantified. Values below this limit are shown in grey.

Variable	Group	Min.	25th	Median	75th	Max.
Water temperature (field) (°C)	breeding	12.3	12.9	15.6	16.6	26.4
	non-breeding	10.7	12.2	14.3	18.9	21.1
	random	9.7	11.3	12.1	14.3	15.9
pH (from field location where sample collected)	breeding	7.9	8.2	8.2	8.9	9.7
	non-breeding	7.1	8.0	8.1	8.5	8.9
	random	8.1	8.5	8.8	8.8	9.0
Specific conductance at 25°C (µS/cm)	breeding	25	197	371	411	473
	non-breeding	109	251	366	440	527
	random	139	211	327	440	504
Suspended solids, total (TSS) (mg/l) (4)	breeding	2.0	8.8	16.0	19.7	39.2
	non-breeding	2.0	4.0	10.8	20.7	50.8
	random	2.0	4.1	12.2	16.7	25.2
Alkalinity, total (mg CaCO3/l)	breeding	9	106	212	228	261
	non-breeding	53	124	192	223	267
	random	65	108	171	234	269
Sulfate (mg/l) (20)	breeding	3.8	3.8	3.8	3.8	3.8
	non-breeding	3.8	3.8	3.8	7.8	13.3
	random	3.8	3.8	3.8	11.7	18.3
Chloride (mg/l) (1)	breeding	1.5	1.7	1.7	2.6	4.1
	non-breeding	1.7	1.9	2.4	7.4	45.4
	random	2.0	2.1	2.4	2.5	5.7
Calcium (mg/l) (1)	breeding	3.6	28.1	54.9	63.7	79.2
	non-breeding	12.7	41.3	69.4	83.8	88.8
	random	19.6	34.4	52.6	60.7	72.9
Magnesium (mg/l) (1)	breeding	0.5	5.8	12.6	20.2	28.5
	non-breeding	2.5	4.2	7.6	16.2	17.6
	random	3.5	5.1	7.4	21.0	29.4
Potassium (mg/l) (1)	breeding	0.5	0.5	1.6	2.5	3.6
	non-breeding	0.5	2.3	2.9	4.8	5.7
	random	2.1	2.3	2.8	3.3	3.8
Sodium (mg/l) (1)	breeding	0.5	1.4	2.0	2.3	3.4
	non-breeding	1.1	1.4	1.6	2.4	9.7
	random	1.5	2.7	3.6	4.6	24.1

recent/current sites from random sites. Fourth, we created a model using field data to separate breeding sites from recent breeding sites. Variables used in model development are shown in tables 1 and 2. Classification trees were developed with differing numbers of splits. The optimal number of splits was selected as the smallest tree size, determined as the modal value after 50 replicate runs, that had a 10-fold cross validation rate within one standard error of the minimum cross validation rate (De'ath and Fabricius, 2000). All statistical analysis presented in this report was conducted in the statistical software R 3.2.1 (R Core Development Team, 2013).

Table 4. Nutrient and organic matter data, including minimum, maximum, and quartile values by site type. Number following units for each constituent, when present, indicates the minimum reporting limit—the value below which the constituent cannot be reliably quantified. Values below this limit are shown in grey.

Variable	Group	Min.	25th	Median	75th	Max.
Ammonium (NH4)-N, total (mg/l) (0.05)	breeding	0.01	0.01	0.01	0.01	0.01
	non-breeding	0.01	0.01	0.01	0.01	0.01
	random	0.01	0.01	0.01	0.02	0.07
Nitrate + nitrite (NO3 + NO2)-N, total (mg/l) (0.1)	breeding	0.01	0.05	0.11	0.13	0.26
	non-breeding	0.00	0.01	0.03	0.32	1.57
	random	0.01	0.02	0.09	0.19	0.38
Nitrogen, total (mg/l) (0.2)	breeding	0.04	0.17	0.41	0.52	0.68
	non-breeding	0.24	0.45	0.50	0.70	2.50
	random	0.04	0.26	0.37	0.42	0.72
Organic nitrogen, total (mg/l)	breeding	0.03	0.07	0.23	0.38	0.54
	non-breeding	0.03	0.17	0.37	0.51	0.92
	random	0.03	0.07	0.19	0.21	0.57
Phosphorus, total (digested) (mg/l) (0.02)	breeding	0.01	0.02	0.02	0.06	0.10
	non-breeding	0.01	0.02	0.05	0.09	0.15
	random	0.01	0.03	0.07	0.12	0.15
Total nitrogen: total phosphorus ratio	breeding	3.3	5.5	6.9	12.7	23.4
	non-breeding	4.4	4.9	10.7	33.4	180.1
	random	2.6	4.2	5.5	6.8	9.5
Volatile solids, total (TVS) (mg/l) (5)	breeding	2.0	3.0	4.0	6.8	12.0
	non-breeding	2.0	2.0	5.6	8.0	10.8
	random	2.0	2.0	2.0	6.2	8.8
Organic carbon, total (mg/l) (0.5)	breeding	1.0	1.8	3.0	6.0	12.0
	non-breeding	1.0	3.1	4.4	9.5	14.9
	random	0.8	1.3	1.9	2.4	2.7
Total organic carbon: total organic nitrogen	breeding	4.0	12.5	14.2	50.6	96.8
	non-breeding	10.8	16.2	18.3	19.1	33.2
	random	4.7	9.1	11.7	22.6	38.1
Total organic carbon: total phosphorus ratio	breeding	43.3	56.9	67.2	213.9	318.6
	non-breeding	51.7	76.6	86.6	200.0	261.4
	random	12.8	18.0	23.2	58.8	115.9

Results

Metric Data

Scores of the non-toad URAP metrics did not differ significantly by site type and indicated that breeding boreal toad populations can be found under a range of site conditions. All sites had high (A or B) values for percent buffer, buffer width, and buffer soil, evaluated within 100 m of sites, whereas half of breeding sites scored as C for percent intact landscape, which is evaluated within 500 m of sites (figure 2). Few random and breeding sites were scored below B for site soil condition, though one breeding site was scored as D due to soil disturbance from livestock trampling and excavation. Two breeding and two non-breeding sites were each scored as C- for hydroperiod due to the presence of dug ponds for water at springheads; no random sites were scored below B (figure 3). All sites except for one breeding and three non-breeding sites scored B or above for the algae metric, and the majority of all sites were scored as A for turbidity. A higher proportion of breeding sites had high levels of vegetation interspersion compared to other site types.

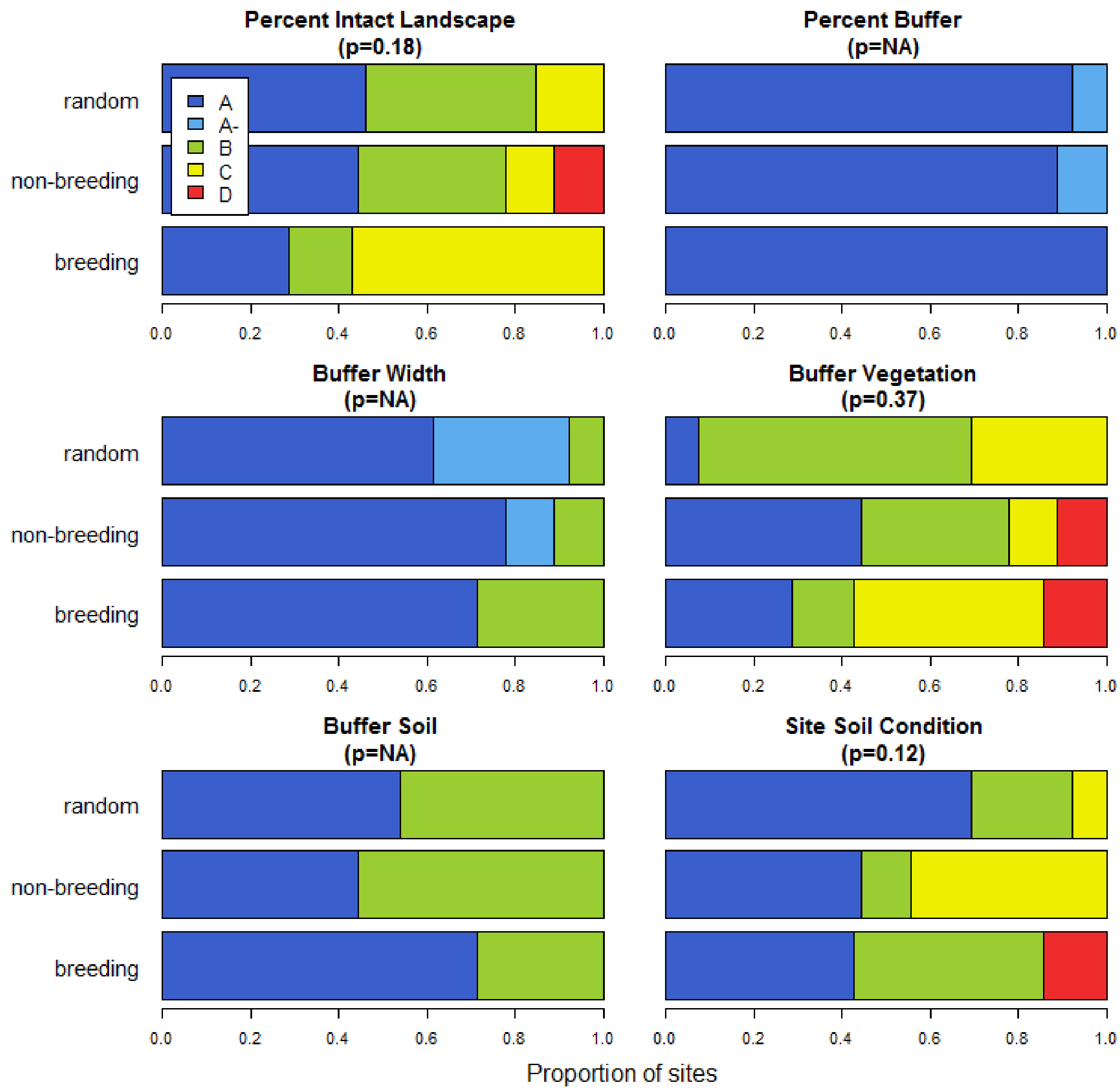


Figure 2. Distribution of landscape and site soil metric scores by site type. Fisher's exact test results for the proportion of sites scored as B or above versus below B, by site type, are indicated by the p-value, with *NA* indicating that no sites scored below B for the metric.

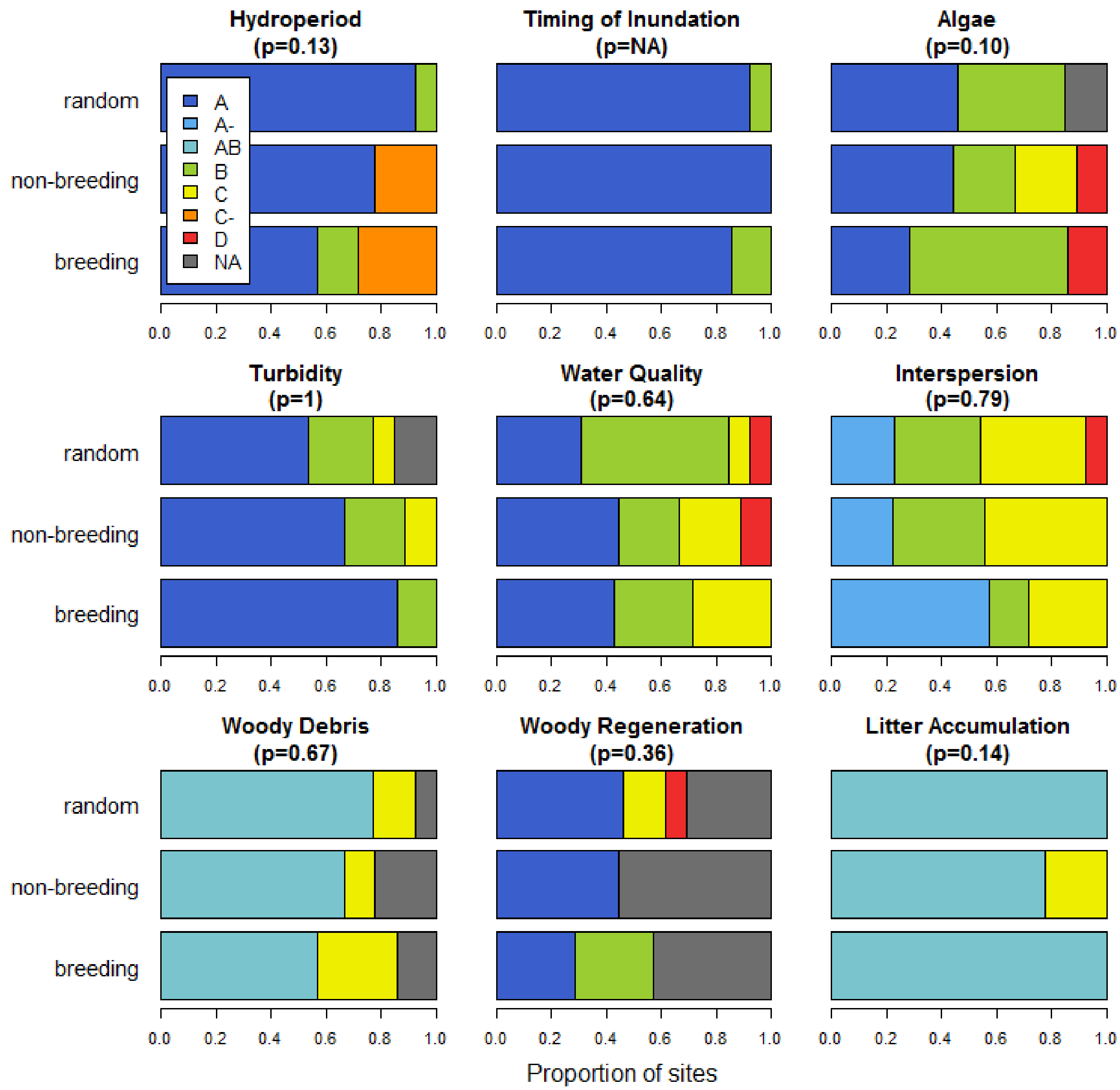


Figure 3. Distribution of hydropattern, water quailty, and vegetation structure metric scores by site type. Fisher's exact test results for the proportion of sites scored as B or above versus below B, by site type, are indicated by the p-value, with *NA* indicating that no sites scored below B for the metric.

Breeding sites had a higher proportion of sites scored as A than non-breeding and random sites for the slope and depth, north shore exposure, and hibernation features metrics (figure 4). All sites were scored as either B or C for shallow water temperature; the proportion of sites in each rank was similar among site types. Two metrics showed significant differences in scoring between site types based on Fisher's exact test. Both breeding and non-breeding sites had a higher proportion of A and B scoring sites for the waterbody type metric than random sites (p=0.01). Breeding sites also a higher proportion

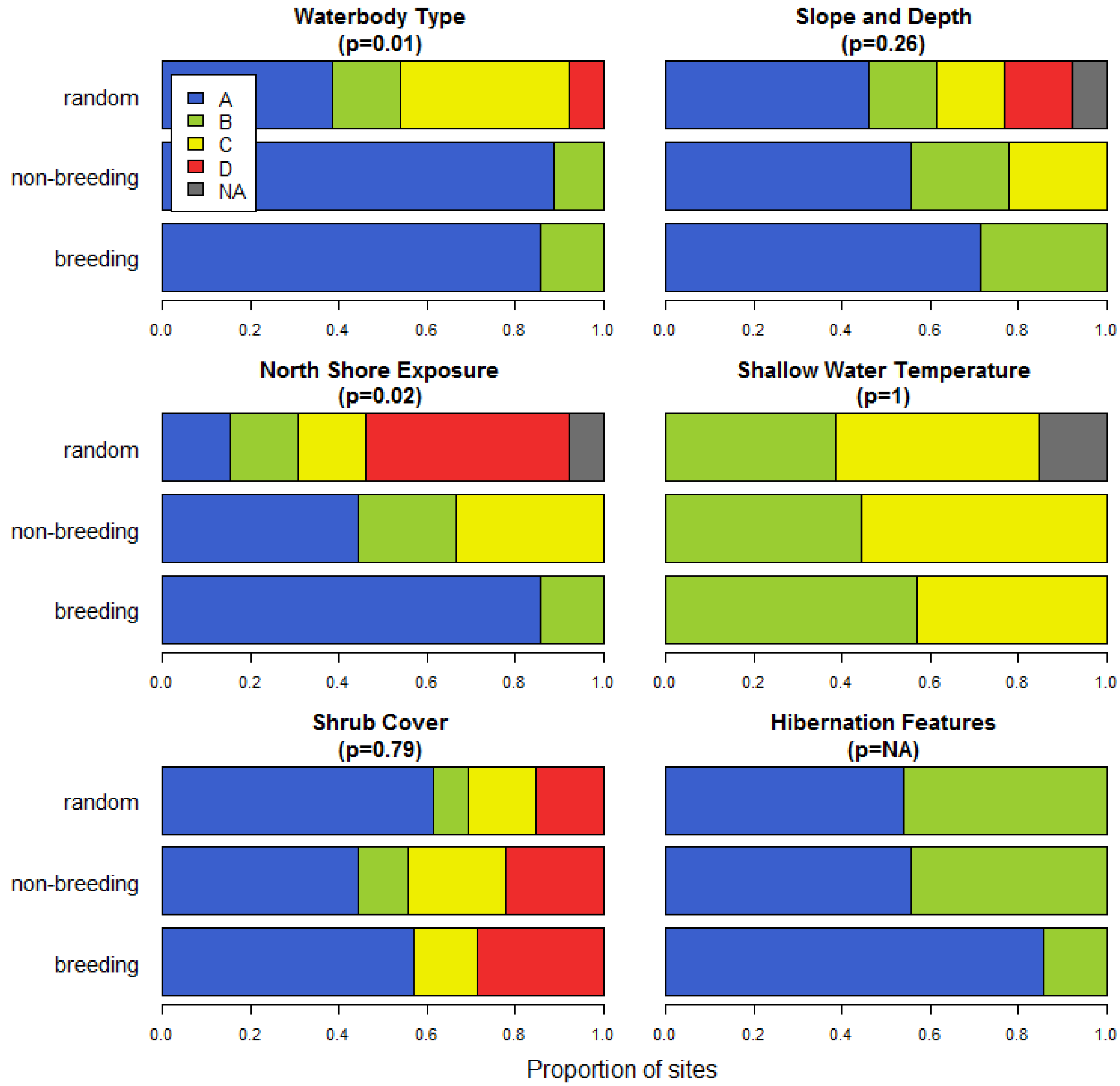


Figure 4. Distribution of boreal toad metric scores by site type. Fisher's exact test results for the proportion of sites scored as B or above versus below B, by site type, are indicated by the p-value, with *NA* indicating that no sites scored below B for the metric.

of A and B sites for the slope and depth metric compared to random sites (p-0.02); differences with non-breeding sites were not significant.

We converted the ranks of the URAP boreal toad metrics to point values using the same conversion used for all URAP metrics, with A=5, B=4, C=3 and D=1, and then took the mean value for each site across all six of the toad-specific metrics. Mean values differed among sites (p=0.01), with Tukey's honest significant difference test indicating that breeding sites had higher mean scores than non-breeding sites (p=0.02) and that non-breeding sites had marginally higher scores than random sites (p=0.08) and were not significantly different from breeding sites (figure 5). We then calculated mean metric values across four of the toad metrics; we dropped the shallow water temperature and shrub cover metrics because they did not appear to be associated with toad breeding or non-breeding sites. Mean values again differed among sites (p=0.003). Both breeding (p=0.004) and non-breeding (p=0.03) sites differed from random sites and did not differ from one another. All but one of the breeding sites had a mean score across the four metrics of at least 4.75, whereas only four of the nine non-breeding sites and three of the thirteen random sites had scores this high. Random sites were the only group of sites with mean scores below 3.75.

We conducted additional analysis of water temperature data due to the poor performance of the shallow water temperature metric. We wanted to determine whether field surveyors appropriately adjusted water quality observations based on conditions at the time of surveys and, if not, whether there were in fact differences in water temperature among site types. We created a linear regression model with temperature as the response variable and weather (coded as clear, cloudy, overcast, or raining), time of day and date as predictor variables, using all temperature data collected at project sites. The resulting model had an adjusted R^2 value of 0.54. Time of day had a strong positive relationship with water temperature ($p<0.001$), day of summer had a weakly negative relationship (p=0.09), and temperature was warmer on clear days compared to cloudy (p=0.05), overcast (p=0.004), or raining ($p<0.001$) days. Next, we calculated the expected temperature on a clear day on July 16 at 4 p.m. using the model's estimated intercept and coefficient values; the expected temperature was

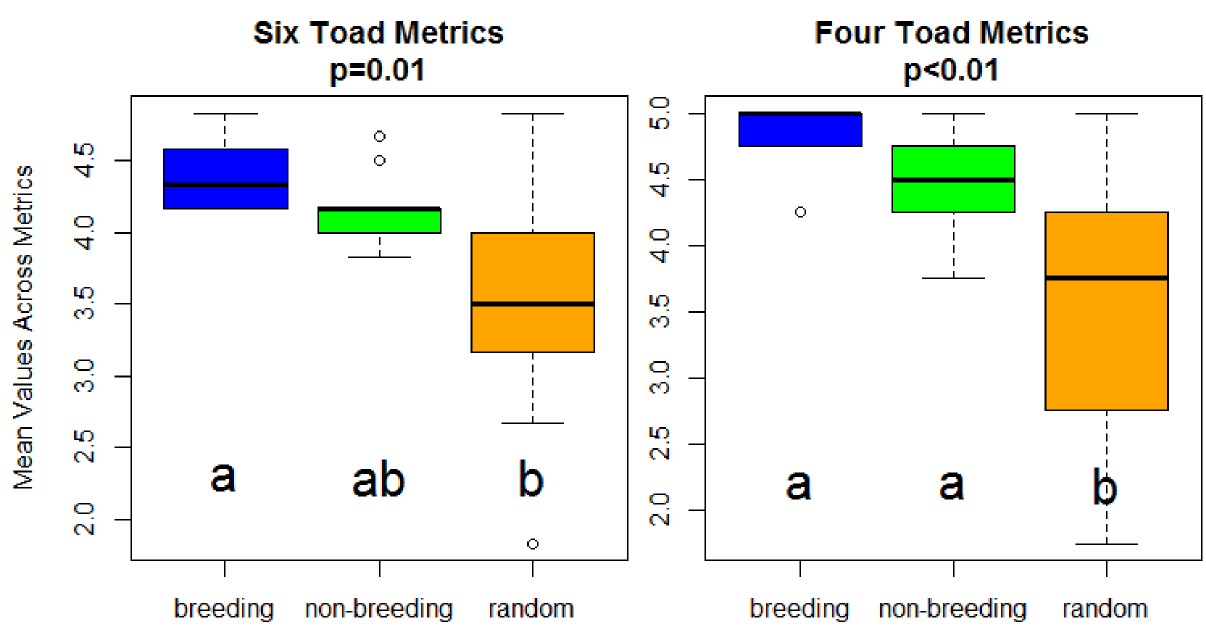


Figure 5. Mean values across all six toad metrics and across all but the shrub cover and water tempeature metrics, by site type. Significant differences in mean values by site type are indicated by analysis of variances p-values of less than 0.05; site types that do not share letters are significantly different from one another based on Tukey's honest significant difference test.

22.1°C. We added the expected temperature to the linear regression model residuals to obtain an estimate of the temperature at each site under standardized conditions (July 16 at 4 p.m., clear). We assumed that sites with large positive or negative residuals may have natural conditions that lead to higher or lower than expected temperatures. Last, we took the maximum value of the standardized temperature at each site. All but one site had a maximum standardized temperatures between 17.9 and 27.4°C, corresponding with a shallow water temperature metric rating of B, even though half of these sites were scored as C in the field. Breeding sites had a median maximum standardized temperatures of 24.4°C, higher than the median values for non-breeding (22.0°C) and random sites (21.4°C), though differences between site types were not statistically significant. Five of the seven breeding sites had maximum standardized temperatures between 23.8 and 25.5°C, whereas less than half of random and non-breeding sites had values above 23.8°C. The two breeding sites with the lowest temperature were located at the lowest elevation of all surveyed sites.

Stressors

Non-native cover was the most commonly recorded buffer stressor for all site types (table 5). Roads were also common in buffers, located in 43% of breeding, 44% of non-breeding, and 54% of random buffers. Trash was less prevalent in and around breeding sites than other sites types and nuisance algae was less prevalent at random sites than other sites, though differences were not statistically significant. The mean amount of land cover change (e.g., natural land cover converted to roads, mines, etc.) at sites was 2.9% (2.7 standard deviation [SD]) change at breeding sites, 5.8% (7.5 SD) at non-breeding sites, and 7.4% (6.5 SD) at random sites. None of the breeding sites, and approximately one third of non-breeding and random sites, had over 5% land cover change in their buffers. Evidence of livestock grazing in sites and/or site buffers was present at 31% of random, 43% of breeding, and 56% of non-breeding sites. Grazing typically appeared to be from the current year rather than historical. Grazing was recorded as high severity in one non-breeding site and as moderate severity in one random site, one breeding, and four non-breeding sites. Wildlife threats were recorded more frequently at breeding and non-breeding sites than at random sites ($p=0.002$). Avian predators, including hawks, falcons, crows, ravens, and robins, were the most commonly recorded threat (table 6).

The severity of stress related to water contaminants, vegetation, hydroperiod, and sedimentation was evaluated separately for each stressor recorded in the buffer. Almost half of non-breeding sites had a moderate severity water contaminant stress recorded, versus 15% of random sites and no breeding sites (table 7). Sedimentation stress was most prevalent and hydroperiod stress was least common at non-breeding sites. Moderate severity vegetation stress was more common at breeding sites than other sites.

Ground and Vegetation Cover

Breeding sites had significantly more cover of submerged and floating leaf aquatic plants than non-breeding and random sites ($p<0.001$, figure 6). All but one breeding site had submerged vegetation, including *Stuckenia pectinata* (sago pondweed, n=3), *Ranunculus aquatilis* (white water buttercup, n=2), *Stuckenia filiformis* (fineleaf pondweed, n=1), *Potamogeton foliosus* (leafy pondweed, n=1), *Callitriche palustris* (vernal water-starwort, n=1), and three unidentified submerged species and two had the

Table 5. Percent of sites with listed stressor, for stressors found at four or more sites. Stressors were either recorded in a 100 m buffer surrounding assessment areas (AAs) or within AAs. Stressors within AAs were grouped into three categories, hydroperiod, physical, and vegetation stress. Numbers in parenthesis following percentages indicate the number of sites where the stressor was recorded as moderate or high (as opposed to low) intensity. Differences in the extent of each stressor among site types were not significant, as indicated by the listed analysis of variance p-values.

Stressor	P-value	Breeding (n=7)	Non-breeding (n=9)	Random (n=13)
Buffer				
Cover of non-native or invasive plant species	0.29	86% (3)	100% (3)	100% (5)
Moderate to heavy formation of filamentous algae	0.89	43% (0)	44% (1)	23% (1)
Pasture, rangeland, managed grazing	0.52	29% (0)	44% (4)	31% (1)
Trash, dumping	0.60	43% (0)	67% (0)	77% (0)
Trails	0.73	14% (0)	22% (0)	31% (0)
Dirt road or high use ATV trail at grade	0.98	29% (0)	33% (0)	31% (0)
Paved Roads	0.96	14% (0)	11% (0)	15% (0)
Hydroperiod - Within Site				
Livestock pugging and entrenchment from paths	0.09	29% (0)	44% (2)	23% (1)
Physical - Within Site				
Trampling, digging, wallowing by livestock	0.16	29% (0)	56% (1)	23% (1)
Trash, dumping	0.11	0% (0)	33% (0)	8% (0)
Vegetation - Within Site				
Grazing and browsing by livestock	0.25	14% (1)	44% (2)	8% (1)
Moderate to heavy formation of filamentous algae	0.30	86% (2)	78% (4)	46% (2)

Table 6. Potential wildlife threats observed at breeding, non-breeding, and random sites. Number of sites where each threat was observed and total number of threats per site is shown.

Site Type/ Threat	Breeding (n=7)	Non-breeding (n=9)	Random (n=13)
Observed Threat			
Badger, fox, raccoon	2	3	0
Avian predator	5	3	2
Snake	0	1	0
Tiger salamander	1	1	0
Trout	2	1	0
Number of Threats at Site			
No threats	1	3	11
1 threat	3	3	2
2 threats	1	3	0
3+ threats	2	0	0

Table 7. Stress types recorded within buffers. The percent of each type by severity and breeding status is shown.

Water Contaminants	Not present	Low	Moderate	High
breeding	71.4%	28.6%	0.0%	0.0%
non-breeding	55.6%	0.0%	44.4%	0.0%
random	46.2%	38.5%	15.4%	0.0%
Sedimentation				
breeding	57.1%	42.9%	0.0%	0.0%
non-breeding	22.2%	66.7%	11.1%	0.0%
random	46.2%	53.8%	0.0%	0.0%
Hydroperiod Stress				
breeding	71.4%	28.6%	0.0%	0.0%
non-breeding	55.6%	44.4%	0.0%	0.0%
random	84.6%	7.7%	7.7%	0.0%
Vegetation Stress				
breeding	14.3%	28.6%	57.1%	0.0%
non-breeding	0.0%	66.7%	22.2%	11.1%
random	15.4%	61.5%	23.1%	0.0%

floating species *Lemna minor* (common duckweed). Only one non-breeding site and three random sites had any submerged aquatic vegetation. Greater cover of aquatic vegetation at breeding sites was not due to greater overall cover of water; water cover at breeding sites did not differ from non-breeding or random sites, though breeding sites had lower mean total water, shallow water and deep water cover values than non-breeding sites. The macroalgae *Chara* was rarely observed at random sites and was more prevalent and occupied a greater portion of the aquatic habitat at non-breeding sites. Non-breeding sites had marginally more *Chara* cover than random sites ($p=0.06$). The percent of water with emergent vegetation was higher in non-breeding sites than breeding and random sites.

Sites did not significantly differ based on the relative cover of introduced plant species or woody species cover, though random sites showed a trend of more woody species than breeding and non-breeding sites. Just under half of the random sites, one non-breeding site, and no breeding sites had over 50% relative cover of woody cover. Random sites had higher mean litter depth than breeding and non-breeding sites ($p=0.04$), having a mean of 5.8 cm depth litter versus 3.0 at breeding sites and 3.6 at non-breeding sites. Non-significant trends indicated more bryophyte cover at breeding sites than random sites and more visible bare soil at breeding and non-breeding sites than random sites.

Water Quality

Water quality data for laboratory analysis was collected from all breeding and non-breeding sites and from six of thirteen random sites; water quality data was not collected at sites with very little or very shallow surface water. None of the tested water quality parameters differed significantly by site type based on ANOVA analysis, though breeding sites had marginally less total potassium than non-

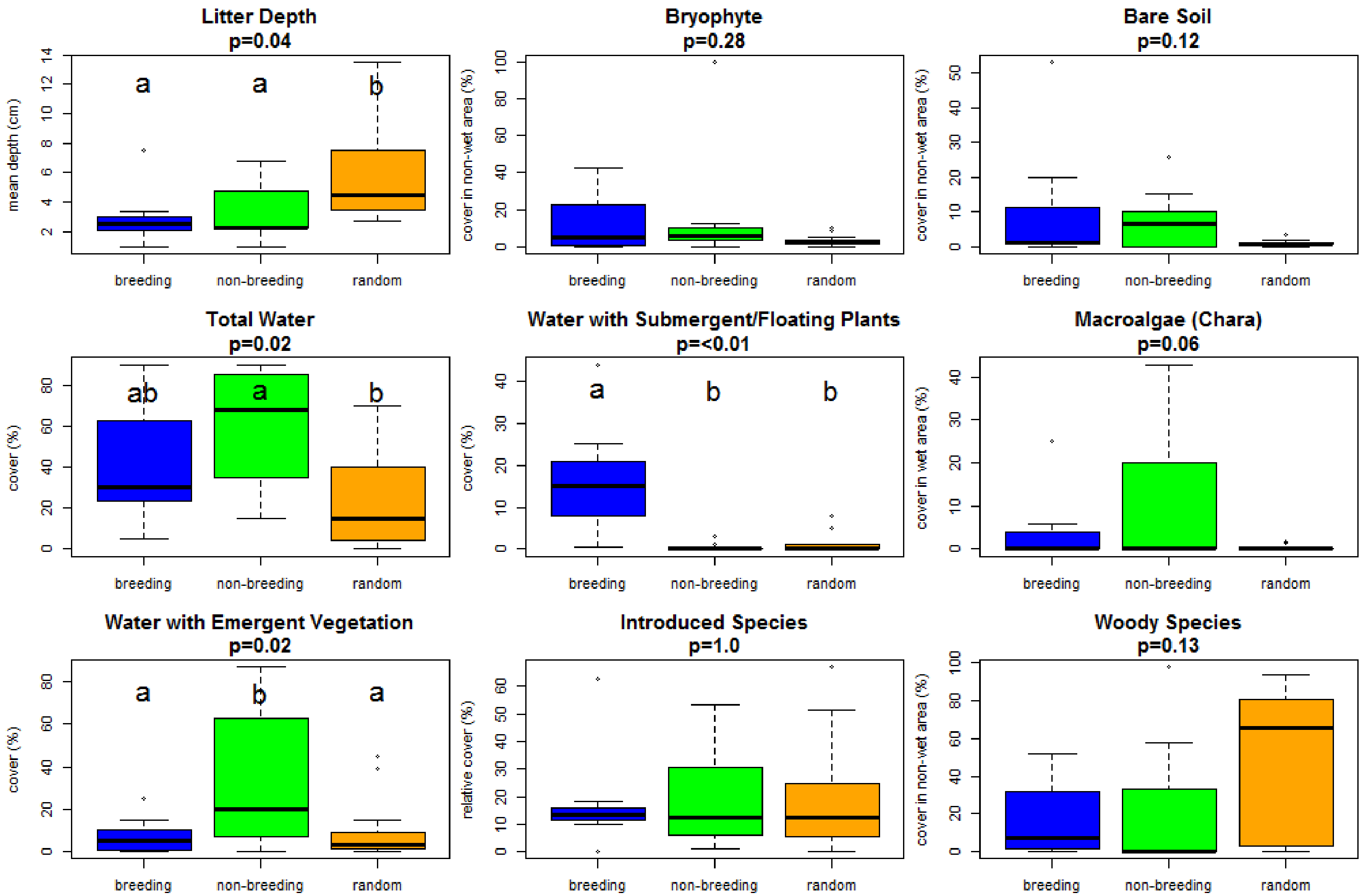


Figure 6. Select ground and vegetation cover measures for breeding, non-breeding, and random sites. Significant differences in cover by site type are indicated by analysis of variances p-values of less than 0.05; site types that do not share letters are significantly different from one another based on Tukey's honest significant difference test. Total water and water with emergent vegetation are strongly positively correlated (Pearson correlation coefficient=0.71); correlations for all other variables are less than or equal to the absolute value of 0.57.

breeding sites (p=0.07, figure 7). Site groups had relatively similar mean and range of values for total suspended solids, conductivity at 25 degrees Celsius and total alkalinity. Breeding sites had higher minimum, 25th percentile, median, and maximum values for water temperature compared to other sites, but a lower 75th percentile of values than non-breeding sites (table 3). Breeding sites had higher pH values at each of the quartiles than non-breeding sites; differences with random sites were not consistent. A plot of the first two axes of a principal components analysis of major anions and cations did not reveal any distinct clusters of sites, though one non-breeding site with high values of calcium and chloride was a clear outlier from all other sites. Several non-breeding and random sites had higher sulfate levels than all other sites, though all sulfate levels were below the minimum reporting limit indicating that the constituent was detected, but at too small of an amount to be accurately quantified.

Nitrogen as ammonium was below the minimum reporting limit at all but one site, and nitrate plus nitrite was below the minimum reporting limit at over half of all sites (table 4). Four of the five highest nitrate plus nitrite values were documented at non-breeding sites (figure 8). High nitrate plus nitrite levels may have been associated with the presence of beaver; all but one of the seven sites with nitrate plus nitrite values above 0.2 mg/l had beaver present, versus six of the fifteen remaining sites. In contrast, only two of the seven sites high nitrate plus nitrite sites and six of the fifteen remaining sites had evidence of current year grazing. Total nitrogen was frequently higher at non-breeding sites than other sites, having higher minimum, maximum, and quartile values, though differences were not significant (figure 8, table 4). Two non-breeding sites had total nitrogen levels that were 1.75 and 3.5 times that documented at all other sites. High nitrogen levels were driven by high levels of nitrate plus nitrite at both sites and by high levels of total organic nitrogen at one site. Quartiles for total organic nitrogen and total organic carbon were highest at non-breeding sites. Mean total digested phosphorus was highest at random sites and lowest at breeding sites

The ratio of total organic carbon to total organic nitrogen (TOC:TON) can be indicative of the type of organic matter in water. Ratios below 15:1 indicate algae or proteins in the water that are more readily decomposed, ratios between 15 and 25:1 indicate green emergent leaves such as cattails, and ratios over 30 indicate non-photosynthetic stems and woody debris (T. Hooker, Utah Division of Water Quality, written communication, 2016). Two-thirds of the non-breeding sites had TOC:TON ratios between 16 and 20, indicating predominantly emergent material in the water; no other sites were in this range (table 8). The majority of breeding and random sites had low ratios indicative of algae and simple proteins in the water, though high ratios were found at least at one third of sites as well.

Previous work has reported that lakes and oceans are typically nitrogen-limited when ratios of total nitrogen to total phosphorus (TN:TP) are less than 9.0 (by mass, reported as 20 molar by Guildford and Hecky, 2000) and phosphorus-limited when TN:TP is greater than 22.6 (by mass, reported as 50 by Guildford and Hecky, 2000). Systems with ratios in between may be limited by either element. Rooted wetland vegetation may obtain more nutrients from soil than from the water column, so these ratios do not necessarily describe limits for many wetland plants but may be more indicative of limitations for algae and floating vegetation. Relatively few sites, and no random sites, had high TN:TP ratios; most sites were in the nitrogen limitation range (table 8). Ratios may not always be precise because some total nitrogen and total phosphorus values were below the minimum reporting limit; however, the overall trend in ratios remains the same even when those sites are excluded.

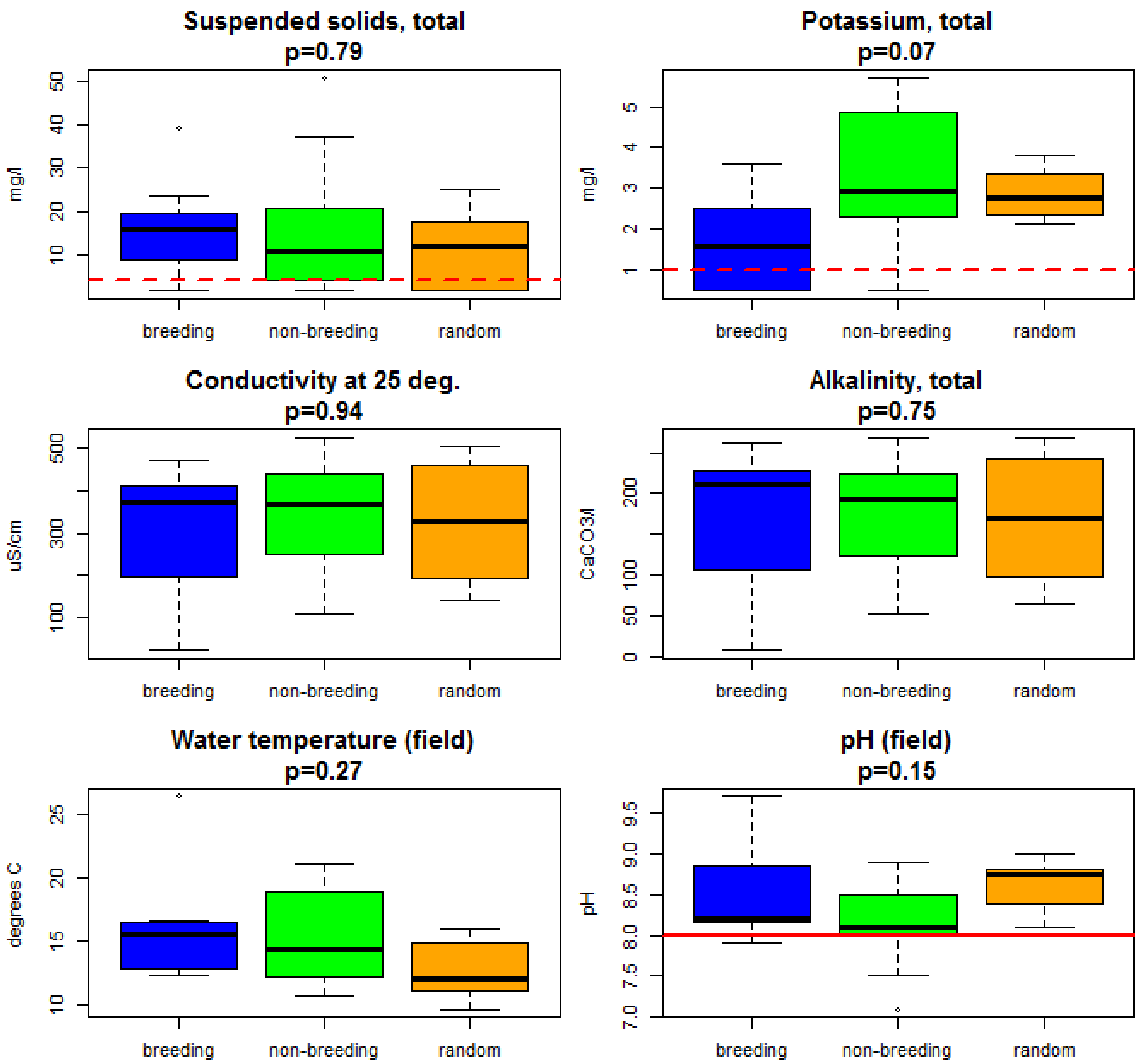


Figure 7. Select water chemistry parameters at breeding, non-breeding, and random sites. Differences between site types were not significant, as indicated by p-values from analysis of variance. Red dashed lines indicate the minimum reporting limit for total suspedned solids and total potassium—the value below which constituents are known to be present but cannot be accurately quantified. The solid red line indicates the pH value observed by Johnson and Speare (2005) to be associated with boreal toad. Conductivity at 24 degrees Celsius and total alkalinity are strongly positively correlated (Pearson correlation coefficient=0.97); correlations for all other variables are less than or equal to the absolute value of 0.51.

Site Classification and Landscape Analysis

The amount of overall wetland area or amount of area by wetland type within 1000 m of sites did not differ by site type (figure 9). Two breeding and two non-breeding sites were not mapped by

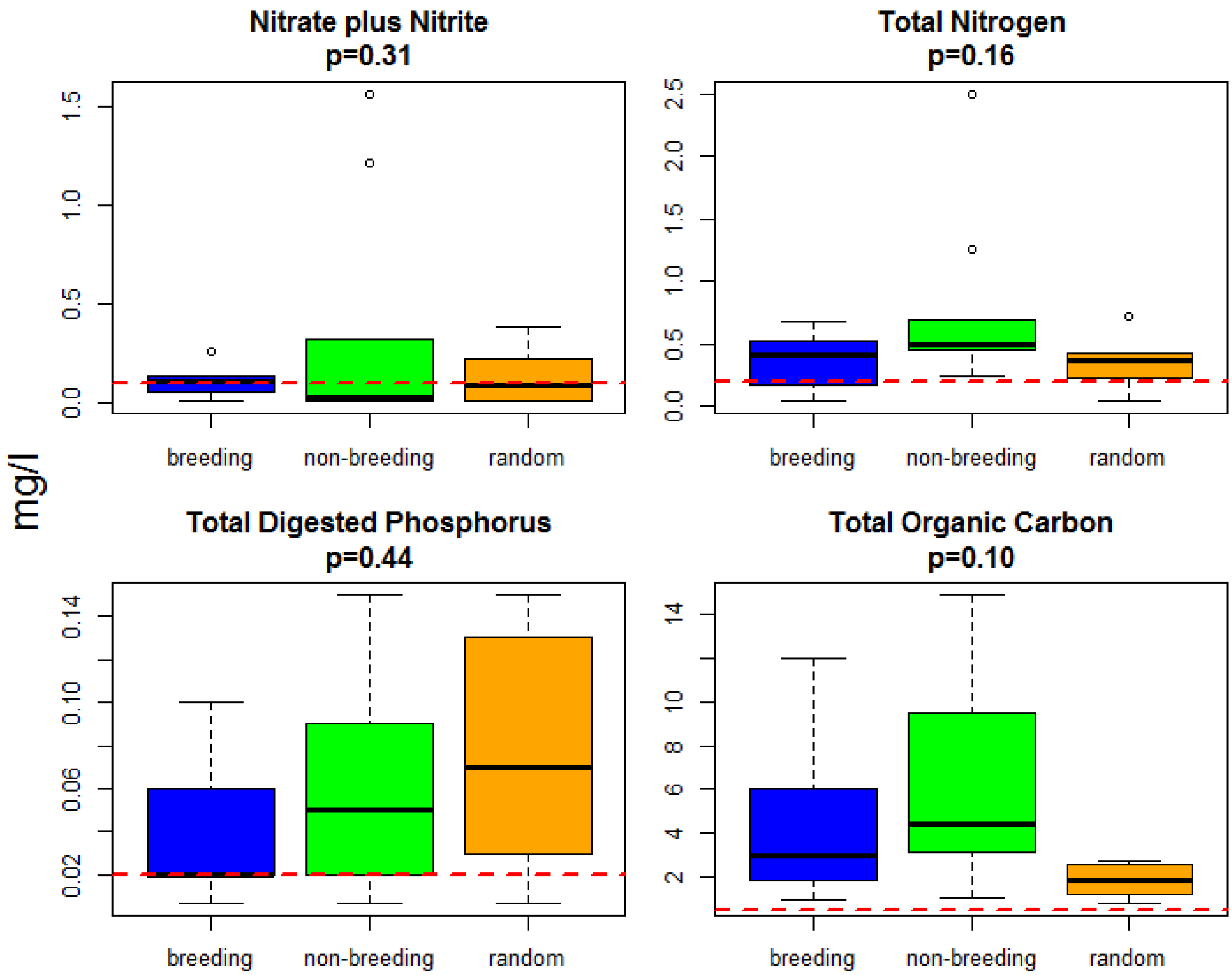


Figure 8. Select nutrient water quality parameters at breeding, non-breeding, and random sites. Differences between site types were not significant, as indicated by p-values from analysis of variance. Red dashed lines indicate the minimum reporting limit, the value below which constituents are known to be present but cannot be accurately quantified. Nitrate plus nitrite and total nitrogen are strongly positively correlated (Pearson correlation coefficient=0.89); correlations for all other variables are less than or equal to the absolute value of 0.59.

NWI; these four sites were removed from analysis of NWI mapping within the AA. Both NWI and field classification data had a higher percent of the AA mapped as aquatic bed at breeding sites and a higher percent of the AA mapped as scrub-shrub and seasonally flooded wetlands at random sites, though most comparisons were not significant (figure 9). Non-breeding sites had a higher percent of the AA mapped as semi-permanently flooded by NWI than random sites (p=0.05), though only four sites overall (three non-breeding and one breeding) had any area mapped with this water regime. The proportion of sites with beaver activity or artificial impoundments at any scale did not differ by site type. All three site types had similar prevalence of field-recorded beaver activity, which was recorded at approximately 43% of breeding and non-breeding sites and 54% of random sites.

Table 8. Percent of sites with total organic carbon to total organic nitrogen (TOC:TON) and total nitrogen to total phospohrus (TN:TP) ratios in particular ratio categories. Sites with values below the minimum reporting limit were removed in the second TN:TP calculation. Ratio classes for TOC:TON may indicate primary organic matter in water and ratio classes for TN:TP may indicate nutrient limitation.

	Breeding	Non-breeding	Random
TOC:TON ratios	**n=7**	**n=9**	**n=13**
>4-14.2 (algae)	57.1%	22.2%	66.7%
>15-26.2 (emergent)	0.0%	66.7%	0.0%
>29-97 (non-photosynthetic and woody stems)	42.9%	11.1%	33.3%
TN:TP ratios	**n=7**	**n=9**	**n=13**
>2-9 (nitrogen limited)	57.1%	44.4%	83.3%
>9-14 (limited by either element)	28.6%	22.2%	16.7%
>23-180 (phosphorus limited)	14.3%	33.3%	0.0%
TN:TP ratios (low value sites removed)	**n=6**	**n=7**	**n=12**
>2-9 (nitrogen limited)	50.0%	57.1%	80.0%
>9-14 (limited by either element)	33.3%	28.6%	20.0%
>23 (phosphorus limited)	16.7%	14.3%	0.0%

Based on the National Land Cover Dataset, all sites had between 94.6 and 100% natural land cover within 1000 m. Agriculture was mapped in the buffer of two sites, but analysis with aerial imagery indicated these areas were erroneously classified. One breeding, four non-breeding, and three random sites had more than 1% developed land cover in the buffer (figure 10). All developed land was mapped as open or low intensity development. Random sites had more deciduous forest cover than all other sites and more total forest cover than non-breeding sites; deciduous forest and overall forest cover were strongly correlated with one another. Differences in surrounding land cover could be related to differences in climate between random sites and all other sites; random sites had warmer mean temperature than other sites (p=0.02) based on analysis of variance on 30-year mean climate data from the PRISM Climate Group (Daly and others, 2008). Major roads were located within 1000 m of one breeding and one non-breeding site and 54% of random sites; differences in the proportion of sites with major roads nearby were marginally significant (Fisher's exact test, p=0.08). Density of all roads and distance to the nearest road did not differ by site type.

Classification Trees

The top landscape classification tree model separating recent/current sites from random sites correctly predicted all recent/current sites and nine of 13 random sites (figure 11a). The tree had one split based on the amount of shrub cover within 1000 m of sites; recent/current sites had at least 8.6% shrub cover. We created a second landscape model excluding the National Land Cover Dataset variables because differences in natural land cover may be due to natural environmental differences between site types rather than attributes important to boreal toad. The second landscape model correctly modeled all recent/current sites and 11 of 13 breeding sites and contained two splits based on the amount of palustrine wetland within 1000 m of sites (figure 11b). However, model results were not readily

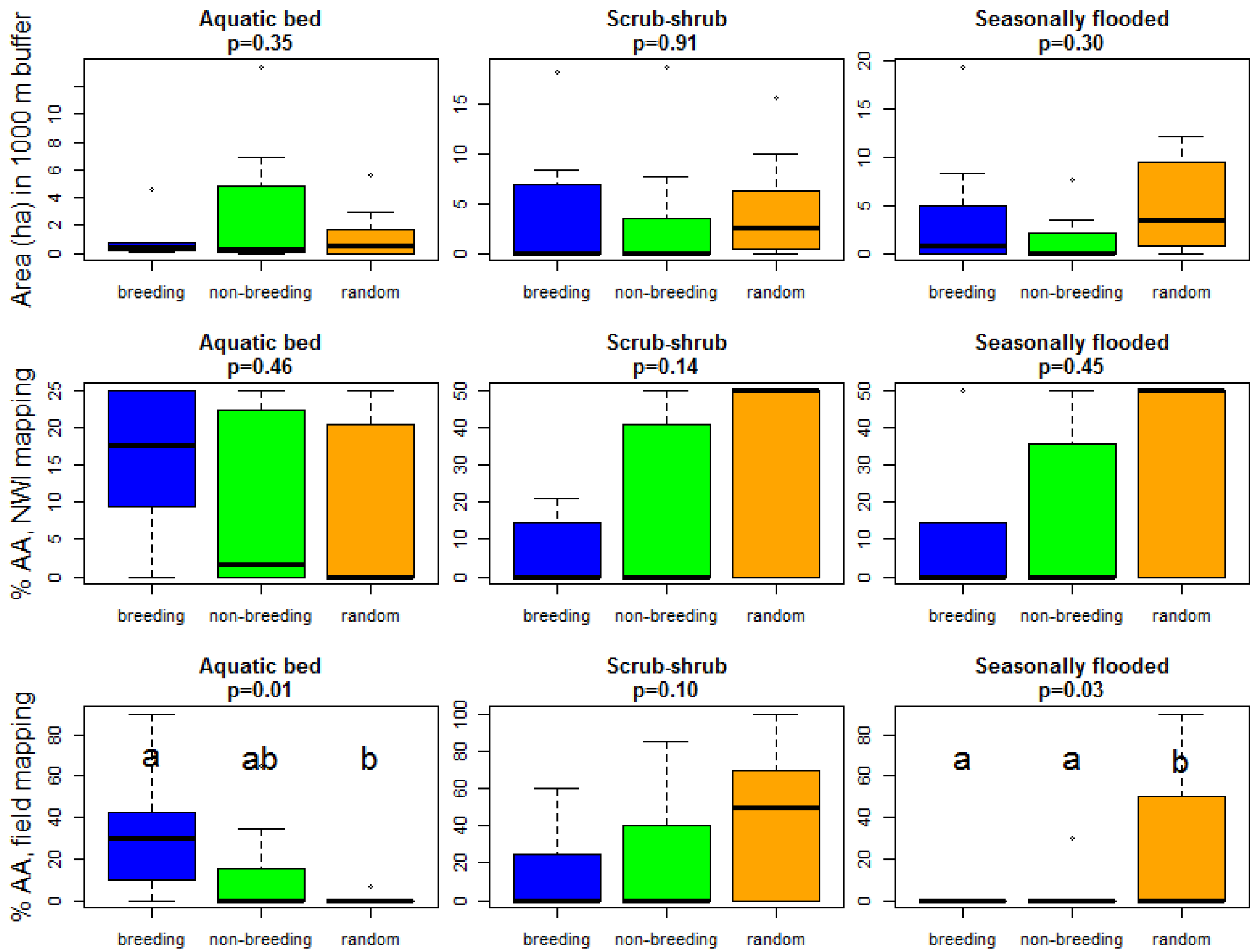
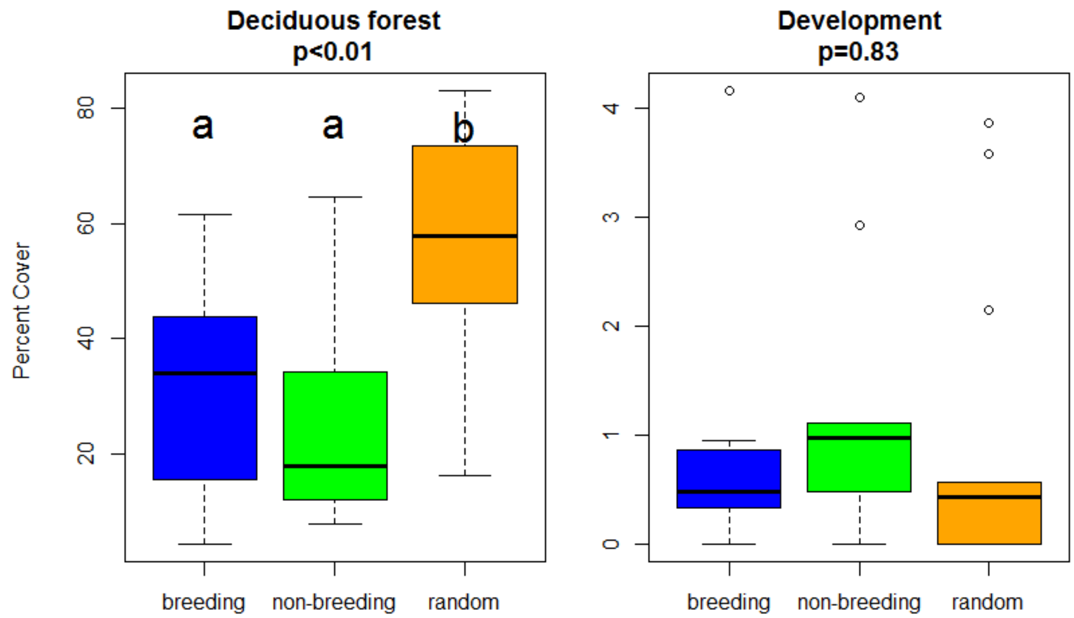


Figure 9. Wetland types surrounding or within assessment areas (AAs), from NWI data (top two rows) or field classification (bottom row) for breeding, non-breeding, and random sites. Significant differences in wetland classification by site type are indicated by analysis of variances p-values of less than 0.05; site types that do not share letters are significantly different from one another based on Tukey's honest significant difference test. Aquatic bed cover in the AA is significantly negatively correlated with field-mapped (Pearson correlation coefficient p= -0.66)and NWI-mapped (P= -0.74) scrub-shrub cover and NWI-mapped seasonally flooded wetlands (P= -0.76) and buffer, NWI-mapped, and AA-mapped scrub-shrub wetland are all inter-correlated (P≥0.62). Correlations for all other variables are less than or equal to the absolute value of 0.58.



Figure

Figure 10. Land cover within 1000 m of survey sites for breeding, non-breeding, and random sites. Significant differences in land cover by site type are indicated by analysis of variance p-values of less than 0.05; site types that do not share letters are significantly different from one another based on Tukey's honest significant difference test. Neither of the variables presented in plots were strongly correlated with one another (Pearson correlation coefficient = -0.16)

interpretable; recent/current breeding sites either had less than 0.37 ha or at least 19 ha of palustrine wetland in the surrounding buffer. The top landscape model to separate breeding and recent breeding sites was the null model.

The top classification tree model based on site data to separate recent/current sites from random sites correctly predicted all random sites and all but one recent/current site using two splits in the data (figure 11c). Sites with mean values across all six toad metrics below 3.8 were classified as random sites. The remaining sites were subject to a second split based on the percent of the dry portion of the AA with tree or shrub cover. Random sites had at least 60% woody species cover. The top classification tree model based on site data to separate breeding and recent breeding sites correctly predicted all recent breeding sites and all but one breeding site (figure 11d). Classification was based on a single split. Sites with at least 0.25% cover of water with submergent or floating (aquatic) vegetation were classified as breeding sites.

We used site data rather than landscape data to estimate the percent of random sites that may have suitable breeding habitat because of the issues with landscape models discussed above. The one random site classified as recent/current breeding also had water with aquatic vegetation, indicating that it may also have suitable breeding habitat. Four of the five random sites having mean toad metric values above 3.8 had some cover of water with aquatic vegetation. All three historical sites (not used in model development) had mean metric values above 3.8, but only one site also had aquatic vegetation and low cover of woody species.

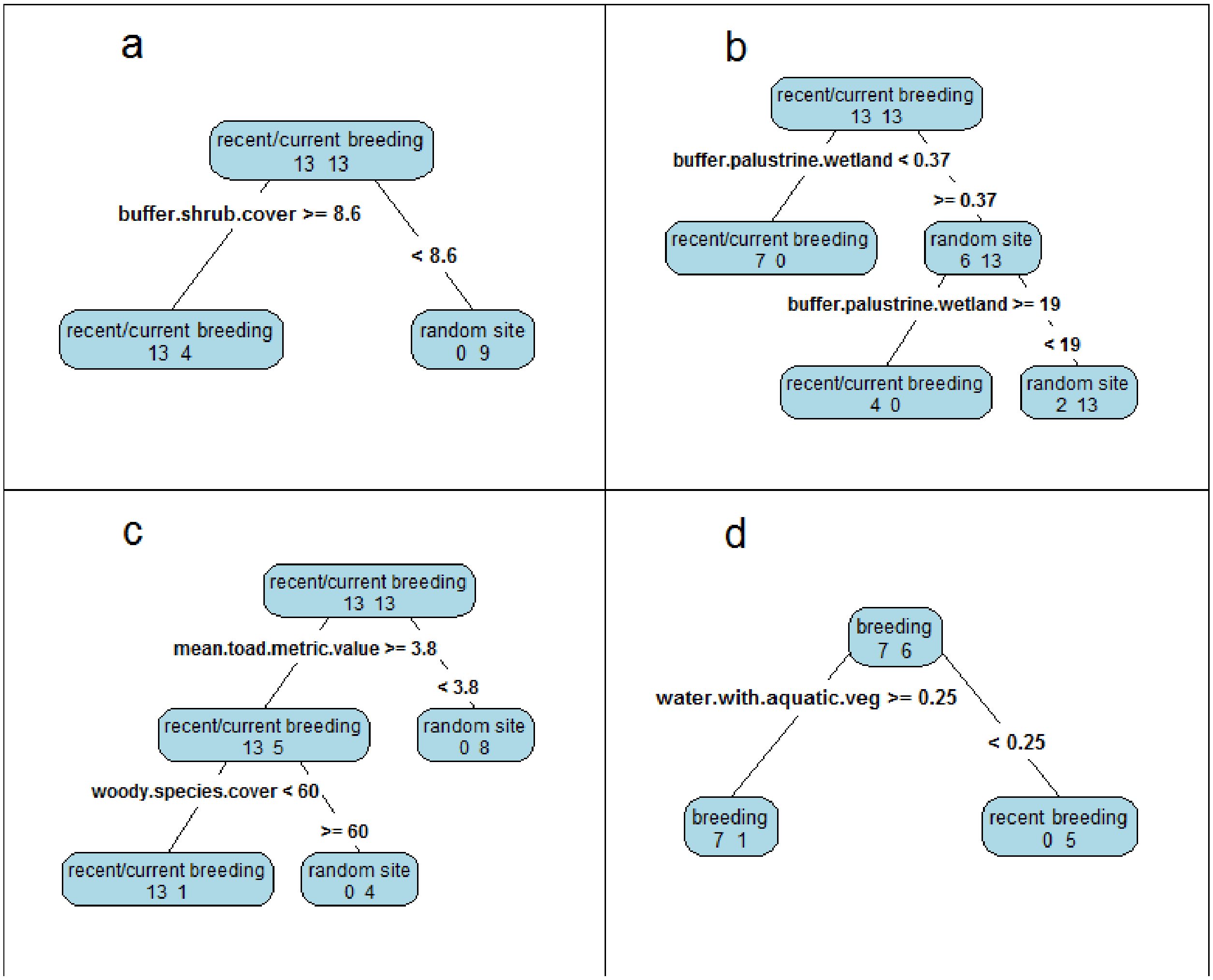


Figure 11. Classification tree results for models of recent/current sites versus random sites using landscape data with (a) and without land cover data (b), recent/current sites versus random sites using field data (c), and breeding versus non-breeding sites using site data (d). Variables include the percent cover of area mapped as shrubs within 1000 m of sites (buffer.shrub.cover), the area in hectares of mapped palustrine wetlands within 1000 m of sites (buffer.palustrine.wetlands), the mean value of the six toad metrics (mean.toad.metric.value), the percent cover of woody plant species within the dry portion of the assessment area (woody.species.cover), and the percent cover of water with floating or submerged vegetation in the assessment area (water.with.aquatic.veg).

Discussion

Attributes of Breeding Sites

Breeding sites exhibited a wide range of conditions in the field, indicating that breeding can sometimes occur close to (usually minor) roads and in wetlands with high cover of non-native plant species, intense soil disturbance, some hydroperiod alteration, and plentiful nuisance algae. Metrics developed specifically for the boreal toad were more helpful than general wetland condition metrics for distinguishing between breeding and random sites. Two of the toad metrics may need to be reconsidered. The shrub cover metric was developed based on previous research that indicated that adults select areas with high shrub cover to prevent evaporative water loss (Oliver, 2006), However, three of seven breeding sites were located in areas with little to no shrub cover and sites with very high (>60%) absolute cover of woody species, including shrubs, in the non-wet portions of AAs were unlikely to have any current or recent breeding, according to classification tree models. Field surveyors observed that high density cover of tall forbs, such as *Rudbeckia occidentalis* (western coneflower) and *Solidago altissima* (Canada goldenrod), was frequently located at breeding sites and may be able to provide similar cover for adult toads. Areas with very high shrub cover may lack basking locations for the toads.

The shallow water temperature metric was based on laboratory studies of egg and tadpole development. Carey and others (2005) reported that boreal toad eggs develop faster at 30°C than at 15°C and will not develop at a temperature of 10°C. Beiswenger (1978) documented that boreal toad tadpoles aggregate in areas with temperatures between 28 and 34°C when exposed to a gradient between 22 to 40°C and that temperatures of 37°C and above were lethal. The range for the 10th to 90th percentile of water temperature estimates for July 16 at breeding and recent breeding sites was 21.0 to 25.4°C, demonstrating that boreal toad eggs and tadpoles frequently develop at lower than optimal temperatures. Temperatures below 20.1°C may be less conducive to breeding; four random sites, and no other sites, had estimated temperatures below this value. Required temperatures are likely dependent on climate. Development has to occur more quickly at cooler, higher elevation sites when breeding takes place later in the summer and water may freeze before tadpoles undergo metamorphosis. Tadpoles at lower elevations may have more time to develop unless they are in shallow pools that dry up by the end of the summer. Accordingly, the coolest temperature breeding sites also were the lowest elevation breeding sites. The fact that the north shore exposure metric was a significant predictor of breeding sites suggests that temperature is likely an important factor for breeding, just not in the ranges suggested by the Ecological Integrity Tables. More appropriate water temperature thresholds for boreal toad should be developed with additional data from breeding locations, and adjustments should be made to estimated water temperatures based on time of day, day of year, and weather.

The presence of water with aquatic vegetation was the strongest and most consistent factor separating breeding sites from both random and non-breeding sites. Aquatic vegetation may directly create favorable habitat conditions for boreal toad. Aquatic vegetation may provide shelter or food in the form of organic detritus, though we did not find scientific literature in support of either possibility. Aquatic plants also may alter water chemistry, raising pH during the day when they remove carbon dioxide from the water for photosynthesis. A field guide to amphibians in the western United States observed that boreal toads are usually found in water with pH greater than 8.0 (Koch and Peterson, 1995); pH values below 6.0 may be particularly detrimental to the species (McGee and Keinath, 2004). One mechanism through which pH could be important to boreal toads is through the relationship between pH and the amphibian chytrid *Batrachochytrium dendrobatidis*, a fungal species associated with large population declines in boreal toad and other amphibian species in some areas, though some infected populations in Utah remain stable. The fungus grows best in a pH range of 6 to 7.5; growth is slower at a pH of 8 and very limited at pH of 9 or above (Johnson and Speare, 2005). However, any possible link between boreal toad, aquatic vegetation, pH, and chytrid is highly speculative. First, we did not find any significant differences in pH between site types, though breeding sites did have a trend towards higher pH values than non-breeding sites. Second, the macroalgae *Chara* spp. is likely to also raise pH values and was somewhat more common and abundant at non-breeding sites. Third, it is unclear whether slowed growth of chytrid in the laboratory actually translates to reduced infection rates of amphibians in high pH natural waterbodies.

Aquatic plant species may serve as indicators of suitable habitat if they are sensitive to environmental factors that are important to boreal toad, though obviously different species have different environmental requirements. Many aquatic plants, including the two most common in this study, exhibit increased growth in warmer water temperatures (Madsen and Brix, 1997; Wersal and others, 2006). *Stuckenia pectinata,* the most commonly recorded submerged species in this study, did not grow well in highly turbid water in Lake Heron, Minnesota (Wersal and others, 2006). Some submerged aquatic species are sensitive to increases in nutrients, as has been reported in estuaries in the eastern United States (Dennison and others, 1993), though studies of European lakes reported that *Stuckenia pectinata* replaces the macroalgae *Chara* spp. under eutrophic conditions (Kufel and Kufel, 2002). Aquatic vegetation at breeding sites *may* be related to warmer temperatures, less turbid water, and/or changes in nutrient levels, but more data are required.

Breeding and recent breeding sites had lower litter depth and a trend towards more visible bare soil compared to random sites. Participants at the Utah boreal toad conservation team meeting in December 2015 commented that there are observational reports of boreal toad populations disappearing after livestock grazing was removed from sites. Waston and others (2003) reported that moderate levels of livestock grazing were associated with Oregon spotted frog locations and hypothesized that intermediate levels of grazing may recreate missing natural disturbances and maintain areas of open water. Other studies, however, have observed that vegetation removal from livestock grazing can increase boreal toad mortality due to desiccation from lack of cover; grazing-related trampling deaths have also been recorded (McGee and Keinath, 2004). Litter depth measurements at sites were derived from only four measurements per site; litter depth and visible bare soil should continue to be evaluated at sites to determine whether ground cover plays a role in suitability for breeding.

Attributes of Non-Breeding Sites

We were not unable to identify a clear cause for why the non-breeding sites no longer appear to support breeding toad populations. Threats listed to boreal toad in the current Utah Wildlife Action Plan include drought, invasive and other problematic species, improper grazing, and abiotic conditions and processes, as well as taxonomic debate and data gaps (Utah Division of Wildlife Resources, 2015). We found no data to support drought being a concern at the non-breeding sites since non-breeding sites generally had as much or more water cover than breeding sites, including cover of water over 20 cm deep that may be less likely to dry up during drought years. We also did not find any evidence to suggest that non-breeding sites had more wildlife predators than breeding sites, though wildlife assessments from single surveys are not very robust. We did not test for the presence of chytrid at sites; site types may differ based on presence of this problematic fungal species. Recent Utah Division of Wildlife Resources testing of boreal toad or other amphibian species was positive for chytrid at four of seven breeding sites. Tests were positive at two and negative at three non-breeding sites; the remaining sites were not tested.

Some studies have reported that improper livestock grazing can be detrimental to boreal toad through direct mortality from trampling and through alteration of natural site conditions (McGee and Keinath, 2004). Improper livestock grazing near amphibian breeding sites can increase potential problematic water quality parameters such as turbidity, ammonium, nitrates, and phosphorus and can lower cover of aquatic and emergent plants (Knutson and others, 2004; Canals and others, 2011), though several studies documented that removing grazing from breeding areas had no impact on amphibian species site occupancy and water quality parameters (Adams and others, 2009; Roche and others, 2012) and in some cases moderate levels of grazing might benefit amphibian species (Watson and others, 2003). We found some evidence to suggest that levels of water quality stress may differ between breeding and non-breeding sites, though stressors were not solely due to livestock grazing. More non-breeding sites had potential issues with sediment and turbidity. Sedimentation stress from roads, trails, and rangeland was recorded in the buffers of 78% of non-breeding sites versus 43% of breeding sites, and 44% of non-breeding versus 14% of breeding sites scored C or worse on metrics related to soil disturbance and turbidity within the AA. High levels of sediment addition can reduce boreal toad tadpole survival and growth rates (Woods and Richardson, 2009). Nutrient addition from livestock grazing could also be an issue at sites. A slightly higher proportion of non-breeding sites had water contaminant stress recorded in the buffer (always related to livestock grazing) than at breeding sites; the stress was also recorded as higher severity at the non-breeding sites. More non-breeding sites had scores of C or lower for the wet or dry nuisance algae metrics (44% versus 14%), and the highest two to four values (depending on constituent) of nitrate plus nitrite, total nitrogen, and total phosphorus were all recorded at non-breeding sites. Addition of nitrogen and phosphorus increased tadpole mortality by about 12% in a mesocosm experiment (Woods and Richardson, 2009); other research reported that boreal toad tadpoles were the least sensitive of five amphibian species to nitrate addition, having no increase in tadpole mortality observed even at the maximum treatment dose of 20 mg/l (Marco and others, 1999). We did not find any link between nutrient levels and observed livestock grazing; high nitrate plus nitrite levels may in fact be associated with the presence of beaver.

Abiotic processes, in addition to nutrient cycling and sedimentation, may play a role in separating breeding and non-breeding sites. Non-breeding sites had a lot of emergent and very little submerged or floating leaf vegetation compared to breeding sites. It is unknown why these differences exist and what, if any, effect they might have on boreal toad populations. Emergent and aquatic plant communities may be indicative of other important site attributes, such as water temperature, nutrient availability, or turbidity. Vegetation may also directly impact species by providing cover or food or altering pH. Different drivers may be affecting different non-breeding sites, making it challenging to determine specific causes of decline. Some sites may no longer have breeding toads due to natural metapopulation dynamics, some due to heavy chytrid infection, and some due to increases in turbidity. Declines may also occur when multiple factors combine to create problematic conditions. For example, high turbidity could potentially lead to reductions in aquatic vegetation, subsequent decreases in pH, and increased rates of chytrid infection while also directly increasing tadpole mortality rates. Aquatic vegetation or other biologic parameters may be better indicators of such multi-factored change than single measures of turbidity or grazing intensity since the latter types of measures may be more susceptible to large within-season changes.

Recommendations

Our results provide limited help in using readily available GIS data to locate new boreal toad populations. Boreal toad breeding in this study was associated with areas mapped as aquatic bed, but not with aquatic bed density in the surrounding landscape, potentially because NWI mapping was often incorrect. We recommend using known breeding locations throughout the state and a more randomly distributed set of random sites to conduct a more thorough landscape analysis. We also support efforts to improve the accuracy of mapped wetland data. In the absence of better data, the best survey approach for locating new populations may be focusing on NWI-mapped aquatic beds close to known breeding populations.

We found several site attributes that are inexpensive and easy to collect that may be worth measuring at sites monitored for boreal toad. The boreal toad metrics were very useful at distinguishing between breeding and random sites. Adjustments may need to be made when large areas are surveyed rather than fixed assessment areas; for example, the metrics could be applied to 80 m sections along streams and then data could be summarized to determine the abundance of suitable habitat in the drainage area. We recommend collecting data on water temperature and pH with a handheld multi-parameter meter, along with time of day, weather, and survey date so that measurements can be adjusted for diurnal and seasonal changes. It may also be helpful to analyze temperature data for sites in different elevation or summer temperature classes since temperature needs may differ by climate. We also recommend collecting data on water clarity with a turbidity tube; see Utah Water Watch's instructions and video (http://extension.usu.edu/utahwaterwatch/htm/tier-1/turbidity/turbidity-tube). Last, we recommend collecting data on whether submerged aquatic vegetation, floating plants, and the macroalgae *Chara* are present at sites. Estimates could be made qualitatively (e.g., none, few, some, lots) or with cover estimates (e.g., percent of water with floating plants), depending on what was more consistent between surveyors. It would be helpful and relatively easy to identify the most common aquatic plants to the genus level (*Stuckenia* spp., *Ranunculus* spp., *Potamogeton* spp., *Callitriche* spp., and *Lemna* spp. in this study, though some *Stuckenia* and *Potamogeton* species are very similar). Surveyors may also need to be trained on distinguishing *Chara* from plant species. Data on aquatic vegetation and water quality parameters would be particularly interesting to collect at current and recent breeding sites to evaluate trends more broadly and provide some baseline data in the event of further population decline. Current field efforts to relocate new populations could also be aided by field surveyors honing in to key site attributes. Based on classification tree model results, the assessment areas at the relocated Lake Creek site and at the historical breeding Lake Martha and Nobletts Creek sites were not likely to have breeding toad populations because of lack of aquatic vegetation. More suitable areas along the lake or streams should be located. We created a modified field form that can serve as a template for future boreal toad habitat assessments (appendix B). The form may need to be modified to meet specific project needs, but includes the basic information that would be useful for assessing condition of breeding habitat and assessing the general suitability of an area used modified habitat metrics.

This project demonstrates the utility of collaboration between the Utah Geological Survey and the Utah Department of Natural Resources' Endangered Species Mitigation Fund to achieve results in addition to the primary objectives of this research. The Utah Geological Survey conducts wetland surveys throughout the state, often on private land or in obscure locations that are not subject to regular surveys by wildlife biologist. Surveyors documented a boreal toad during routine Jordan watershed project surveys, in large part due to training and a heightened awareness for amphibian species that occurred as a result of this project. The individual was documented at a site where the species had not been seen in almost 30 years; and surveyors were equipped with the knowledge needed to photograph identifying characteristics and contact Utah Division of Wildlife Resources staff immediately. We also shared our data on boreal toad observations from the known breeding sites with and information about potential fencing issues at some of the sites surveyed. The Utah Geological Survey should continue training field surveyors to document amphibian species and continue collecting boreal toad habitat data during field surveys. Data collection adds only a little time to field surveys and can provide information on the relative abundance of suitable habitat in project areas. Only one of thirteen randomly selected sites in the Jordan watershed were suitable for boreal toad, indicating that suitable habitat may be uncommon. Final habitat suitability estimates for the watershed should be obtained at the conclusion of the two-year Jordan watershed project.

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Appendix A

Boreal Toad Habitat Assessment Field Form Used in 2015 Field Surveys

Site ID:________________________ Survey Date:_____________ Surveyors:________________________________

Indicate presence of potential breeding habitats within AA or 100 m buffer. Record detailed information from one of each habitat type present within or immediately adjacent to AA. You may record data on more than one feature of a particular habitat type to capture variability within the feature.

Beaver pond	AA buffer	**Reservoir**	AA buffer	**Pool or open water in wetland**	AA buffer
Stream/river backwater	AA buffer	**Other pond/lake**	AA buffer		

Feat. #[1]	Type[2]	In AA?	Shore (N, NE, etc.) or Center[3]	Shore Slope (Gentle, Mod., Steep, NA)[3]	Survey Time (24 hour time)	Current Weather (Clear, Cloudy, Overcast, Precips.)	Water Temp. (°C) @ ~10 cm depth	Collect in deeper tadpole habitat			% Water in Depth Categories			Vegetation Typical of Area Where Water Temperature Taken			
								pH	EC (uS)	Depth (cm)	<20 cm	20-50 cm	>50 cm	SAV?	Emerg-ent?	Floating Leaf?	Canopy Cover?
		Y N		G M S N										None Few >Few	None Few >Few	None Few >Few	None Few >Few
Notes:																	
		Y N		G M S N										None Few >Few	None Few >Few	None Few >Few	None Few >Few
Notes:																	
		Y N		G M S N										None Few >Few	None Few >Few	None Few >Few	None Few >Few
Notes:																	
		Y N		G M S N										None Few >Few	None Few >Few	None Few >Few	None Few >Few
Notes:																	
		Y N		G M S N										None Few >Few	None Few >Few	None Few >Few	None Few >Few
Notes:																	
		Y N		G M S N										None Few >Few	None Few >Few	None Few >Few	None Few >Few
Notes:																	

[1]Number features sequentially starting at one, using the same number on two sets of measurements if more than one measurement is taken within the same feature.
[2]Types include B: beaver pond, S: stream/river backwater, R: reservoir, P: other pond/lake, W: pool or open water in wetland.
[3]Select center for small pools, ponds and openings that are unlikely to have much differentiation between temperatures across the waterbody. Only measure shore slope for features with distinct shores.

Walk four transects 100 m out from the edge of the AA in each cardinal direction and note hibernation features observed.

Transect	Woody Debris Piles	Animal Burrows	Loose Soil	Other Hibernation Features (rocky chambers near streams, rotted tree root channels, abandoned beaver lodges, overhanging stream banks)
N	None Few >Few	None Few >Few	None Few >Few	None Few >Few **List:**
E	None Few >Few	None Few >Few	None Few >Few	None Few >Few **List:**
S	None Few >Few	None Few >Few	None Few >Few	None Few >Few **List:**
W	None Few >Few	None Few >Few	None Few >Few	None Few >Few **List:**
Overall	None Few >Few	None Few >Few	None Few >Few	None Few >Few **List:**

Notes

Rank egg mass habitat found within or immediately adjacent to AA. If surface water typically present, but dried up due to drought or survey late in the growing season, select C for types of waterbodies and estimate slope and north shoreline.

Rank	Types of Waterbodies Within or Immediately Adjacent to AA
A	Lentic and large enough not to dry up and deep enough not to freeze at night during summer—lakes, ponds (especially beaver ponds), large pools (including artificially created ponds and pools).
B	Lotic: low-velocity, low-gradient streams, springs.
C	Lotic: rivers, streams or lentic but very small or uniformly shallow—temporary pools, small puddles.
D	No surface water typically present at site.
Rank	**Slope and Water Depth Near Shore**
A	Predominately gentle slopes and/or large area, esp. along north shores, with gentle slopes; water <10 cm common
B	Mixture of gentle and steeper slopes having some areas with <10 cm deep water; gentle slopes common but not predominant and not occupying the majority of the north shores.
C	Gentle slopes present, but uncommon; few areas with water <10 cm deep.
D	All shoreline with steep slopes; water <10 cm not present.

Rank	Presence of North Shore (Long Axis of Waterbody)	Rank	Daytime Summer Water Temp. in Shallows
A	Ample north shore present. Long axis of waterbody arranged E-W and/or waterbody with ample shoreline along both axes (i.e., rounded pond).	A	28–34 °C
B	Moderate amount of north shore present. Long axis of waterbody arranged NE-SW or NW-SE or may be N-S if minor axis almost as long as major axis (i.e., wide oval pond).	B	16–27 °C or 35 °C
C	Minor amount of north slope present. Long axis of waterbody may be NNE-SSW or NNW-SSE or may be arranged N-S with moderately wide minor axis (if pond) or some meandering (if stream) creating some north shore.	C	11–15 °C or 36 °C
D	Little or no north shore present. Long axis of waterbody north to south with little shoreline along minor axis (typically narrow waterbodies such as a stream) .	D	≤10 °C or ≥37 °C
		NA	No water present

Notes on egg mass habitat:

Rank adult habitat and hibernation habitat found within area spanning AA and 100 m buffer

Rank	Shrub Cover in AA and 100 m Buffer (Evaluate along stream floodplain or in valley bottom near pond/lake)
A	Ample shrub cover near waterbodies. Generally this will entail at least a third of the area along a stream floodplain or valley bottom near a pond or lake with understory of moderate to dense shrub cover.
B	Moderate shrub cover near waterbodies, with approximately 21 to 33% of area with moderate/dense shrub cover, or shrubs widespread but scattered.
C	Low shrub cover near waterbodies, with approximately 5 to 20% of area having moderate/dense shrub cover.
D	No or only a few scattered shrubs present (<4% shrub cover).
Rank	**Hibernation Features within AA and 100 m Buffer**
A	Features such as burrows (esp. ground squirrels), interstices of beaver dams, old beaver lodges, overhanging stream banks, rocky chambers near streams, cavities under boulders or tree roots, loose soil, and/or woody debris piles common and connected to summertime habitat.
B	Above features present but not abundant. Some area with features may be disconnected from summertime habitat due to low use roads or other low severity fragmentation, but some features not fragmented from site.
C	Above features present but rare and/or only present on very steep slopes or disconnected from summertime habitat by busy roads, development, or other severe fragmentation.
D	None of the above features present.

Notes adult habitat

Mark below to indicate potential predators observed during site surveys

Species	Observed?	Species	Observed?	Species	Observed?
Gray jay	**Y N**	Tiger salamander	**Y N**	Badger	Sighting Den Not observed
Raven or crow	**Y N**	Trout	**Y N**	Fox	Sighting Tracks Not observed
Robin	**Y N**	Snake	**Y N**	Raccoon	Sighting Tracks Not observed

Notes on predators

Appendix B

Modified Boreal Toad Habitat Assessment Field Form

Boreal Toad Habitat Assessment Field Form

Surveyor Names:____________________________
Site ID[1]: ____________________________________
Site Name[1]:_________________________________
UTME[1]:___ ___ ___ ___ ___ ___
UTMN[1]: ___ ___ ___ ___ ___ ___ ___

Survey Date:__________________________
Survey Time (24 Hr.):__________________
Current Weather and Cloud Cover (circle one):
Clear(0% cloud) Mostly Clear(<25%) Partly Cloudy(25-50%)
Mostly Cloudy(50-99%) Overcast(100%) Light rain
Heavy rain Snow
Air Temperature:______ °C

Boreal Toad Status at Site (select one):
____Active breeding location (within past 5 years)
____Recent breeding location (past 6 to ~20 years)
____Active/recent adult location (within past 20 years)
____Historical adult location (exact location may be unknown)
____Potential new site (no known boreal toad sightings)
If known:
Breeding last documented in _______ (year)
Adult last documented in _______ (year)

Features Present at Site (select all that apply)
___1 Beaver pond active inactive unknown (circle)
___2 Stream/river backwater
___3 Reservoir
___4 Other pond or lake
___5 Pool or open water in wetland
___6 Other (describe________________________________)

Additional Site Description, including Management Notes[1]:

Vegetation Growing in Water (select all that apply)
____ 1 Duckweed / Lemna spp. (Floating Leaf)
____ 2 Pondweed / Stuckenia spp. (SAV)
____ 3 White water buttercup / Ranunculus aquatilis (SAV)
____ 4 Water-starwort / Callitriche spp. (SAV)
____ 5 Macroalgae / Chara spp. (Chara)
____ 6 Sedge / Carex spp. (Emergent)
____ 7 Grass / Poaceae (Emergent)
____ 7 Misc. Forb Species / Mimulus, Veronica, etc. (Emergent)
____ 8 Other species:________________________________

Feature Type (# from above): _____ Boreal Toad Observations in Feature (circle)[2]: Egg Mass Tadpole Adult None
Depth Categories in Feature[2] _____ % <20 cm _____ % 20-50 cm _____ % >50 cm
Cover of Water in Feature with:[2] ____% No Veg. ____% Floating ____% SAV ____% Chara ____% Emergent
Depth at measurement: ____ cm Shore[2] (N, NE, etc., or Center):______ Shore Slope[2]: Gentle Mod. Steep NA
Temperature:____ °C pH:____ EC:____ uS Turbidity Tube Depth (circle) > or = ______ cm
Vegetation at measurement:
Chara: None Few >Few *SAV:* None Few >Few *Floating Leaf:* None Few >Few *Emergent:* None Few >Few *Canopy Cover:* None Few >Few
Measurement Location Notes:

Feature Type (# from above): _____ Boreal Toad Observations in Feature (circle)[2]: Egg Mass Tadpole Adult None
Depth Categories in Feature[1] _____ % <20 cm _____ % 20-50 cm _____ % >50 cm
Cover of Water in Feature with:[1] ____% No Veg. ____% Floating ____% SAV ____% Chara ____% Emergent
Depth at measurement: ____ cm Shore[3] (N, NE, etc., or Center):______ Shore Slope[3]: Gentle Mod. Steep NA
Temperature:____ °C pH:____ EC:____ uS Turbidity Tube Depth (circle) > or = ______ cm
Vegetation at measurement:
Chara: None Few >Few *SAV:* None Few >Few *Floating Leaf:* None Few >Few *Emergent:* None Few >Few *Canopy Cover:* None Few >Few
Measurement Location Notes:

Feature Type (# from above): _____ Boreal Toad Observations in Feature (circle)[2]: Egg Mass Tadpole Adult None
Depth Categories in Feature[1] _____ % <20 cm _____ % 20-50 cm _____ % >50 cm
Cover of Water in Feature with:[1] ____% No Veg. ____% Floating ____% SAV ____% Chara ____% Emergent
Depth at measurement: ____ cm Shore[2] (N, NE, etc., or Center):______ Shore Slope[2]: Gentle Mod. Steep NA
Temperature:____ °C pH:____ EC:____ uS Turbidity Tube Depth (circle) > or = ______ cm
Vegetation at measurement:
Chara: None Few >Few *SAV:* None Few >Few *Floating Leaf:* None Few >Few *Emergent:* None Few >Few *Canopy Cover:* None Few >Few
Measurement Location Notes:

[1]Generally describe area surveyed if not a discrete feature. Management concerns may include fencing issues, evidence of livestock or recreational disturbance, etc.
[2]Only record once per unique features (e.g., once per beaver pond, but record separately for each beaver pond)
[3]Select center for small pools and opening that are unlikely to have much differentiation in temperature. Only measure shore slope for features with distinct shores.

Boreal Toad Habitat Assessment Field Form

Rank egg mass habitat found at site. If surface water typically present, but dried up due to drought or survey late in the growing season, select C for types of waterbodies and estimate slope and north shoreline.	
Rank	**Types of Waterbodies Within or Immediately Adjacent to AA**
A	Lentic and large enough not to dry up and deep enough not to freeze solid at night during summer—lakes, ponds (especially beaver ponds), large pools (including artificially created ponds and pools).
B	Lotic: low-velocity, low-gradient streams, springs.
C	Lotic: rivers, streams or lentic but very small or uniformly shallow (temporary pools, small puddles).
D	No surface water typically present at site.
Rank	**Slope and Water Depth Near Shore**
A	Mostly gentle slopes and/or large area, esp. along north shores, with gentle slopes; water <10 cm common.
B	Mixture of gentle and steeper slopes having some areas with <10 cm deep water; gentle slopes common but not predominant and not occupying the majority of the north shores.
C	Gentle slopes present, but uncommon; few areas with water <10 cm deep.
D	All shoreline with steep slopes; water <10 cm not present.
Rank	**Presence of North Shore (Long Axis of Waterbody)**
A	Ample north shore present. Long axis of waterbody arranged E-W and/or waterbody with ample shoreline along both axes (i.e., rounded pond).
B	Moderate amount of north shore present. Long axis of waterbody arranged NE-SW or NW-SE or may be N-S if minor axis almost as long as major axis (i.e., wide oval pond).
C	Minor amount of north slope present. Long axis of waterbody may be NNE-SSW or NNW-SSE or arranged N-S with moderately wide minor axis (if pond) or some meandering (if stream) creating some north shore.
D	Little or no north shore present. Long axis of waterbody north to south with little shoreline along minor axis (typically narrow waterbodies such as a stream).
Rank adult habitat and hibernation habitat found within 140 m of potential egg mass habitat.	
Rank	**Hibernation Features**
A	Features such as burrows (esp. ground squirrels), interstices of beaver dams, old beaver lodges, overhanging stream banks, rocky chambers near streams, cavities under boulders or tree roots, loose soil, or woody debris piles common and connected to summertime habitat.
B	Above features present but not abundant. Some area with features may be disconnected from summertime habitat due to low use roads or other low severity fragmentation, but some connected features present.
C	Above features present but rare or only present on very steep slopes or disconnected from summertime habitat by busy roads, development, or other severe fragmentation.
D	None of the above features present.
Rank	**Cover of Shrubs or Understory-Forming Tall Forbs (e.g., goldenrod, coneflower); Evaluate along stream floodplain or in valley bottom near pond/lake. Cover estimates pertain to area without standing water.**
??	Very abundant cover near waterbodies. Over 60% of non-water area along stream floodplain or valley bottom with understory cover. Over-abundant cover may be problematic for species.
A	Ample cover near waterbodies. Generally this will entail 33 to 60% of the area along a stream floodplain or valley bottom near a pond or lake with moderate to dense cover of understory-forming species.
B	Moderate cover near waterbodies, with approximately 21 to 33% of area having moderate/dense cover, or cover abundant, but very patchy
C	Low cover near waterbodies, with approximately 5 to 20% of area having moderate/dense cover
D	No or only a few scattered areas with cover present (<4% cover)
List Predominant Understory Cover Type at Sites (e.g., willow, forbs, etc.) and Notes About Any Metric:	

Observations of potential predators?	____ Jay / Raven / Crow / Robin / Hawk
____ Tiger Salamander	____ Snake
____ Trout	____ Badger / Fox / Raccoon