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Amphibian Occupancy and Functional Connectivity of Restored Wetlands in the Missouri River Floodplain

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AMPHIBIAN OCCUPANCY AND FUNCTIONAL CONNECTIVITY OF RESTORED WETLANDS IN THE MISSOURI RIVER FLOODPLAIN

by

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Wetland decline may threaten many taxa including shorebirds, amphibians, and fish. As agencies increase restoration of wetland habitat, monitoring is crucial to inform the process. Permeable skin sensitive to water quality and biphasic life histories requiring both terrestrial and aquatic habitat make amphibians good indicators of wetland health. I modeled amphibian occupancy in restored Missouri River bends to determine habitat characteristics associated with the presence of amphibians.

Occupancy modeling acknowledges imperfect detection and allows the inclusion of detection covariates. To assess detection I examined two methods currently used to assess anuran occupancy in wetlands, aural anuran surveys and tadpole dip-netting. I assessed survey and site-specific factors that may influence detection success of anuran species using these two methods and found that water temperature appears to play a role in aural detection of some species during call surveys. Slope impacts detection of tadpoles and may be indicative of a sampling bias.

I incorporated the top detection models into my candidate models testing the effect of habitat characteristics on amphibian occupancy. My results indicate that the slope of a wetland is driving occupancy of many species at the research sites. In most cases slope had a negative impact on occupancy. Landscape characteristics, like connectivity of wetlands, facilitate between-patch dispersal and may be just as important to the local persistence of amphibians. I assessed connectivity for anurans of

wetlands within a bend and recommend locations for new restorations that can improve connectivity of the bend. I found that average connectivity of a bend may not be the best indicator of functional connectivity. All of the research bends had clusters of wetlands that were highly connected to one another but relatively unconnected to the rest of the complex.

I suggest that future site selection should focus on shallow, gently sloping wetlands and that a few well-placed restorations could increase functional connectivity of the complex and improve the resilience of amphibian populations to droughts, floods, and localized disturbances like land-use changes.

Michelle Hellman

I would like to dedicate this work to my parents, Dennis and Sharon Hellman, who have been immensely supportive throughout my life and my studies, to my sister, Heather Wilt, who started me on a path of science and has given me great encouragement along the way, and to Mike Zundel, who has been patient and calm when I was neither.

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I would like to thank the U.S. Army Corps of Engineers without whom there would be no project. Their funding of this project and their continued efforts at restoration along the Missouri River shows a dedication to improving and conserving wildlife habitat for generations to come.

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CHAPTER 1: INTRODUCTION

Floodplain wetlands are one of the most commonly degraded and destroyed ecosystems in the world (Tockner et al. 2008) that provide critical habitat to many species. Amphibians, reptiles, fish and waterfowl require wetlands to breed and forage. Wetlands provide critical ecosystem services including water filtration, erosion control, and nutrient retention that improve groundwater and river water quality (Costanza et al. 1997). They can be biological "hotspots" and increase regional biodiversity (Hansson et al. 2005). Historically wetlands have been eliminated for agriculture, urban development, and flood control (Galat et al. 1998). Amphibians, which are wetland-dependent for much, if not all, of their life history, have experienced severe global and local declines (Semlitsch 2000, Collins and Holliday 2005). The local population decline of several species has been documented in the Missouri River floodplain, including the Smallmouth Salamander (*Ambystoma texanum*) and the Northern Cricket Frog (*Acris crepitans*) (Lannoo et al. 1994).

The Missouri River is the second longest waterway in North America. The River extends from headwaters in Montana to the confluence with the Mississippi River near St. Louis (Figure 1.1). The Missouri River watershed drains nearly one-sixth of the mainland United States (CERC 2009). The Lower Missouri River, from Sioux City, Iowa to the Mississippi River, is the most channelized and managed section of the River and is the focus of current restoration projects by the U.S. Army Corps of Engineers (Galat et al. 1998). The Basin is part of the central flyway and plays a crucial role as stopover habitat during the migration of millions of waterfowl, shorebirds, and songbirds and contains breeding grounds for the least tern (*Sternula antillarum*), piping plover (*Charadrius melodus*), and bald eagle (*Haliaeetus leucocephalus*) (MRRP 2009). More than 156 species of fish including pallid sturgeon (*Scaphirhynchus albus*) and American paddlefish (*Polyodon spathula*) inhabit the main channel, side-channels, and backwaters of the Missouri River.

The U.S. Army Corps of Engineers has been responsible for providing flood control and maintaining navigation along the Missouri River since the enaction of the Missouri River Bank Stabilization and Navigation Act in 1912 (U.S. Army Corps of Engineers 2010). The U.S. Army Corps of Engineers has channelized the lower and central portions of the river and installed dams to control water levels. They also built levees at each of the major river bends to prevent flooding and to ensure that water levels remain sufficient for navigation (U.S. Army Corps of Engineers 2006). Although these measures have significant economic and public safety benefits they have also contributed to the loss of floodplain wetlands. As of 2003, more than 211,000ha (522,000ac) of Missouri River riparian habitat were lost as a result of the Bank Stabilization and Navigation Project (U.S. Army Corps of Engineers 2006).

The loss of quality habitat and the consequential decline of riparian wetland-dependent species led to legislative action to help restore the lost habitat (U.S. Army Corps of Engineers 2006). In 1986 Congress passed the Missouri River Mitigation Project which authorized the purchase of 67,481ha (166,750ac) along the Missouri River in Iowa, Nebraska, Kansas and Missouri. In Nebraska, the project aims to restore 10785ha (26,652ac) (U.S. Army Corps of Engineers 2006). These properties are being managed to preserve existing wetlands as well as to create new mitigation wetlands. The objectives of the Missouri River Mitigation Project are to restore historic habitat and side-channels in the Missouri River floodplain and to provide or create habitat for fish, waterfowl, mammals, and amphibians.

The Natural Resources Conservation Service (a division of the U.S. Department of Agriculture) is working in conjunction with the U.S. Army Corps of Engineers to improve wetland quality and connectivity in the Missouri River floodplain. The Natural Resources Conservation Service's Wetland Reserve Enhancement Program, started in 2004, is an incentive program for landowners adjacent to U.S. Army Corps of Engineers restorations. Landowners agree to manage their land for wetland preservation and in turn receive financial and technical assistance. The Wetland Reserve Enhancement Program has a goal of restoring 7,248 hectares (18,800 acres) (Natural Resources Conservation Service 2010). As of 2010, landowners had already enrolled over 4,000 hectares (10,000 acres) in the program (The Nature Conservancy 2010).

Wetland restorations are created in a variety of ways. In the simplest approach, flood-prevention measures are removed and land is allowed to flood seasonally. In a more hands-on approach, the U.S. Army Corps of Engineers employs several engineering and management tools. Backwaters and chutes (open, often lined channel that is used to divert water into irrigation canals and other inland reservoirs) that have filled with sediment and debris are dredged to restore flows. Dikes, chutes and levees may be notched to create aquatic habitat (Missouri River Recovery Program, MRRP 2007). Desirable aquatic vegetation can be introduced to provide habitat and help prevent invasions by undesirable or invasive hydrophilic plants. When flow-through or groundwater is insufficient pumping can occur to maintain water levels (Missouri River Recovery Program 2007).

In addition to creating and preserving wetland habitat, the U.S. Army Corps of Engineers is focusing efforts on monitoring the success of these restorations. Scientists and agency personnel from Iowa, Nebraska, Kansas and Missouri have begun monitoring at the restored river bends. Current research focuses on fish species and herpetofauna utilizing restored areas (A. Bruce, U.S. Army Corps of Engineers, personal communication). Future monitoring programs will be developed to assess waterfowl and migratory bird use at these sites with an emphasis on threatened and endangered species including the Least Tern and the Piping Plover (A. Bruce, U.S. Army Corps of Engineers, personal communication). The information gathered will be used to improve current and future restoration attempts by the U.S. Army Corps of Engineers. The scope and cost of the Missouri River Mitigation Project makes these monitoring efforts crucial to its success.

Due to their sensitivity to water quality and their variable life cycle requiring both aquatic and terrestrial habitat, amphibians can be used as indicators of wetland quality (Welsh and Ollivier 1998, Semlitsch 2000). Determining amphibian assemblages at mitigated wetlands can assess how well a wetland is functioning (Micacchion 2002). Agencies in Ohio and Missouri have developed indices using amphibians as a metric for wetland health (Shulse et al. 2009). Further consideration of species presence in relation to wetland characteristics can create guidelines for future restorations.

I surveyed amphibians and wetland habitat in three restored river bends along the lower Missouri River in southeast Nebraska. I modeled environmental and habitat factors that may influence the presence and successful detection of anurans found during surveys. Habitat covariates found to influence amphibian occupancy can inform future restoration and improve management of existing wetlands. I also assessed the connectivity of the wetland complexes with reference to anuran species and modeled how connectivity could change with wetland loss. Site selection within a connectivity framework can improve resilience of amphibian populations in floodplain wetlands as well as improve functioning of the wetland complexes for commensal species. Recommendations made here will be part of a four-state assessment provided to the U.S. Army Corps of Engineers.

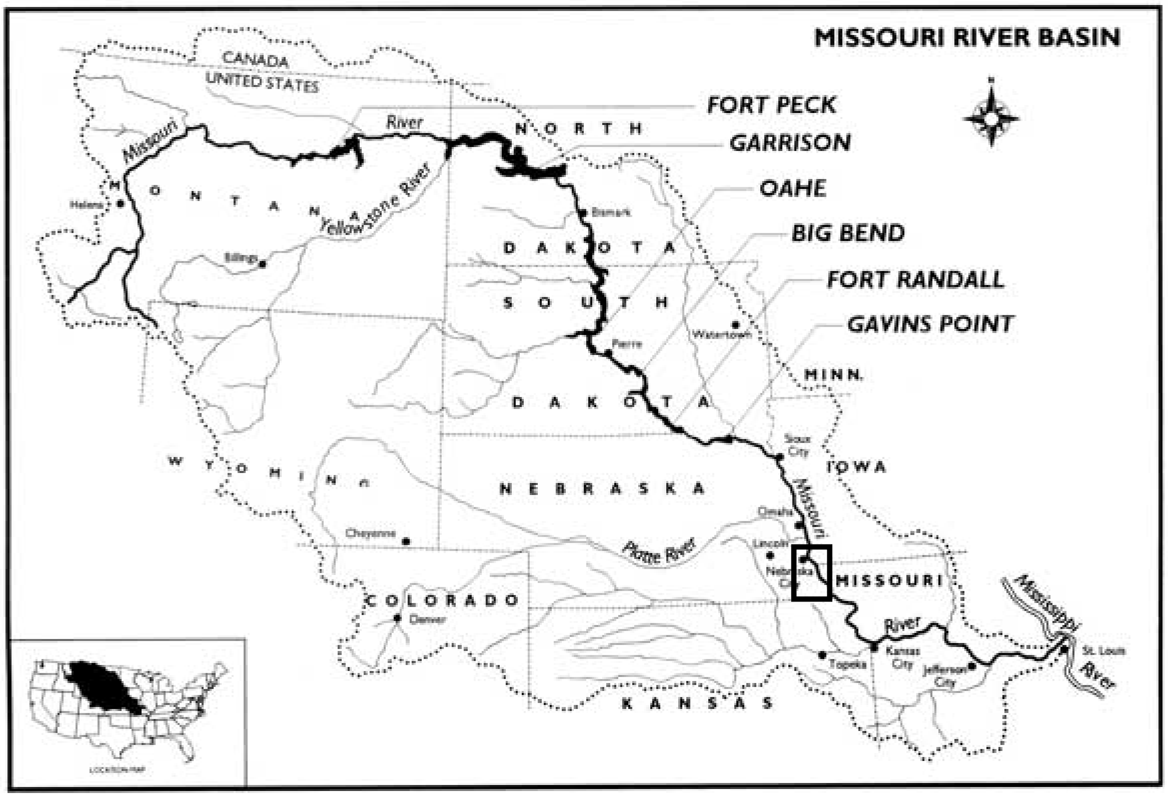

Figure 1.1. *The Missouri River watershed.* The Missouri River watershed includes all or part of ten states and drains nearly one sixth of the continental United States. My study area is indicated by the rectangle. Image used with the permission of the Missouri Department of Natural Resources, Water Resources Center.

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CHAPTER 2: FACTORS INFLUENCING DETECTION OF AMPHIBIANS USING AURAL AND DIP-NET SURVEYS

INTRODUCTION

The rapid decline of amphibians worldwide has been attributed to disease (Pounds et al. 2006), habitat loss or degradation (Gardner et al. 2007, Stuart et al. 2004), and climate change (Daszak et al. 2005, Buckley and Beebee 2005). This has resulted in an increasing need to monitor at-risk amphibian populations. Some intensive monitoring studies utilize drift fences, pitfall traps, dip-netting, and simulated refugia traps to assess population levels at individual wetlands (Pechmann et al. 1989, Rubbo and Kiesecker 2005, Daszak et al. 2005). Such studies offer rich data on population sizes, recruitment rates, and species evenness within the wetland or wetlands being studied, but are constricted to a small spatial scale. To assess presence at a larger spatial scale, the North American Amphibian Monitoring Program uses roadside call surveys to detect amphibians along predetermined routes. The program, conducted by U.S. Geological Survey's Patuxent Wildlife Research Center, uses volunteers to survey routes in 25 states. This produces abundant low-precision presence data across a large spatial scale.

In the last decade occupancy modeling (MacKenzie and Royle 2001) has emerged as a tool to assess presence that is well-suited to large landscapes or patchy habitats. Occupancy models allow variable occupancy (or likelihood that a "patch" is occupied by a species of interest) and detection rates (the likelihood that, if present, a species will be successfully detected) to be calculated for species within a habitat patch. Occupancy data is a binomial representation of presence or absence (or more correctly detection and lack of detection) based on a minimum of two repeat visits within an ecologically defined period of time.

A feature of MacKenzie's occupancy model is the ability to incorporate variation in detection that may result from survey specific or site specific covariates (MacKenzie et al. 2006). Species' behavior and life history can also affect detection likelihoods and result in variable detection success. Several studies have compared detection rates among survey methods (Gunzberger 2007), observers (Lotz and Allen 2007), and species (Schmidt 2005). Gunzbereger found untimed aural surveys to have higher detection success across species than other methods, including dip-netting. Most amphibian monitoring occurs using aural surveys similar to the five minute survey used by the North American Amphibian Monitoring Program. It is possible that tadpole dip-netting could have better detection success for some amphibian species than a timed aural survey. To test this I chose two sampling methods that target different anuran life stages, timed call surveys for adults and effort-capped dip-netting for larvae. Using MacKenzie's detection-based occupancy models and a multi-model inference approach I tested a suite of models with survey and site specific covariates that may impact detection. I discuss factors that appear to influence detection and compare detection probabilities between sampling methods.

MATERIALS AND METHODS

Study Area

I selected research wetlands located in three river bends undergoing restoration by the U.S. Army Corps of Engineers, Hamburg Bend in Otoe County and Kansas Bend and Langdon Bend in Nemaha County in southeast Nebraska (Fig. 2.1). The Langdon Bend

Mitigation Site consists of 529 hectares (1,308 acres) of former agricultural land purchased by the U.S. Army Corps of Engineers. The site has undergone restoration including the reopening of a historic side-channel and the addition of shallow water habitat. To supplement rainwater fed wetlands at this site the Corps has installed two water pumps designed to flood wetlands in autumn to provide habitat for migratory waterfowl. These plans were completed in 2000 and the site is operational (U.S. Army Corps of Engineers 2006). The Kansas Bend Mitigation Site is located on 427 hectares (1,056 acres) purchased by the Army Corps. Privately owned farmland bisects the U.S. Army Corps of Engineers property. As part of restoration efforts two historic side-channels have been dredged and reopened using the same methods utilized in the Langdon restoration. However, in the Kansas bend both channels will be connected at both ends to the main channel. The side-channels were reopened in 2004, and Nebraska Game and Parks has assumed management of much of the site (U.S. Army Corps of Engineers 2006). The Hamburg Bend site consists of 637 hectares (1,576 acres) of former agricultural property purchased by the Army Corps. The majority of restoration efforts at this site focused on restoring a historic side-channel. Hamburg bend was among the first restorations in Nebraska and work was completed in 1996 (U.S. Army Corps of Engineers 2006).

I initially selected 55 sites to survey within the bends described above. The actual number of wetlands used in analysis varied with seasonal flooding and drying. The specific wetland sites were selected primarily using National Wetland Inventory and hydric soils GIS layers. I visited the sites on foot with a GPS unit and locations were recorded for repeat visits. I included in the study some additional wetlands encountered at the bends that had not been indicated in the GIS coverage. Several wetland types are represented within each river bend, including: sloughs, irrigation ditches, farmed ephemeral wetlands, unfarmed ephemeral waters, tributaries, and backwaters (Tables 2.1 and 2.2). Some properties that have been recently purchased by the U.S. Army Corps of Engineers or are newly enrolled in the Natural Resources Conservation Services's Wetland Reserve Enhancement Program still contain corn stubble and relatively bare soils, while other sites had well-established aquatic vegetation.

Anuran Call Survey

I conducted surveys over two years, 2010 and 2011, during three seasons, April, May, and June, and sampled each wetland holding water twice to allow for detection rates within seasons. Exceptions occurred when sites were flooded and wetlands were unreachable or wetland perimeters were undefinable. When this occurred, data were recorded at a safely reachable point nearest to the original site location. Call surveys are well established as a method to monitor and detect anuran species in wetlands (Van Gorp 1999, Genet and Sargent 2003). Most male anurans vocalize attraction calls during some or all of their breeding season. These vocalizations allow researchers to identify species present at a given wetland by conducting a simple call survey. Conducting separate surveys over a three month period captures seasonal variation in chorus assemblages. I began call surveys at least 30min after sunset and stood five to ten meters from the water's edge to avoid disturbing the chorus. I used a two minute acclimation period to allow any individuals disturbed by the approach to resume calling. The acclimation period was followed by a five minute call survey. I recorded the five minute survey on a digital recorder (Olympus DM-10) which I checked later for any missed or misidentified species (Lotz and Allen 2007). During the five minute listening period, all species heard were noted.

Tadpole Dip-netting

Some species' breeding season, and therefore vocalization period, may only last a few days after a major rain event. Other species such as the Plains Spadefoot Toad (*Spea bombifrons*) may be exceedingly rare or otherwise have a low detection rate, or may not call at all as in the case of the Smallmouth Salamander (*Ambystoma texanum*). Tadpole dip-netting is an alternative to call surveys to estimate detection rates and presence. I sampled each site using a dip-net twice during each of the three seasons, except when sites had dried or were unreachable due to flooding. As with call surveys, if floodwaters were connected to the original site and prevented us from reaching the sampling point, data were collected from a safely approachable location nearest to the original site. If a site was unreachable and not thought to be connected to the floodwaters no sampling occurred.

In 2010, I attempted to dip-net around the entire perimeter of the wetland, with up to an hour of sampling effort per site. I used a combination of visual detection and targeted sweeps to assess tadpole species present. In an attempt to standardize sampling, I altered the methods in 2011 to a spatially constrained sample. I sampled 100m of shoreline in each direction with the call survey point at the center. I examined the shallows for visible tadpoles and egg masses. Additionally, I made a sweep every 10 m along the 200 m transect and noted all species caught. Two members of my research team sampled each site independently, usually on the same day. Survey data was arbitrarily assigned to survey 1 or survey 2 for analysis. To avoid interference between the two samples, the second researcher waited at least 30 minutes for the water to clear and the tadpoles to return to the water's edge.

Although the Chytrid fungus has only been documented once in Nebraska, it poses a threat to amphibians world-wide (Bosch et al. 2001, Oullet et al. 2005) and precautions should be taken to prevent the spread. All tadpole dip-netting supplies were disinfected in a 5% bleach water solution and scrubbed if necessary between wetlands (Department of Environment and Climate Change, Sydney).

Covariates

Several habitat and environmental factors were considered as potential covariates for the detection of anuran species. Some covariates (wind speed, air temperature) were collected only from 2011 while others (water temperature and time) were initially collected during call surveys but expanded to include tadpole samples. During both call surveys and tadpole sampling we recorded: the day, time of day, water temperature, wind speed, air temperature and presence of precipitation. Along the 200m of shoreline being sampled, a water depth measurement was taken 1m from the shoreline at 10m intervals. An average slope was calculated for each wetland. Every sweep of the dip-net was assigned a category of woody, herby or open water describing the habitat the dip-net penetrated. These were used to calculate a percentage of each aquatic vegetation type present along the 200m transect (number of sweeps designated as each vegetation type divided by the total number of sweeps). I estimated the size of each wetland as <0.83, 0.84-2.02, or >2.02 hectares (<2, 2.1-5, and >5.1 acres). Moonshine may affect visibility and calling behavior of anurans, and was calculated as a product of cloud cover and moon phase. I obtained hourly cloud cover data for Omaha Eppley Airport and Falls City Municipal Airport from the National Oceanic and Atmospheric Administration's database. Eppley Airfield is located in Omaha, Nebraska north of Hamburg (the northernmost bend) and Falls City Municipal Airfield is located in Falls City, Nebraska and south of Langdon (the southernmost bend). To estimate cloud cover at my research bends I took the average of the hourly cloud cover reported at each airfield. To account for moonlight I used nightly moon phase date from the U.S. Naval Observatory. Moonshine was then calculated as the product of % clear sky (1-%cloud cover) and the percent of the moon that was currently illuminated. All non-categorical covariates were scaled to within 0 and 1 to enable disparately scaled covariates to be modeled together.

Statistical Methods

I proposed a set of 12 candidate models to explain detection of adult anurans using call surveys (Tables 2.). The model set included a null and global model. The remaining adult detection models included six survey-specific covariates and one site-specific covariate thought to impact detection. Some models were proposed to explain variation in calling behavior due to environmental factors. *Day* tested if the day of year (or day since April 1) affected the likelihood of an individual calling. *Moonshine* tested if anurans were sensitive to nighttime visibility and would alter calling behavior in response to greater moonlight. *Time of day* tested whether calling activity might vary over a single night. *Water temperature* and *air temperature* tested whether physical responses to temperature would affect calling behavior. Other models were proposed to explain variation in a researcher's ability to hear calls. *Wind speed* tested the impact of wind speed on detection. Greater wind speeds can reduce the ability of a researcher to hear a call but may also make anurans less likely to call. *Wetland size* tested the impact of the size of the wetland on the ability to detect a calling anuran within the site. Three models were proposed to test a combination of environmental covariates. *Environmental conditions 1* proposed that water temperature, air temperature, and wind speed could all impact detection. *Environmental conditions 1 and day* builds on the first model by testing the inclusion of day of year. *Environmental conditions 2* builds on the first model by incorporating nighttime visibility, or moonshine, in addition to water temperature, air temperature, and wind speed.

I proposed a second set of eight candidate models to explain detection of tadpoles using dip-netting (Tables 2.2). The model set included a null and global model. As with adult detection, I proposed that *day* and *time of day* could impact detection by affecting tadpole behavior. *Water temperature* tests the assumption that tadpoles will respond to differing water temperatures by inhabiting different areas of a wetland. Because sampling occurs at the edge of a wetland, detection would vary under this assumption. *Slope* tests the effect of the slope of the first meter of shallows on successful detection. This proposed effect may manifest from a variety of causes. Not only can the slope of a wetland affect oviposition by an adult female and therefore the original location of tadpoles, but tadpole behavior may be influenced by slope. Finally, the likelihood that a tadpole is caught in a dip-net may also be impacted by the slope of a wetland. In some wetlands there may be an interaction of water temperature and slope and this was tested with *water temperature and slope. Aquatic vegetation* tests the effect of woody or herbaceous vegetation and open water on the successful detection of tadpoles. Detection explained by this model could indicate differing success of the dip-net to penetrate vegetation or demonstrate a micro-habitat preference among tadpoles.

The proposed models were tested using multi-model inference in Program PRESENCE (Hines 2006). Due to the small sample size and large number of covariates in my model sets, I report the corrected Akaike Information Criterion (AIC) score for all models. Confidence sets were selected as all models with ≥10% the weight of the top model. Due to the high uncertainty of occupancy modeling of species with low detection rates, I did not model a species or life-stage during any month in which it had less than 10% naïve occupancy.

Any models that failed to converge to greater than two significant figures or otherwise failed to run successfully were deleted from analysis but are acknowledged here. Models are presented in descending order of weight and logit-scale parameter estimates are provided parenthetically.

RESULTS

Western Chorus Frog (*Pseudacris triseriata*)

April 2010

Western chorus frogs were heard calling at 23 sites during the first survey and at seven sites during the second survey. The top adult detection models were *environmental conditions 1 and day* (β_{water_temp}= 44.02 ± 27.75 and β_{day}= -28.98±9.34), the *global* model (β_{day}= -46.23±16.28, β_{water_temp}= 88.48±36.25, β_{moon}= -2.49±3.03, β_{time}= -3.15±19.8, β_{small}= 4.34±1.91, and β_{medium}= 7.65±2.99) and *day* (β_{day}= -23.40±7.68) (Table 2.5).

Western chorus frog tadpoles were captured at 16 sites during the first survey and at 18 sites during the second survey. The top tadpole detection model was the *global* model (β_{day}=63.13±23.16 and β_{slope}=-19.66±6.87) (Table 2.5).

May 2010

Western chorus frogs were heard calling at 5 sites in each of the surveys. The top adult detection models were the *null* model followed by *time of day* (β_{time}= 12.52±2.74), *water temperature* (β_{water_temp}= -7.36±10.02), *day* (β_{day}= -6.25±9.51), *moonshine* (β_{moon}= -0.71±1.4), and *wetland size* (β_{small}= 1.14±1.22 and β_{medium}= 0.92±1.29) (Table 2.6).

Western chorus frog tadpoles were captured at 18 sites in the first survey and 14 in the second survey. All tadpole detection models carried ≥ %10 of weight of the top model and no models were excluded from the confidence set. The models were *day* (β_{day}= 48.14±9.98), the *global* model (β_{day}= 35.02±9.78 and β_{slope}= -8.77±6.47), the *null*, and *slope* (β_{slope}= -18.83±8.69) (Table 2.6).

April 2011

Western chorus frogs were heard calling at 30 sites during the first survey and at 27 sites during the second survey. The only adult detection model excluded from the confidence set was the *global* model. The top models were *moonshine* (β_{moon}= -2.61±1.55), the *null*, *environmental conditions 1* (β_{water_temp}= 45.54±22.43, β_{air_temp}= -37.40, and β_{wind}= 0.78±1.16), *air temperature* (β_{air_temp}= -10.96±7.99), *day* (β_{day}= -8.09±9.17), *environmental conditions 2* (β_{moon}= -1.69±1.7, β_{water_temp}= 37.92±25.03, β_{wind}= 0.55±1.16, and β_{air_temp}= -33.83±16), *wind speed* (β_{wind}= 0.77±1.25), *environmental conditions 1 and day* (β_{water_temp}= 36.2425.79, β_{wind} = 0.91±1.17, β_{air_temp}= -37.05±16.62, and β_{day}= -9.46±12.18), *time of day* (β_{time}= 2.41±9.28), *water temperature* (β_{water_temp}= 1.56±13.82), and *wetland size* (β_{small}= 0.94±1.06 and β_{medium}= 0.08±1.11) (Table 2.7).

Western chorus frog tadpoles were captured at three sites during the first survey and at six sites during the second survey. The top tadpole detection model was the *global* model (β_{day}= -196.31±17.04, β_{time}= -84.63±10.31, β_{water_temp}= -5.11±29.69, β_{slope}= -8.85±10.8, β_{woody}= -29.02±12.52, and β_{herby}= -0.94±7.41) (Table 2.7).

May 2011

Western chorus frogs were heard calling at seven sites during the first survey and at eleven sites during the second survey. The top adult detection models were *air temperature* (β_{air_temp}= -13.18±6.8), *water temperature* (β_{water_temp}= -15.63±9.05), *day* (β_{day}= 17.71±9.56), the *null*, *moonshine* (β_{moon}= 1.13±0.99), *wind speed* (β_{wind}= -0.38±0.64), *time of day* (β_{time}= 3.33±8.18), and *environmental conditions 1* (β_{water_temp}= 10.6±31, β_{air_temp}= -21.17±24.2, and β_{wind}= -0.53±0.79) (Table 2.8).

Western chorus frog tadpoles were captured at 13 sites during the first survey and at 16 sites during the second survey. The top tadpole detection models were *water temperature and slope* (β_{water_temp}= 25.07±9.27 and β_{slope}= -7.53±3.37) and *slope* (β_{slope}= -8.85±3.34) (Table 2.8).

June 2011

Western chorus frog tadpoles were captured at five sites during the first survey and at seven sites during the second survey. The top tadpole detection models were *water temperature and slope* (β_{water_temp}= -73.17±15.68 and β_{slope}= -12.46±3.93), *time of day* (β_{time}= -22.47±10.47), and the *null* model (Table 2.9).

Northern cricket frog (*Acris crepitans*)

April 2010

Northern cricket frogs were heard calling at six sites during the first survey and at 14 sites during the second survey. The *global* model failed to run and was removed from the model set. The top adult detection models were *environmental conditions 1 and day* (β_{day}= 24.81±11.98 and β_{water_temp}= 65.87±43.22), *environmental conditions 2*(β_{water_temp}= 67.51±35.85 and β_{moon}= 4.44±1.87), *day* (β_{day}= 22.38±9.59), and *moonshine* (β_{moon}= 3.42±1.61) (Table 2.10).

May 2010

Northern cricket frogs were heard calling at 14 sites during the first survey and at 19 sites during the second survey. The top adult detection models were *day* (β_{day}= 20.79±12.66), *water temperature* (β_{water_temp}= 25.30±12.51), *moonshine* (β_{moon}= 2.39±1.50), the *null*, *environmental conditions 1 and day* (β_{day}= 11.12±21.20 and β_{water_temp}= 14.50±24.65), *environmental conditions 2*(β_{water_temp}= 22.39±18.68 and β_{moon}= 0.45±2.08), and *time* (β_{time}= 12.83±2.19) (Table 2.11).

June 2010

Northern cricket frogs were heard calling at 19 sites during the first survey and at 16 sites during the second survey. The top adult detection models were *environmental conditions 1 and day* (β_{day}= -10.18±5.14 and β_{water_temp}= 43.29±15.40), *water temperature*

(β_{water_temp}= 31.64±14.26), *time of day* (β_{time}= 24.75±2.25), the *null, day* (β_{day}= -6.01±5.52), *environmental conditions 2* (β_{water_temp}= 33.20±14.79 and β_{moon}= -0.32±0.89), and the *global* model (β_{day}= -20.39±7.22, β_{time}= 25.96±7.10, β_{water_temp}= 63.68±19.74, β_{moon}= 2.03±1.44, β_{small}= 1.06±1.09, and β_{medium}= -0.69±0.96) (Table 2.12).

May 2011

Northern cricket frogs were heard calling at 17 sites during the first survey and at 16 sites during the second survey. The top adult detection models were *water temperature* (β_{water_temp}= 29.04±10.69), *environmental conditions 1 and day* (β_{day}= 43.20±14.92, β_{water_temp}= 41.73±18.31, β_{wind}= 1.78±0.88, and β_{air_temp}= -0.66±10.73), and *environmental conditions 1* (β_{water_temp}= 35.76±20.03, β_{wind}= 0.28±0.67, and β_{air_temp}= -6.75±12.43) (Table 2.13).

June 2011

Northern cricket frogs were heard calling at 21 sites during the first survey and at 16 sites during the second survey. *Environmental conditions* 1 *and day* and *environmental conditions 2* failed to converge and were removed from the model set. The top adult detection models were the *null, wetland size* (β_{small}= 1.03±0.64 and β_{medium}= -0.11±0.63), *water temperature* (β_{water_temp}= 8.39±8.42), *moonshine* (β_{moon}= 1.21±1.39), *day* (β_{day}= -4.93±7.79), *air temperature* (β_{air_temp}= 2.06±6.11), *time* (β_{time}= -1.39±6.93), and *wind speed* (β_{wind}= 0.07±0.69) (Table 2.14).

Cope's gray treefrog (*Hyla chrysoscelis*)

April 2010

Cope's gray treefrogs were heard calling at 18 sites during the first and second survey. The top adult detection models were *water temperature* (β_{water_temp}= 54.00±23.34), *environmental conditions 2* (β_{water_temp}= 54.68±23.37 and β_{moon}= 0.41±1.11), and *environmental conditions 1 and day* (β_{day}= -1.32±5.25 and β_{water_temp}= 53.91±23.41) (Table 2.15).

May 2010

Cope's gray treefrogs were heard calling at 16 sites during the first survey and at 24 sites during the second survey. *Wetland* size failed to converge and was deleted from the model set. The top adult detection models were *environmental conditions 1 and day* (β_{day}= 117.00±10.13 and β_{water_temp}= 33.83±20.71) and *day* (β_{day}= 124.13±6.37) (Table 2.16).

Cope's gray treefrog tadpoles were captured at six sites during each of the surveys. The top tadpole models were *day* (β_{day}= 102.74±5.03), *slope* (β_{slope}= -9.24±5.18), the *null*, and the *global* model (β_{day}= 93.66±5.28 and β_{slope}= -1.57±5.04) (Table 2.16).

June 2010

Cope's gray treefrogs were heard calling at 15 sites during the first survey and at 20 sites during the second survey. The top adult detection models were *moonshine* (β_{moon}= 2.27±1.40), *environmental conditions 2* (β_{water_temp}= -29.77±20.46 and β_{moon}= 2.78±20.46), the *null*, *time of day* (β_{time}= 17.56±2.26), the *global* model (β_{day}= -15.53±8.01, β_{time}= 32.28±6.30, β_{water_temp}= 2.10±23.07, β_{moon}= 6.42±2.18, β_{small}=

0.64±1.15, and β_{medium}= -2.30±1.11), *day* (β_{day}= 5.34±6.19), *water temperature* (β_{water_temp}= -14.02±20.10), *wetland size* (β_{small}= -0.33±1.08 and β_{medium}= -1.54±1.03), and *environmental conditions 1 and day* (β_{day}= 8.69±6.72 and β_{water_temp}= -24.97±19.94) (Table 2.17).

Cope's gray treefrog tadpoles were captured at 17 sites during the first survey and 12 sites during the second survey. The top tadpole detection models were the *null, day* (β_{day}= 6.23±6.54), *slope* (β_{slope}= -3.76±4.45), and the *global* model (β_{day}= 4.96±7.01 and β_{slope}= -2.82±4.70) (Table 2.17).

May 2011

Cope's gray treefrogs were heard calling at 16 sites during the first survey and at 15 sites during the second survey. The top adult detection models were *environmental conditions 1 and day* (β_{day}= 53.67±5.34, β_{water_temp}= 30.00±16.55, β_{wind}= 0.11±0.80, and air temperature β_{air_temp}= 23.78±11.68), *water temperature* (β_{water_temp}= 30.38±6.82), and *environmental conditions 1* (β_{water_temp}= 24.64, wind β_{wind}= -1.03±0.68, and β_{air_temp}= 7.14±7.11) (Table2.18).

June 2011

Cope's gray treefrogs were heard calling at 21 sites during the first survey and at 16 sites during the second survey. The top adult detection models were *water temperature* (β_{water_temp}= 15.38±8.99), the *null, air temperature* (β_{air_temp}= 8.18±6.62), *day* (β_{day}= -11.37±6.25), *time of day* (β_{time}= -8.52±4.75), *wind speed* (β_{wind}= 0.65±0.77), *wetland size* (β_{small}= 0.75±0.67 and β_{medium}= -0.28±0.63)], *moonshine* (β_{moon}=

0.76±1.1.45), and *environmental conditions 1* (β_{water_temp}= 19.42±14.48, β_{wind}= 0.80±0.78, and β_{air_temp}= -2.77±10.42) (Table 2.19).

Cope's gray treefrog tadpoles were captured at six sites during the first survey and seven sites during the second survey. The top tadpole detection models were *water temperature* (β_{water_temp}= 786.80±9.72), *water temperature and slope* (β_{water_temp}= 848.74±10.6 and β_{slope}= 1.75±7.27), and *aquatic vegetation* (β_{woody}= -5.57±9.13 and β_{herby}= -3.09±1.64) (Table 2.19).

Plains leopard frog (*Lithobates blairi*)

April 2010

Plains leopard frogs were heard calling at 18 sites during the first survey and at 20 sites during the second survey. The top adult detection models were the *null, day* (β_{day}= 3.76±3.94), *time of day* (β_{time}= 6.27±10.70, *water temperature* (β_{water_temp}= -1.38±2.81), *moonshine* (β_{moon}= -0.14±0.92), *wetland size* (β_{small}= 0.39±1.41 and β_{medium}= -0.84±1.32), *environmental conditions 1 and day* (β_{day}= 3.47 and β_{water_temp}= 9.95±16.07), and *environmental conditions 2* (β_{water_temp}= 11.10±15.54 and β_{moon}= -0.11±0.92) (Table 2.20).

Plains leopard frog tadpoles were captured at 18 sites during the first survey and at 20 sites during the second survey. The top tadpole detection models were *slope* (β_{slope}= -6.33±2.83), the *global* model (β_{day}= 1.20±10.60 and β_{slope}= -6.35±2.83), and the *null* (Table 2.20).

May 2010

Plains leopard frogs were heard calling at six sites during the first survey and at 19 sites during the second survey. The top adult detection models were *moonshine* (β_{moon}= 2.85±1.47), *day* (β_{day}= 21.74±9.64), *wetland size* (β_{small}= 1.79±0.81 and β_{medium}= 0.74±0.9), *environmental conditions 2* [water temperature (β_{water_temp}= 11.35±21.05) and moonshine (β_{moon}= 2.63±1.68)], *environmental conditions 1 and day* [day (β_{day}= 20.00±11.80) and water temperature (β_{water_temp}= 9.24±21.90)], *water temperature* (β_{water_temp}= 26.54±15.65), the *global* model (β_{day}= -10.31±14.87, β_{time}= 14.47±4.68, β_{water_temp}= 13.40±12.96, β_{moon}= 2.29±2.15, β_{small}=2.23±0.99, and β_{medium}= 0.70±1.01), *time of day* (β_{time}= 11.63±3.59), and the *null* (Table 2.21).

Plains leopard frog tadpoles were captured at 21 sites during the first survey and at 20 sites during the second survey. The top tadpole detection models were *slope* (β_{slope}= -6.50±2.51), the *global* model (β_{day}= -1.48±12.61 and β_{slope}= -6.69±2.97), the *null,* and *day* (β_{day}= 13.49±18.19) (Table 2.21).

June 2010

Plains leopard frogs were heard calling at 10 sites during the first survey and at 12 sites during the second survey. The top adult detection models were *moonshine* (β_{moon}= 1.58±0.87), the *null, environmental conditions 2* (β_{water_temp}= 1.86±13.68 and β_{moon}= 1.53±0.93), *water temperature* (β_{water_temp}= 9.59±10.60), *day* (β_{day}= 2.51±4.32), and *time of day* (β_{time}= -2.85±7.18) (Table 2.22).

Plains leopard frog tadpoles were captured at 15 sites during the first survey and at 9 sites during the second survey. The top tadpole detection models were the *null* model, *day* (β_{day}= 12.50±7.27), *slope* (β_{slope}= -6.39±5.05), and the *global* model (β_{day}= 7.82±8.33 and β_{slope}= -3.86±5.51) (Table 2.22).

April 2011

Plains leopard frogs were heard calling at 30 sites during the first survey and at 19 sites during the second survey. The top adult detection models were *environmental conditions 1* (β_{water_temp}= 18.51±17.41, β_{wind}= -2.44±1.05, and β_{air_temp}= 17.72±12.29), *environmental conditions 2* (β_{moon}= 1.89±1.36, β_{water_temp}= 22.41±19.06, β_{wind}= -1.91±1.10, and β_{air_temp}= 9.99±15.43), *water temperature* (β_{water_temp}= 35.28±11.62), *environmental conditions 1 and day* (β_{day}= 2.30±11.06, β_{water_temp}= 21.13±21.48, β_{wind}= -2.47±1.06, and β_{air_temp}= 16.94±13.47), and *air temperature* (β_{air_temp}= 22.59±8.60) (Table 2.23).

May 2011

Plains leopard frogs were heard calling at 13 sites during the first survey and at 25 sites during the second survey. The top adult detection models were *environmental conditions 1 and day* (β_{day}= 71.07±8.98, β_{water_temp}= 44.26±11.44, β_{wind}= -0.24±0.75, and β_{air_temp}= -3.10±6.74), *environmental conditions 2* (β_{moon}= 3.69±1.52, β_{water_temp}= 29.19±16.21, β_{wind}= -0.42±0.88, and β_{air_temp}= -7.13±9.84), *moonshine* (β_{moon}= 2.75±1.10), and the *global* model (β_{day}= 27.08±27.94, β_{moon}= 2.30±1.85, β_{time}= -25.37±10.08, β_{water_temp}= 38.97±17.48, β_{wind}= -0.85±1.00, β_{air_temp}= -5.93±9.57, β_{small}= 1.70±1.05, and β_{medium}= 0.62±1.01) (Table 2.24).

Plains leopard frog tadpoles were captured at 23 sites during the first survey and at 20 sites during the second survey. The top tadpole detection models were *water* *temperature* (β_{water_temp}= 32.45±11.06), *day* (β_{day}= 36.07±9.89), *water temperature and slope* (β_{water_temp}= 34.01±10.95 and β_{slope}= -2.70±2.48), *time of day* (β_{time}= 8.09±5.82), the *null* model, and *aquatic vegetation* (β_{woody}= -1.13±2.52 and β_{herby}= 2.94±1.77) (Table 2.24).

June 2011

Plains leopard frogs were heard calling at 12 sites during the first survey and at 12 sites during the second survey. The top adult detection models were the *null* model, *moonshine* (β_{moon}= 3.00±2.47), *day* (β_{day}= -7.03±13.57), *time of day* (β_{time}= -5.79±15.76), *water temperature* (β_{water_temp}= 6.07±12.45), *wind speed* (β_{wind}= -0.26±0.96), *air temperature* (β_{air_temp}= 1.17±7.88), and *wetland size* (β_{small}= 0.52±1.17 and β_{medium}= -0.66±1.09) (Table 2.25).

Plains leopard frog tadpoles were captured at 25 sites during the first survey and at 27 sites during the second survey. The top tadpole detection models were the *null* model, *time of day* (β_{time}= -22.35±56.42), *day* (β_{day}= 17.05±1.25), *water temperature* (β_{water_temp}= -23.58±23.59), *slope* (β_{slope}= 4.57±5.22), *aquatic vegetation* (β_{woody}= -5.08±9.72 and β_{herby}= -4.35±4.24), *water temperature and slope* (β_{water_temp}= -19.08±34.74 and β_{slope}= 1.54±7.87), and the *global* model (β_{day}= 53.741±10.72, β_{time}= -4.768±16.483, β_{water_temp}= -8.729±34.247, β_{slope}= -4.867±7.3, β_{woody}= -0.687±5.956, and β_{herby}= 3.629±1.886) (Table 2.25).

American bullfrog (*Lithobates catesbeiana*)

May 2010

American bullfrog tadpoles were captured at four sites during the first survey and at three sites during the second survey. All tadpole detection candidate models were selected in the confidence set. The top models were the *null* model, *day* (β_{day}= 15.86±10.69), *slope* (β_{slope}= 8.87±7.71), and the *global* model (β_{day}= 55.73±7.99 and β_{slope}= -22.73±8.79) (Table 2.26).

June 2010

American bullfrogs were heard calling at six sites during the first survey and at 11 sites during the second survey. *Water temperature* and *environmental conditions 1 and day* failed to converge and were deleted from the model set. The top adult detection models were *moonshine* (β_{moon}= 1.33±1.08), *environmental conditions 2* (β_{water_temp}=12.49±12.67 and β_{moon}= 1.51±0.77), *wetland size* (β_{small}= -1.35±0.78 and β_{medium}= 0.29±0.66), *day* (β_{day}= -6.21±4.22), the *null* model, and *time of day* (β_{time}= 11.95±6.21) (Table 2.27).

May 2011

American bullfrog tadpoles were captured at four sites during the first survey and at five sites during the second survey. The top tadpole detection models were *slope* (β_{slope}= 20.74±11.43), *time of day* (β_{time}= -12.31±7.14), *water temperature and slope* (β_{water_temp}= -2.95±10.95 and β_{slope}= 20.97±11.74), and the *null* model (Table 2.28).

June 2011

American bullfrogs were heard calling at 11 sites during the first survey and at seven sites during the second survey. The top adult detection models were the *null* model, and *water temperature* (β_{water_temp}= 10.03±10.49) (Table 2.29).

American bullfrog tadpoles were captured at four sites during the first survey and at seven sites during the second survey. The top tadpole detection models were *slope* (β_{slope}= 15.30±6.11) and *water temperature and slope* (β_{water_temp}= 38.88±22.24 and β_{slope}= 16.21±5.19) (Table 2.29).

Woodhouse's toad (*Anaxyrus woodhousii*)

April 2010

Woodhouse's toads were heard calling at 13 sites during the first survey and at four sites during the second survey. The top adult detection models were *day* (β_{day}= -17.97), *moonshine* (β_{moon}= -3.78±1.60), *environmental conditions 1 and day* (β_{day}= -17.44±7.65 and β_{water_temp}= 17.76±26.80), and *environmental conditions 2* (β_{water_temp}= 10.74±26.84 and β_{moon}= -3.69±1.63) (Table2.30).

Woodhouse's toad tadpoles were captured at five sites during the first survey and at nine sites during the second survey. The top tadpole detection models were *slope* (β_{slope}= -18.79±6.87) and the *global* model (β_{day}= -3.37±12.30 and β_{slope}= -18.62±6.86) (Table 2.30).

May 2010

Woodhouse's toads were heard calling at six sites during the first survey and at seven sites during the second survey. *Wetland size* failed to converge and was deleted from the model set. The top adult detection models were the *null* model, *time of day* (β_{time}= 27.6±9.97), *water temperature* (β_{water_temp}= 13.94±18.11), *day* (β_{day}= 6.64±11.74), *moonshine* (β_{moon}= 0.69±1.65), *environmental conditions 2* (β_{water_temp}= 19.69±27.16 and β_{moon}= -0.69±2.53), and *environmental conditions 1 and day* (β_{day}= -1.38±19.59 and β_{water_temp}= 15.70±30.54) (Table 2.31).

June 2010

Woodhouse's toads were heard calling at one site during the first survey and at five sites during the second survey. The *null* model and *day* failed to converge and were deleted from the model set. The top adult detection models were *moonshine* (β_{moon}= 1.33±1.08), *water temperature* (β_{water_temp}= 17.41±19.78), *environmental conditions 1 and day* (β_{day}= 10.39±9.40 and β_{water_temp}= 7.74±21.20), *time of day* (β_{time}= -0.72±14.96), *environmental conditions 2* (β_{water_temp}= 11.32±20.20 and β_{moon}= 1.06±1.15), and *wetland size* (β_{small}= 0.75±1.19 and β_{medium}= 0.64±1.27) (Table 2.32).

May 2011

Woodhouse's toads were heard calling at eight sites during the first survey and at four sites during the second survey. *Environmental conditions 2* failed to converge and was deleted from the model set. The top adult detection models were *air temperature* (β_{air_temp}= 17.18±5.17), *water temperature* (β_{water_temp}= 26.38±8.07), and *environmental conditions 1* (β_{water_temp}= 15.74±15.36, β_{wind}= 0.17±0.69, and β_{air_temp}= 7.64±9.54) (Table 2.33).

Detection probabilities

Detection probabilities associated with the null model (assumes no covariates impact detection) varied among species, life stages, and seasons. Two notable exceptions are the Northern cricket frog whose tadpoles were never caught in sufficient numbers to model, and the Plains leopard frog which has a higher detection probability in all months of both years with larval dip-netting than with call surveys.

DISCUSSION

Western chorus frog (*Pseudacris triseriata*)

There are several environmental factors that may impact detection probabilities of Western chorus frog adults. In April, 2010 higher water temperature appears to have a positive influence on detection probabilities. Chorus frogs are the first species to call in Eastern Nebraska and may arrive at wetlands while temperatures are still very chilly and quite variable. Calling is energetically expensive and calling behavior often slows or ceases in cold water until conditions are more conducive to active advertisement. In the remaining three months under consideration (May, 2010 and April and May, 2011) the picture is far less clear. Due to the number of models that were selected and the selection of the null each time, little can be inferred at these times.

The *global* model was selected in three of the five months analyzed for Western chorus frog tadpoles. Although this indicates that all of the covariates considered in the candidate models could be influencing detection, parameter estimates indicate slope may play a prominent role. Appearing in the *global* model as well as many of the other selected models (ex. *Water temperature and slope*) slope seems to be inversely related to detection success in all months. Selection of slope as a plausible model for detection likely indicates a sampling bias as steeper sided wetlands are more difficult to effectively sample. In a gently sloping wetland the net makes contact with the substrate very quickly and as the net is drawn toward the shoreline nearly all tadpoles in the way will be swept effectively into the net. A steeper sided wetland makes it more difficult to execute an effective sweep and may allow more tadpoles to escape capture.

Northern cricket frog (*Acris crepitans*)

The *null* model was selected in three of the five months for which Northern cricket frog detection probabilities were modeled. This is not surprising when considering the loud and distinctive nature of their call (imagine two marbles being banged against one another). In the remaining two months (April 2010 and May 2011) both water temperature and day appear to impact detection probabilities.

There were few captures of Northern cricket frog tadpoles and there were never enough caught in a season to meet the 10% naïve occupancy criterion for modeling.

Cope's gray treefrog (*Hyla chrysoscelis*)

Many environmental factors appear in the selected models for Cope's gray treefrog adult detection. Water temperature (alone or in multivariate models) appears near the top of every confidence set. In all months but June, 2010 I found a positive relationship between water temperature and detection. However, the *null* model was selected in June, 2010 and 2011 indicating that detection may be unaffected by the covariates considered in my analysis.

The *null* model was selected in two of the three months for which detection of Cope's gray treefrogs was modeled. In June, 2011 water temperature appeared to have a large positive effect on detection probabilities.

Plains leopard frog (*Lithobates blairi*)

The only month in which the *null* model was not selected for Plains leopard frog adults was May, 2011. In this month several models containing water and air temperature were selected. Parameter estimates indicate that water temperature may have a positive impact on detection while air temperature may have a slight negative impact.

The *null* model was selected in all months to explain Plains leopard frog tadpole detection. Although the selection criterion of choosing of all models containing 10% the weight of the top model is more generous than the more widely used 2ΔAICc, it is important to note that the *null* model was selected as the top model in three of the five months assessed. Therefore it is highly unlikely that the covariates measured are impacting detection probabilities of tadpoles.

American bullfrog (*Lithobates catesbeiana*)

The height of American bullfrog calling occurs in July and thus detections were low or non-existent in the three selected seasons. Bullfrogs were heard calling in June of 2010 and 2011. The *null* model was selected in both months. In June of both years the Missouri River floodplain was experiencing moderate to severe flooding and this may have impacted calling behavior.

American bullfrog tadpoles often overwinter and may not metamorphose for two or even three years. This means that despite the late calling season of bullfrogs, their tadpoles are present in many water bodies year round. Of the three months in which captures were numerous enough to model detection, the null model was selected twice. In June, 2011 the selected models indicate that both slope and water temperature have a positive impact on detection.

Woodhouse's toad (*Anaxyrus woodhousii*)

Factors influencing detection of adult Woodhouse's toads are unclear. In April, 2010 day appears to play a large role which is indicative of expected survey specific differences (adults were heard calling at 13 sites during the first survey and at only four sites during the second survey). In May of 2010 the *null* model was selected as the top model. In June of 2010 moonshine and water temperature appear to play a role. In May of 2011 air and water temperature appear in all of the selected models.

Woodhouse's toad tadpoles were only captured in sufficient numbers once during the two years of the study. In April of 2010 the selected models indicate that both slope and day of year may be affecting detection probabilities.

Implications for Monitoring

The selection of large numbers of candidate models as plausible to explain detection probabilities makes inferring broad-sweeping conclusions difficult. Additionally, the selection of the null in many of the confidence sets suggests that perhaps none of the covariates impact detection. However, some conclusions can be drawn that may inform future survey strategies. The phenologies and life histories of amphibians in the study area are varied. Some species are highly terrestrial and only inhabit the wetlands during brief opportunistic breeding seasons and then disperse back into the surrounding landscape. Others are almost entirely aquatic and occupy the wetland year-round. Therefore seasonal timing is an important part of the planning process, and preliminary visits to the study area may be advised. Although I attempted to control for this by selecting phenologically determined sampling periods, this variability in wetland use may account for differing detection successes. Modeling a species' detection only during the height of its calling season could ameliorate some of these issues.

Behavioral and physiological differences can affect how sensitive a species is to environmental conditions such as water or air temperature and moonshine. Water temperature and air temperature are known to impact the calling behavior of adults of many species (Oseen and Wassersug 2002) and were seen in several of the selected models. However, the high specific heat of water causes a latent response of water temperature. Species that call from the banks may be most affected by current air temperature while those in the water might call enthusiastically on an abruptly chilly night but remain relatively silent after an extended period of cool weather. Therefore both current and recent weather conditions should be considered when planning a survey, and if possible temperatures should be recorded in association with surveys. Finally, calling behavior and the acoustic properties of a call can impact detection success. Leopard frogs often call from underwater and emit a low "chuck" while chorus frogs call from the shallows or the shoreline and emit a high trill. The leopard frog is difficult to hear under ideal conditions (low to no wind or extraneous noise) and nearly impossible to hear when conditions are windy or over the calls of more rambunctious species.

Dip-netting captures spontaneous/opportunistic breeding anurans that may be missed in call surveys and important non-anuran (non-calling) amphibian species such as salamanders, and can be used as a measure of reproduction at a site. In many amphibian monitoring programs however, there is no advantage to monitoring larval anurans in place of adults, and little clear advantage to monitoring larval anurans in addition to adults. Dip-netting is logistically more difficult than call surveys, requires greater skill to identify individuals correctly, and in most cases (a noted exception being the Northern cricket frog) yielded similar naïve occupancy estimates when accounting for the expected lag between adult calling and tadpole emergence. The utility of tadpole sampling however could be improved if researchers target a specific species and sample only when life history traits dictate. Northern cricket frog decline may necessitate species-specific monitoring. Targeting cricket frog tadpole emergence in late May through early August may be an important step in ensuring that these short-lived amphibians are reproducing successfully at a site.

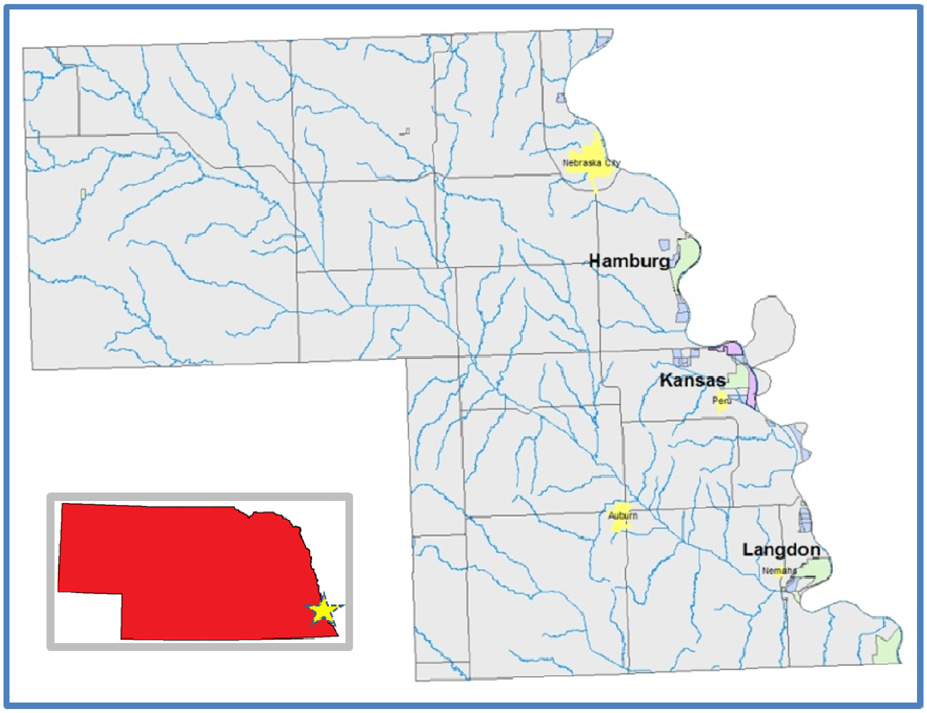

Figure 2.1 *Research bends.* Detection of amphibians was assessed in three restored Missouri River bends. Fifty five wetland sites representing a variety of wetland types were selected across the three bends. Research sites were located in Hamburg bend (River mile 557) in Otoe County, and Kansas (River mile 548) and Langdon (River mile 534) bends in Nemaha County in southeast Nebraska along the lower Missouri River.

Table 2.1. *Research Sites, Hamburg and Langdon Bends.* Three restored river bends along the Missouri River (river mile 557-528) in southeast Nebraska were selected to assess amphibian occupancy as a metric for wetland success. Wetlands were selected in ArcMap as intersections of hydric soils and National Wetland Inventory polygons. Initial selections were visited to assess current status and additional wetlands encountered while in the bends were included in the study. Sites selected represented a variety of engineering categories used the U.S. Army Corps of Engineers. Each wetland was assigned a site number, the wetland type was determined, and a GPS location was taken.

Name	Wetland Type	Latitude	Longitude
Hamburg Research Sites			
H9	Tributary	40.59478	-95.77416
H11	Scour Hole	40.60105	-95.77130
H12	Tributary	40.60559	-95.79135
H14	Tributary	40.58963	-95.78448
H15F	Ephemeral, unfarmed	40.58395	-95.78078
H15S	Tributary	40.58444	-95.78220
H34	Ephemeral, farmed	40.53872	-95.78388
H59	Ground Fed Permanent	40.57660	-95.78010
H64	Ditch	40.54506	-95.77943
H65N	Ditch	40.54155	-95.78173
H65S	Ditch	40.54160	-95.78172
Langdon Research Sites			
L37	Ground Fed Permanent	40.32483	-95.65586
L39	Ephemeral, farmed	40.33432	-95.63966
L43	Ground Fed Permanent	40.33962	-95.65435
L44	Ditch	40.34520	-95.65708
L46	Ditch	40.33448	-95.66757
L51N	Ephemeral, unfarmed	40.32288	-95.65952
L51S	Ephemeral, farmed	40.32279	-95.65964
L53	Backwater	40.32922	-95.64075
L54E	Ephemeral, unfarmed	40.34186	-95.64357
L54W	Ground Fed Permanent	40.34156	-95.64455
L55E	Ditch	40.34013	-95.65951
L55W	Ditch	40.33957	-95.66021
L70	Backwater	40.34894	-95.63411

Table 2.2. *Research Sites, Kansas Bend*. Three restored river bends along the Missouri River (river mile 557-528) in southeast Nebraska were selected to assess amphibian occupancy as a metric for wetland success. Wetlands were selected in ArcMap as intersections of hydric soils and National Wetland Inventory polygons. Initial selections were visited to assess current status and additional wetlands encountered while in the bends were included in the study. Sites selected represented a variety of engineering categories used the U.S. Army Corps of Engineers. Each wetland was assigned a site number, the wetland type was determined, and a GPS location was taken.

Name	Wetland Type	Latitude	Longitude
Kansas Research Sites			
K2	Ephemeral, unfarmed	40.48175	-95.72298
K6	Ephemeral, unfarmed	40.48025	-95.71866
K7	Ground Fed Permanent	40.47885	-95.71381
K10	Ground Fed Permanent	40.48343	-95.71973
K23	Tributary	40.47711	-95.71013
K24	Tributary	40.47371	-95.70198
K25	Impoundment	40.48340	-95.70690
K27	Impoundment	40.47732	-95.70813
K30	Ephemeral, unfarmed	40.50184	-95.70430
K32	Ground Fed Permanent	40.51362	-95.71594
K56I	Ditch	40.49219	-95.70470
K56O	Ephemeral, unfarmed	40.49229	-95.70358
K57N	Ditch	40.50857	-95.70990
K57S	Ephemeral, unfarmed	40.50821	-95.71032
K66	Impoundment	40.49382	-95.71946
K67F	Impoundment	40.49458	-95.72079
K67S	Tributary	40.49426	-95.72108
K68	Tributary	40.48308	-95.71446
K69	Impoundment	40.49425	-95.72041
K71	Tributary	40.49408	-95.72070

Table 2.3. *Candidate adult detection models.* Models were created based on the work of MacKenzie (2001) and used *a priori* selection of covariates that may impact detection of adult anurans. Covariates were survey-specific (water temperature, air temperature, wind speed, moonshine, time of day, day of year) or site-specific (wetland size). MacKenzie's occupancy model allows the incorporation of detection covariates. To test detection alone, the occupancy, or □ half of the equation, was held as the *null* model for occupancy (occupancy was assumed to be independent of the covariates).

Name	Model	# of parameters
Null	□(.), p(.)	2
Day	□(.), p(Day[1])	3
Moonshine	□(.), p(Moonshine[2])	3
Time of Day	□(.), p(Time[3])	3
Water Temperature	□(.), p(Water Temp[4])	3
*Air Temperature	□(.), p(Air Temp[5])	3
*Wind Speed	□(.), p(Wind Speed[5])	3
Wetland Size	□(.), p(<2.0ac + 2.1-5.0ac[6])	4
*Environmental Conditions 1	□(.), p(Water Temp + Air Temp + Wind Speed)	5
*Environmental Conditions 1 and Day	□(.), p(Day + Water Temp + Air Temp + Wind Speed)	6
*Environmental Conditions 2	□(.), p(Moonshine + Water Temp + Air Temp + Wind Speed)	6
*Global	□(.), p(Day+ Moonshine + Time + Water Temp + Air Temp + Wind Speed + <2.0ac + 2.1-5.0ac)	11

* Models containing covariates not measured in 2010 (wind speed and air temperature) were modified to exclude missing covariates in 2010 analysis. In the event that the modified model was redundant with another model in the set one of the redundant models was dropped.
1. Day was represented as day since April 1.
2. Moonshine was calculated as the phase of moon * (1-%cloud cover). Cloud cover data was obtained from two airports, one north of the northernmost sites and one south of the southernmost sites. The average of the two airports' reported cloud cover was taken hourly.
3. Time was measured as the time of day at the start of the survey
4. Water temperature was measured at a depth of 4cm with an instant read probe thermometer.
5. Wind speed and air temperature were measured using a Kestrel anemometer.
6. Each wetland was visually assessed and assigned to a size category of small (<0.83ha or <2ac), medium (0.84-2.02ha or 2.1-5ac), or large (>2.02ha or 5.1ac).

Table 2.4. *Candidate tadpole detection models.* Models were created based on the work of MacKenzie (2001) and used *a priori* selection of covariates that may impact detection of larval anurans. Covariates were survey-specific (water temperature, time of day, day of year) or site-specific (slope, aquatic vegetation: % herbaceous, % woody, and % open). MacKenzie's occupancy model allows the incorporation of detection covariates. To test detection alone, the occupancy, or □ half of the equation, was held as the *null* model for occupancy (occupancy was assumed to be independent of the covariates).

Name	Model	# of parameters
Null	□(.), p(.)	2
Day	□(.), p(Day[1])	3
*Time of Day	□(.), p(Time[2])	3
*Water Temperature	□(.), p(Water Temp[3])	3
Slope	□(.), p(%Slope 0-1m[4])	3
*Aquatic Vegetation	□(.), p(% Herbaceous + %Woody[5])	4
*Water Temperature + Slope	□(.), p(Water Temp + Slope)	4
*Global	□(.), p(Day + Time + Water Temp + %Slope + %Herbaceous +%Woody)	8

* Models containing covariates not measured in 2010 or not recorded during tadpole dip-netting (water temperature, time, and aquatic vegetation) were modified to exclude missing covariates in 2010 analysis. In the event that the modified model was redundant with another model in the set one of the redundant models was dropped.

1. Day was represented as day since April 1.
2. Time was the time of day at the beginning of the survey
3. Water temperature was measured at a depth of 4cm with an instant read probe thermometer.
4. Slope was calculated from water depth1m from the shoreline. Depth was measured at 20 1m intervals and averaged for a site.
5. Each dip-net sweep was designated as having passed through woody, herbaceous, or open water habitat. Percentages were calculated based on the total number of sweeps in a wetland (usually 20).

Table 2.5. *Detection models for the western chorus frog April 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, western chorus frog (23, 7, n=42)						
□(.),p(environmental conditions 1 and day)	**4**	**93.33**	**0.00**	**0.375**	**1.000**	**84.25**
□(.),p(global)	**8**	**93.58**	**0.25**	**0.330**	**0.881**	**73.22**
□(.),p(day)	**3**	**93.93**	**0.60**	**0.277**	**0.741**	**87.3**
□(.),p(moonshine)	3	100.06	6.73	0.013	0.035	93.43
□(.),p(environmental conditions 2)	4	102.13	8.80	0.005	0.012	93.05
□(.),p(.)	2	112.80	19.47	0.000	0.000	108.49
□(.),p(wetland size)	4	113.52	20.19	0.000	0.000	104.44
□(.),p(water temperature)	3	114.74	21.41	0.000	0.000	108.11
□(.),p(time of day)	3	115.11	21.78	0.000	0.000	108.48
Tadpole detection, western chorus frog (16,18, n=42)						
□(.),p(global)	**4**	**75.14**	**0.00**	**0.984**	**1.000**	**66.06**
□(.),p(slope)	3	84.63	9.49	0.009	0.009	78.00
□(.),p(day)	3	85.52	10.38	0.005	0.006	78.89
□(.),p(.)	2	87.25	12.11	0.002	0.002	82.94

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically.

Table 2.6. *Detection models for the western chorus frog in May, 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, western chorus frog (5,5, n=42)						
□(.),p(.)	**2**	**65.32**	**0.00**	**0.309**	**1.000**	**61.01**
□(.),p(time of day)	**3**	**66.04**	**0.72**	**0.215**	**0.696**	**59.41**
□(.),p(water temperature)	**3**	**67.12**	**1.80**	**0.125**	**0.406**	**60.49**
□(.),p(day)	**3**	**67.22**	**1.90**	**0.119**	**0.386**	**60.59**
□(.),p(moonshine)	**3**	**67.38**	**2.06**	**0.110**	**0.356**	**60.75**
□(.),p(wetland size)	**4**	**69.07**	**3.75**	**0.047**	**0.153**	**59.99**
□(.),p(environmental conditions 1 and day)	4	69.55	4.23	0.037	0.120	60.47
□(.),p(environmental conditions 2)	4	69.57	4.25	0.037	0.119	60.49
□(.),p(global)	8	77.45	12.14	0.001	0.002	57.09
Tadpole detection, western chorus frog (18,14, n=42)						
□(.),p(day)	**3**	**98.33**	**0.00**	**0.455**	**1.000**	**91.70**
□(.),p(global)	**4**	**99.44**	**1.11**	**0.261**	**0.574**	**90.36**
□(.),p(.)	**2**	**100.45**	**2.12**	**0.158**	**0.347**	**96.14**
□(.),p(slope)	**3**	**100.89**	**2.56**	**0.126**	**0.278**	**94.26**

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically.

Table 2.7. *Detection models for the western chorus frog in April, 2011*. Twelve models were tested for adult detection and eight models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, western chorus frog (30,27, n=42)						
□(.),p(moonshine)	**3**	**98.22**	**0.00**	**0.229**	**1.000**	**91.59**
□(.),p(.)	**2**	**99.10**	**0.88**	**0.148**	**0.645**	**94.79**
□(.),p(environmental conditions 1)	**5**	**99.22**	**1.00**	**0.139**	**0.608**	**87.55**
□(.),p(air temperature)	**3**	**99.44**	**1.22**	**0.125**	**0.543**	**92.81**
□(.),p(day)	**3**	**100.58**	**2.36**	**0.070**	**0.307**	**93.95**
□(.),p(environmental conditions 2)	**6**	**100.81**	**2.59**	**0.063**	**0.274**	**86.41**
□(.),p(wind speed)	**3**	**101.02**	**2.80**	**0.057**	**0.247**	**94.39**
□(.),p(environmental conditions 1 and day)	**6**	**101.32**	**3.10**	**0.049**	**0.212**	**86.92**
□(.),p(time of day)	**3**	**101.35**	**3.13**	**0.048**	**0.209**	**94.72**
□(.),p(water temperature)	**3**	**101.41**	**3.19**	**0.047**	**0.203**	**94.78**
□(.),p(wetland size)	**4**	**102.65**	**4.43**	**0.025**	**0.109**	**93.57**
□(.),p(global)	10	110.23	12.01	0.001	0.002	83.13
Tadpole detection, western chorus frog (3,6, n=42)						
□(.),p(global)	**8**	**47.68**	**0.00**	**0.865**	**1.000**	**27.32**
□(.),p(aquatic vegetation)	4	53.54	5.86	0.046	0.053	44.46
□(.),p(water temperature and slope)	4	53.78	6.10	0.041	0.047	44.70
□(.),p(slope)	3	55.19	7.51	0.020	0.023	48.56
□(.),p(time of day)	3	56.74	9.06	0.009	0.011	50.11
□(.),p(water temperature)	3	56.80	9.12	0.009	0.010	50.17
□(.),p(.)	2	57.46	9.77	0.007	0.008	53.15
□(.),p(day)	3	59.30	11.62	0.003	0.003	52.67

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.8. *Detection models for the western chorus frog in May, 2011.* Twelve models were tested for adult detection and eight models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, western chorus frog (7,11, n=40)						
□(.),p(air temperature)	**3**	**86.86**	**0.00**	**0.309**	**1.000**	**80.19**
□(.),p(water temperature)	**3**	**87.28**	**0.42**	**0.250**	**0.811**	**80.61**
□(.),p(day)	**3**	**88.82**	**1.96**	**0.116**	**0.375**	**82.15**
□(.),p(.)	**2**	**88.89**	**2.04**	**0.111**	**0.361**	**84.57**
□(.),p(moonshine)	**3**	**89.86**	**3.00**	**0.069**	**0.223**	**83.19**
□(.),p(wind speed)	**3**	**90.87**	**4.01**	**0.042**	**0.135**	**84.20**
□(.),p(time of day)	**3**	**91.16**	**4.30**	**0.036**	**0.116**	**84.49**
□(.),p(environmental conditions 1)	**5**	**91.40**	**4.55**	**0.032**	**0.103**	**79.64**
□(.),p(wetland size)	4	92.47	5.62	0.019	0.060	83.33
□(.),p(environmental conditions 1 and day)	6	94.04	7.18	0.009	0.028	79.49
□(.),p(environmental conditions 2)	6	94.18	7.32	0.008	0.026	79.63
□(.),p(global)	10	101.85	14.99	0.000	0.001	74.26
Tadpole detection, western chorus frog (13,16, n=40)						
□(.),p(water temperature and slope)	**4**	**91.10**	**0.00**	**0.773**	**1.000**	**81.96**
□(.),p(slope)	**3**	**94.25**	**3.14**	**0.160**	**0.208**	**87.58**
□(.),p(water temperature)	3	97.87	6.76	0.026	0.034	91.20
□(.),p(global)	8	98.79	7.68	0.017	0.021	78.14
□(.),p(day)	3	98.57	7.46	0.019	0.024	91.90
□(.),p(.)	2	102.55	11.45	0.003	0.003	98.23
□(.),p(aquatic vegetation)	4	102.93	11.83	0.002	0.003	93.79
□(.),p(time of day)	3	104.89	13.78	0.001	0.001	98.22

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.9. *Detection models for the western chorus frog in June, 2011.* Eight models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Tadpole detection, western chorus frog (5,7, n=34)						
□(.),p(water temperature and slope)	**4**	**59.45**	**0.00**	**0.630**	**1.000**	**50.07**
□(.),p(time)	**3**	**62.88**	**3.43**	**0.113**	**0.180**	**56.25**
□(.),p(.)	**2**	**63.38**	**3.93**	**0.088**	**0.140**	**59.07**
□(.),p(water temperature)	3	64.21	4.76	0.058	0.092	57.58
□(.),p(slope)	3	64.37	4.92	0.054	0.085	57.74
□(.),p(day)	3	65.69	6.24	0.028	0.044	59.06
□(.),p(aquatic vegetation)	4	66.22	6.77	0.021	0.034	57.14
□(.),p(global)	8	68.42	8.97	0.007	0.011	48.06

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.10. *Detection models for the northern cricket frog April, 2010.* Nine models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, northern cricket frog (6,14, n=42)						
□(.),p(environmental conditions 1 and day)	**4**	**81.07**	**0.00**	**0.382**	**1.000**	**71.99**
□(.),p(environmental conditions 2)	**4**	**81.56**	**0.49**	**0.299**	**0.783**	**72.48**
□(.),p(day)	**3**	**81.83**	**0.76**	**0.261**	**0.684**	**75.20**
□(.),p(moonshine)	**3**	**85.72**	**4.65**	**0.037**	**0.098**	**79.09**
□(.),p(time of day)	3	88.62	7.55	0.009	0.023	81.99
□(.),p(water temperature)	3	89.71	8.64	0.005	0.013	83.08
□(.),p(.)	2	90.55	9.48	0.003	0.009	86.24
□(.),p(wetland size)	4	90.98	9.91	0.003	0.007	81.90

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.11. *Detection models for the northern cricket frog May, 2010*. Nine models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, northern cricket frog (14,19, n=42)						
□(.),p(day)	**3**	**101.76**	**0.00**	**0.263**	**1.000**	**95.13**
□(.),p(water temperature)	**3**	**101.80**	**0.04**	**0.258**	**0.980**	**95.17**
□(.),p(moonshine)	**3**	**102.95**	**1.19**	**0.145**	**0.552**	**96.32**
□(.),p(.)	**2**	**103.69**	**1.93**	**0.100**	**0.382**	**99.38**
□(.),p(environmental conditions 1 and day)	**4**	**103.85**	**2.09**	**0.092**	**0.352**	**94.77**
□(.),p(environmental conditions 2)	**4**	**104.20**	**2.44**	**0.078**	**0.295**	**95.12**
□(.),p(time of day)	**3**	**104.97**	**3.21**	**0.053**	**0.201**	**98.34**
□(.),p(wetland size)	4	108.27	6.51	0.010	0.039	99.19
□(.),p(global)	8	111.90	10.14	0.002	0.006	91.54

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.12. *Detection models for the northern cricket frog June, 2010.* Nine models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, northern cricket frog (19,16, n=36)						
□(.),p(environmental conditions 1 and day)	**4**	**92.57**	**0.00**	**0.347**	**1.000**	**83.28**
□(.),p(water temperature)	**3**	**93.85**	**1.28**	**0.183**	**0.527**	**87.10**
□(.),p(time of day)	**3**	**94.23**	**1.66**	**0.151**	**0.436**	**87.48**
□(.),p(.)	**2**	**94.72**	**2.15**	**0.118**	**0.341**	**90.36**
□(.),p(day)	**3**	**95.83**	**3.26**	**0.068**	**0.196**	**89.08**
□(.),p(environmental conditions 2)	**4**	**96.26**	**3.69**	**0.055**	**0.158**	**86.97**
□(.),p(global)	**8**	**97.28**	**4.71**	**0.033**	**0.095**	**75.95**
□(.),p(moonshine)	3	97.10	4.53	0.036	0.104	90.35
□(.),p(wetland size)	4	99.64	7.07	0.010	0.029	90.35

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.13. *Detection models for the northern cricket frog May, 2011.* Twelve models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, northern cricket frog (17,16, n=40)						
□(.),p(water temperature)	**3**	**101.37**	**0.00**	**0.629**	**1.000**	**94.70**
□(.),p(environmental conditions 1 and day)	**6**	**103.27**	**1.90**	**0.243**	**0.387**	**88.72**
□(.),p(environmental conditions 1)	**5**	**105.89**	**4.53**	**0.065**	**0.104**	**94.13**
□(.),p(environmental conditions 2)	6	106.88	5.51	0.040	0.064	92.33
□(.),p(air temperature)	3	109.51	8.14	0.011	0.017	102.84
□(.),p(global)	10	111.11	9.74	0.005	0.008	83.52
□(.),p(.)	2	112.76	11.40	0.002	0.003	108.44
□(.),p(wind speed)	3	113.51	12.14	0.001	0.002	106.84
□(.),p(day)	3	113.67	12.30	0.001	0.002	107.00
□(.),p(moonshine)	3	114.84	13.47	0.001	0.001	108.17
□(.),p(time of day)	3	115.10	13.73	0.001	0.001	108.43
□(.),p(wetland size)	4	116.24	14.88	0.000	0.001	107.10

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.14. *Detection models for the northern cricket frog June, 2011.* Twelve models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, northern cricket frog (21,16, n=34)						
□(.),p(.)	**2**	**98.42**	**0.00**	**0.244**	**1.000**	**94.03**
□(.),p(wetland size)	**4**	**98.81**	**0.39**	**0.201**	**0.822**	**89.43**
□(.),p(water temperature)	**3**	**99.83**	**1.41**	**0.121**	**0.493**	**93.03**
□(.),p(moonshine)	**3**	**100.06**	**1.64**	**0.107**	**0.440**	**93.26**
□(.),p(day)	**3**	**100.56**	**2.14**	**0.084**	**0.343**	**93.76**
□(.),p(air temperature)	**3**	**100.72**	**2.30**	**0.077**	**0.316**	**93.92**
□(.),p(time of day)	**3**	**100.80**	**2.38**	**0.074**	**0.304**	**94.00**
□(.),p(wind speed)	**3**	**100.82**	**2.40**	**0.073**	**0.301**	**94.02**
□(.),p(environmental conditions 1)	5	104.57	6.16	0.011	0.046	92.43
□(.),p(global)	10	113.57	15.15	0.000	0.001	84.00

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.15. *Detection models for the Cope's gray tree frog in April, 2010.* Nine models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, Cope's gray treefrog (18,18, n=42)						
□(.),p(water temperature)	**3**	**100.20**	**0.00**	**0.544**	**1.000**	**93.57**
□(.),p(environmental conditions 2)	**4**	**102.51**	**2.31**	**0.171**	**0.315**	**93.43**
□(.),p(environmental conditions 1 and day)	**4**	**102.59**	**2.39**	**0.165**	**0.303**	**93.51**
□(.),p(.)	2	104.85	4.65	0.053	0.098	100.54
□(.),p(time of day)	3	106.29	6.09	0.026	0.048	99.66
□(.),p(day)	3	107.13	6.93	0.017	0.031	100.5
□(.),p(moonshine)	3	107.16	6.96	0.017	0.031	100.53
□(.),p(wetland size)	4	109.40	9.20	0.005	0.010	100.32
□(.),p(global)	8	111.92	11.72	0.002	0.003	91.56

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.16. *Detection models for the Cope's gray tree frog in May, 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, Cope's gray treefrog (16,24, n=42)						
□(.),p(environmental conditions 1 and day)	**4**	**89.40**	**0.00**	**0.452**	**1.000**	**80.32**
□(.),p(day)	**3**	**89.55**	**0.15**	**0.419**	**0.928**	**82.92**
□(.),p(environmental conditions 2)	4	94.06	4.66	0.044	0.097	84.98
□(.),p(water temperature)	3	94.15	4.75	0.042	0.093	87.52
□(.),p(global)	8	95.49	6.09	0.021	0.048	75.13
□(.),p(moonshine)	3	95.62	6.22	0.020	0.045	88.99
□(.),p(.)	2	103.32	13.92	0.000	0.001	99.01
□(.),p(time of day)	3	105.62	16.22	0.000	0.000	98.99
Tadpole detection, Cope's gray treefrog(6,6, n=42)						
□(.),p(day)	**3**	**59.91**	**0.00**	**0.442**	**1.000**	**53.28**
□(.),p(slope)	**3**	**61.00**	**1.09**	**0.256**	**0.580**	**54.37**
□(.),p(.)	**2**	**61.85**	**1.94**	**0.168**	**0.380**	**57.54**
□(.),p(global)	**4**	**62.31**	**2.40**	**0.133**	**0.301**	**53.23**

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.17. *Detection models for the Cope's gray tree frog in June, 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, Cope's gray treefrog (16,24, n=42)						
□(.),p(environmental conditions 1 and day)	**4**	**89.40**	**0.00**	**0.452**	**1.000**	**80.32**
□(.),p(day)	**3**	**89.55**	**0.15**	**0.419**	**0.928**	**82.92**
□(.),p(environmental conditions 2)	4	94.06	4.66	0.044	0.097	84.98
□(.),p(water temperature)	3	94.15	4.75	0.042	0.093	87.52
□(.),p(global)	8	95.49	6.09	0.021	0.048	75.13
□(.),p(moonshine)	3	95.62	6.22	0.020	0.045	88.99
□(.),p(.)	2	103.32	13.92	0.000	0.001	99.01
□(.),p(time of day)	3	105.62	16.22	0.000	0.000	98.99
Tadpole detection, Cope's gray treefrog(6,6, n=42)						
□(.),p(day)	**3**	**59.91**	**0.00**	**0.442**	**1.000**	**53.28**
□(.),p(slope)	**3**	**61.00**	**1.09**	**0.256**	**0.580**	**54.37**
□(.),p(.)	**2**	**61.85**	**1.94**	**0.168**	**0.380**	**57.54**
□(.),p(global)	**4**	**62.31**	**2.40**	**0.133**	**0.301**	**53.23**

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.18. *Detection models for the Cope's gray tree frog in May, 2011.* Twelve models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, Cope's gray treefrog (16,15, n=40)						
□(.),p(environmental conditions 1 and day)	**6**	**81.55**	**0.00**	**0.689**	**1.000**	**67.00**
□(.),p(water temperature)	**3**	**85.37**	**3.82**	**0.102**	**0.148**	**78.70**
□(.),p(environmental conditions 1)	**5**	**85.97**	**4.43**	**0.075**	**0.109**	**74.21**
□(.),p(environmental conditions 2)	6	86.24	4.69	0.066	0.096	71.69
□(.),p(air temperature)	3	86.21	4.66	0.067	0.097	79.54
□(.),p(global)	10	93.88	12.33	0.001	0.002	66.29
□(.),p(day)	3	110.72	29.17	0.000	0.000	104.05
□(.),p(.)	2	111.14	29.60	0.000	0.000	106.82
□(.),p(time of day)	3	112.01	30.46	0.000	0.000	105.34
□(.),p(wind speed)	3	112.37	30.82	0.000	0.000	105.70
□(.),p(moonshine)	3	113.49	31.94	0.000	0.000	106.82
□(.),p(wetland size)	4	114.04	32.50	0.000	0.000	104.90

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.19. *Detection models for the Cope's gray tree frog in June, 2011.* Twelve models were tested for adult detection and eight models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, Cope's gray treefrog (26,20, n=34)						
□(.),p(water temperature)	**3**	**92.09**	**0.00**	**0.225**	**1.000**	**85.29**
□(.),p(.)	**2**	**92.61**	**0.52**	**0.173**	**0.772**	**88.30**
□(.),p(air temperature)	**3**	**93.32**	**1.23**	**0.121**	**0.540**	**86.69**
□(.),p(day)	**3**	**93.61**	**1.52**	**0.105**	**0.467**	**86.98**
□(.),p(time of day)	**3**	**93.72**	**1.63**	**0.099**	**0.442**	**87.09**
□(.),p(wind speed)	**3**	**94.19**	**2.10**	**0.079**	**0.350**	**87.56**
□(.),p(wetland size)	**4**	**94.33**	**2.24**	**0.073**	**0.326**	**85.25**
□(.),p(moonshine)	**3**	**94.65**	**2.56**	**0.062**	**0.278**	**88.02**
□(.),p(environmental conditions 1)	**5**	**95.83**	**3.74**	**0.035**	**0.154**	**84.16**
□(.),p(environmental conditions 2)	6	97.14	5.05	0.018	0.080	82.74
□(.),p(global)	10	103.67	11.58	0.001	0.003	76.57
Tadpole detection, Cope's gray treefrog (6,7, n=34)						
□(.),p(water temperature)	**3**	**40.85**	**0.00**	**0.629**	**1.000**	**34.05**
□(.),p(water temperature and slope)	**4**	**43.42**	**2.57**	**0.174**	**0.277**	**34.04**
□(.),p(aquatic vegetation)	**4**	**44.34**	**3.49**	**0.110**	**0.175**	**34.96**
□(.),p(.)	2	46.09	5.24	0.046	0.073	41.70
□(.),p(time)	3	47.12	6.27	0.027	0.043	40.32
□(.),p(slope)	3	48.49	7.64	0.014	0.022	41.69

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.20. *Detection models for the plains leopard frog April, 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, plains leopard frog (18,20, n=42)						
□(.),p(.)	**2**	**113.37**	**0.00**	**0.311**	**1.000**	**109.06**
□(.),p(day)	**3**	**114.76**	**1.39**	**0.155**	**0.498**	**108.13**
□(.),p(time of day)	**3**	**115.14**	**1.77**	**0.128**	**0.412**	**108.51**
□(.),p(water temperature)	**3**	**115.18**	**1.81**	**0.125**	**0.404**	**108.55**
□(.),p(moonshine)	**3**	**115.66**	**2.29**	**0.099**	**0.318**	**109.03**
□(.),p(wetland size)	**4**	**115.85**	**2.48**	**0.090**	**0.289**	**106.77**
□(.),p(environmental conditions 1 and day)	**4**	**116.83**	**3.46**	**0.055**	**0.177**	**107.75**
□(.),p(environmental conditions 2)	**4**	**117.61**	**4.24**	**0.037**	**0.120**	**108.53**
□(.),p(global)	8	124.81	11.45	0.001	0.003	104.45
Tadpole detection, plains leopard frog (17,14, n=42)						
□(.),p(slope)	**3**	**99.92**	**0.00**	**0.599**	**1.000**	**93.29**
□(.),p(global)	**4**	**102.35**	**2.43**	**0.178**	**0.297**	**93.27**
□(.),p(.)	**2**	**102.44**	**2.52**	**0.170**	**0.284**	**98.13**
□(.),p(day)	3	104.75	4.83	0.054	0.089	98.12

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.21. *Detection models for the plains leopard frog May, 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, plains leopard frog (6,19, n=42)						
□(.),p(moonshine)	**3**	**102.68**	**0.00**	**0.246**	**1.000**	**96.05**
□(.),p(day)	**3**	**102.77**	**0.09**	**0.235**	**0.956**	**96.14**
□(.),p(wetland size)	**4**	**103.57**	**0.89**	**0.158**	**0.641**	**94.49**
□(.),p(environmental conditions 2)	**4**	**104.90**	**2.22**	**0.081**	**0.330**	**95.82**
□(.),p(environmental conditions 1 and day)	**4**	**105.07**	**2.39**	**0.074**	**0.303**	**95.99**
□(.),p(water temperature)	**3**	**105.14**	**2.46**	**0.072**	**0.292**	**98.51**
□(.),p(global)	**8**	**105.82**	**3.14**	**0.051**	**0.208**	**85.46**
□(.),p(time of day)	**3**	**105.99**	**3.31**	**0.047**	**0.191**	**99.36**
□(.),p(.)	**2**	**106.55**	**3.87**	**0.036**	**0.145**	**102.24**
Tadpole detection, plains leopard frog (21,20, n=42)						
□(.),p(slope)	**3**	**103.08**	**0.00**	**0.610**	**1.000**	**96.45**
□(.),p(global)	**4**	**105.52**	**2.44**	**0.180**	**0.295**	**96.44**
□(.),p(.)	**2**	**106.15**	**3.07**	**0.132**	**0.216**	**101.84**
□(.),p(day)	**3**	**107.19**	**4.11**	**0.078**	**0.128**	**100.56**

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.22. *Detection models for the plains leopard frog June, 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, plains leopard frog (10,12, n=36)						
□(.),p(moonshine)	**3**	**90.98**	**0.00**	**0.442**	**1.000**	**84.23**
□(.),p(.)	**2**	**92.74**	**1.76**	**0.183**	**0.414**	**88.38**
□(.),p(environmental conditions 2)	**4**	**93.51**	**2.53**	**0.125**	**0.282**	**84.22**
□(.),p(water temperature)	**3**	**94.41**	**3.43**	**0.080**	**0.180**	**87.66**
□(.),p(day)	**3**	**94.81**	**3.83**	**0.065**	**0.147**	**88.06**
□(.),p(time of day)	**3**	**95.03**	**4.05**	**0.058**	**0.132**	**88.28**
□(.),p(wetland size)	4	96.85	5.87	0.023	0.053	87.56
□(.),p(environmental conditions 1 and day)	4	96.89	5.91	0.023	0.052	87.60
□(.),p(global)	8	103.09	12.11	0.001	0.002	81.76
Tadpole detection, plains leopard frog (15,9, n=36)						
□(.),p(.)	**2**	**91.05**	**0.00**	**0.321**	**1.000**	**86.69**
□(.),p(day)	**3**	**91.21**	**0.16**	**0.297**	**0.925**	**84.46**
□(.),p(slope)	**3**	**91.35**	**0.30**	**0.277**	**0.862**	**84.60**
□(.),p(global)	**4**	**93.28**	**2.23**	**0.105**	**0.328**	**83.99**

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.23. *Detection models for the plains leopard frog April, 2011.* Twelve models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, plains leopard frog (30,19, n=42)						
□(.),p(environmental conditions 1)	**5**	**108.49**	**0.00**	**0.365**	**1.000**	**96.82**
□(.),p(environmental conditions 2)	**6**	**109.29**	**0.80**	**0.244**	**0.669**	**94.89**
□(.),p(water temperature)	**3**	**110.09**	**1.60**	**0.164**	**0.448**	**103.46**
□(.),p(environmental conditions 1 and day)	**6**	**111.18**	**2.69**	**0.095**	**0.260**	**96.78**
□(.),p(air temperature)	**3**	**111.27**	**2.78**	**0.091**	**0.248**	**104.64**
□(.),p(moonshine)	3	113.92	5.43	0.024	0.066	107.29
□(.),p(day)	3	116.73	8.24	0.006	0.016	110.10
□(.),p(wind speed)	3	117.71	9.22	0.004	0.010	111.08
□(.),p(global)	10	117.88	9.39	0.003	0.009	90.78
□(.),p(.)	2	118.21	9.72	0.003	0.008	113.90
□(.),p(time of day)	3	119.42	10.93	0.002	0.004	112.79
□(.),p(wetland size)	4	122.61	14.12	0.000	0.001	113.53

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.24. *Detection models for the plains leopard frog May, 2011.* Twelve models were tested for adult detection and eight models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, plains leopard frog (13,25, n=40)						
□(.),p(environmental conditions 1 and day)	**6**	**106.07**	**0.00**	**0.427**	**1.000**	**91.52**
□(.),p(environmental conditions 2)	**6**	**106.85**	**0.78**	**0.289**	**0.677**	**92.30**
□(.),p(moonshine)	**3**	**108.13**	**2.06**	**0.152**	**0.357**	**101.46**
□(.),p(global)	**10**	**110.66**	**4.59**	**0.043**	**0.101**	**83.07**
□(.),p(environmental conditions 1)	5	111.01	4.95	0.036	0.084	99.25
□(.),p(wind speed)	3	112.61	6.54	0.016	0.038	105.94
□(.),p(time of day)	3	113.26	7.19	0.012	0.027	106.59
□(.),p(water temperature)	3	114.25	8.18	0.007	0.017	107.58
□(.),p(day)	3	114.53	8.46	0.006	0.015	107.86
□(.),p(.)	2	114.64	8.58	0.006	0.014	110.32
□(.),p(wetland size)	4	115.81	9.75	0.003	0.008	106.67
□(.),p(air temperature)	3	115.84	9.77	0.003	0.008	109.17
Tadpole detection, plains leopard frog (23,20, n=40)						
□(.),p(water temperature)	**3**	**86.68**	**0.00**	**0.365**	**1.000**	**80.01**
□(.),p(day)	**3**	**87.41**	**0.73**	**0.253**	**0.694**	**80.74**
□(.),p(water temperature and slope)	**4**	**88.44**	**1.77**	**0.151**	**0.414**	**79.30**
□(.),p(time of day)	**3**	**89.61**	**2.93**	**0.084**	**0.231**	**82.94**
□(.),p(.)	**2**	**89.66**	**2.99**	**0.082**	**0.225**	**85.34**
□(.),p(aquatic vegetation)	**4**	**91.27**	**4.60**	**0.037**	**0.100**	**82.13**
□(.),p(slope)	3	91.98	5.30	0.026	0.071	85.31
□(.),p(global)	8	96.41	9.73	0.003	0.008	75.76

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.25. *Detection models for the plains leopard frog June, 2011.* Twelve models were tested for adult detection and eight models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, plains leopard frog (12,12, n=34)						
□(.),p(.)	**2**	**88.42**	**0.00**	**0.259**	**1.000**	**84.03**
□(.),p(moonshine)	**3**	**88.90**	**0.48**	**0.203**	**0.785**	**82.27**
□(.),p(day)	**3**	**90.33**	**1.91**	**0.100**	**0.384**	**83.70**
□(.),p(time of day)	**3**	**90.41**	**1.99**	**0.096**	**0.369**	**83.78**
□(.),p(water temperature)	**3**	**90.42**	**2.00**	**0.095**	**0.367**	**83.79**
□(.),p(wind speed)	**3**	**90.59**	**2.17**	**0.087**	**0.337**	**83.96**
□(.),p(air temperature)	**3**	**90.64**	**2.22**	**0.085**	**0.329**	**84.01**
□(.),p(wetland size)	**4**	**91.44**	**3.02**	**0.057**	**0.220**	**82.36**
□(.),p(environmental conditions 1)	5	95.16	6.74	0.009	0.034	83.49
□(.),p(environmental conditions 2)	6	96.06	7.64	0.006	0.022	81.66
□(.),p(environmental conditions 1 and day)	6	97.49	9.07	0.003	0.011	83.09
□(.),p(global)	10	106.60	18.18	0.000	0.000	79.50
Tadpole detection, plains leopard frog (25,27, n=34)						
□(.),p(.)	**2**	**66.19**	**0.00**	**0.239**	**1.000**	**61.80**
□(.),p(time)	**3**	**66.31**	**0.12**	**0.225**	**0.940**	**59.68**
□(.),p(day)	**3**	**67.13**	**0.94**	**0.149**	**0.624**	**60.50**
□(.),p(water temperature)	**3**	**67.36**	**1.17**	**0.133**	**0.556**	**60.73**
□(.),p(slope)	**3**	**67.73**	**1.54**	**0.111**	**0.462**	**61.10**
□(.),p(aquatic vegetation)	**4**	**68.39**	**2.20**	**0.079**	**0.332**	**59.31**
□(.),p(water temperature and slope)	**4**	**69.77**	**3.58**	**0.040**	**0.167**	**60.69**
□(.),p(global)	**8**	**70.81**	**4.63**	**0.024**	**0.099**	**50.45**

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.26. *Detection models for the American bullfrog May, 2010.* Four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Tadpole detection, American bullfrog (4,3, n=42)						
□(.),p(.)	**2**	**51.10**	**0.00**	**0.429**	**1.000**	**46.79**
□(.),p(day)	**3**	**52.16**	**1.06**	**0.252**	**0.587**	**45.53**
□(.),p(slope)	**3**	**52.86**	**1.76**	**0.178**	**0.414**	**46.23**
□(.),p(global)	**4**	**53.31**	**2.21**	**0.142**	**0.331**	**44.23**

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.27. *Detection models for the American bullfrog June, 2010.* Nine models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, American bullfrog (6,11, n=36)						
□(.),p(moonshine)	**3**	**79.45**	**0.00**	**0.451**	**1.000**	**72.70**
□(.),p(environmental conditions 2)	**4**	**81.01**	**1.56**	**0.207**	**0.458**	**71.72**
□(.),p(wetland size)	**4**	**82.07**	**2.62**	**0.122**	**0.270**	**72.78**
□(.),p(day)	**3**	**83.10**	**3.65**	**0.073**	**0.161**	**76.35**
□(.),p(.)	**2**	**83.06**	**3.61**	**0.074**	**0.164**	**78.70**
□(.),p(time of day)	**3**	**83.58**	**4.13**	**0.057**	**0.127**	**76.83**
□(.),p(global)	8	86.13	6.68	0.016	0.035	64.80

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.28. *Detection models for the American bullfrog May, 2011.* Eight models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Tadpole detection, American bullfrog (4,5, n=40)						
□(.),p(slope)	**3**	**53.55**	**0.00**	**0.496**	**1.000**	**46.88**
□(.),p(time of day)	**3**	**55.71**	**2.16**	**0.168**	**0.340**	**49.04**
□(.),p(water temperature and slope)	**4**	**55.95**	**2.41**	**0.149**	**0.300**	**46.81**
□(.),p(.)	**2**	**56.73**	**3.19**	**0.101**	**0.203**	**52.41**
□(.),p(day)	3	58.94	5.39	0.033	0.068	52.27
□(.),p(water temperature)	3	59.07	5.52	0.031	0.063	52.40
□(.),p(aquatic vegetation)	4	60.49	6.95	0.015	0.031	51.35
□(.),p(global)	8	62.47	8.92	0.006	0.012	41.82

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.29. *Detection models for the American bullfrog June, 2011.* Twelve models were tested for adult detection and eight models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, American bullfrog (11,7, n=34)						
□(.),p(.)	**3**	**52.08**	**0.00**	**0.577**	**1.000**	**45.28**
□(.),p(water temperature)	**4**	**53.23**	**1.15**	**0.325**	**0.562**	**44.15**
□(.),p(wind speed)	8	57.94	5.86	0.031	0.053	37.58
□(.),p(time of day)	3	58.77	6.69	0.020	0.035	52.14
□(.),p(moonshine)	2	58.93	6.85	0.019	0.033	54.62
□(.),p(environmental conditions 1)	3	59.81	7.73	0.012	0.021	53.18
□(.),p(environmental conditions 2)	4	60.47	8.39	0.009	0.015	51.39
□(.),p(environmental conditions 1 and day)	3	60.82	8.74	0.007	0.013	54.19
Tadpole detection, American bullfrog (4,7, n=34)						
□(.),p(slope)	**3**	**52.08**	**0.00**	**0.577**	**1.000**	**45.28**
□(.),p(water temperature and slope)	**4**	**53.23**	**1.15**	**0.325**	**0.562**	**44.15**
□(.),p(global)	8	57.94	5.86	0.031	0.053	37.58
□(.),p(day)	3	58.77	6.69	0.020	0.035	52.14
□(.),p(.)	2	58.93	6.85	0.019	0.033	54.62
□(.),p(time)	3	59.81	7.73	0.012	0.021	53.18
□(.),p(aquatic vegetation)	4	60.47	8.39	0.009	0.015	51.39
□(.),p(water temperature)	3	60.82	8.74	0.007	0.013	54.19

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.30. *Detection models for the Woodhouse's toad April, 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	AICc	Δ	w	l	K	-2l
Adult detection, Woodhouse's toad (13,4, n=42)						
□(.),p(day)	**3**	**77.16**	**0.00**	**0.441**	**1.000**	**70.53**
□(.),p(moonshine)	**3**	**78.10**	**0.94**	**0.275**	**0.625**	**71.47**
□(.),p(environmental conditions 1 and day)	**4**	**79.18**	**2.02**	**0.161**	**0.364**	**70.1**
□(.),p(environmental conditions 2)	**4**	**80.39**	**3.23**	**0.088**	**0.199**	**71.31**
□(.),p(global)	8	84.22	7.06	0.013	0.029	63.86
□(.),p(.)	2	84.52	7.36	0.011	0.025	80.21
□(.),p(water temperature)	3	85.95	8.79	0.005	0.012	79.32
□(.),p(time of day)	3	86.82	9.66	0.004	0.008	80.19
□(.),p(wetland size)	4	87.56	10.40	0.002	0.006	78.48
Tadpole detection, Woodhouse's toad (5,9, n=42)						
□(.),p(slope)	**3**	**61.32**	**0.00**	**0.763**	**1.000**	**54.69**
□(.),p(global)	**4**	**63.70**	**2.38**	**0.232**	**0.304**	**54.62**
□(.),p(.)	2	72.19	10.87	0.003	0.004	67.88
□(.),p(day)	3	73.77	12.45	0.002	0.002	67.14

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.31. *Detection models for the Woodhouse's toad May, 2010.* Nine models were tested for adult detection and four models were tested for tadpole detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, Woodhouse's toad (6,7, n=42)						
□(.),p(.)	**2**	**67.25**	**0.00**	**0.316**	**1.000**	**62.94**
□(.),p(time of day)	**3**	**67.80**	**0.55**	**0.239**	**0.758**	**61.17**
□(.),p(water temperature)	**3**	**69.02**	**1.77**	**0.130**	**0.412**	**62.39**
□(.),p(day)	**3**	**69.24**	**1.99**	**0.117**	**0.369**	**62.61**
□(.),p(moonshine)	**3**	**69.40**	**2.15**	**0.108**	**0.341**	**62.77**
□(.),p(environmental conditions 2)	**4**	**71.40**	**4.15**	**0.040**	**0.125**	**62.32**
□(.),p(environmental conditions 1 and day)	**4**	**71.46**	**4.21**	**0.038**	**0.122**	**62.38**
□(.),p(global)	8	73.66	6.42	0.013	0.040	53.30
Tadpole detection, Woodhouse's toad (6,4, n=42)						
□(.),p(day)	**3**	**50.10**	**0.00**	**0.467**	**1.000**	**43.47**
□(.),p(global)	**4**	**51.01**	**0.91**	**0.297**	**0.635**	**41.93**
□(.),p(slope)	**3**	**51.58**	**1.48**	**0.223**	**0.477**	**44.95**
□(.),p(.)	2	57.26	7.16	0.013	0.028	52.95

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.32. *Detection models for the Woodhouse's toad June, 2010.* Nine models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, Woodhouse's toad (1,5, n=36)						
□(.),p(moonshine)	**3**	**46.56**	**0.00**	**0.289**	**1.000**	**39.81**
□(.),p(water temperature)	**3**	**47.05**	**0.49**	**0.226**	**0.783**	**40.30**
□(.),p(environmental conditions 1 + day	**4**	**47.41**	**0.85**	**0.189**	**0.654**	**38.12**
□(.),p(time of day)	**3**	**48.05**	**1.49**	**0.137**	**0.475**	**41.30**
□(.),p(environmental conditions 2)	**4**	**48.74**	**2.18**	**0.097**	**0.336**	**39.45**
□(.),p(wetland size)	**4**	**50.14**	**3.58**	**0.048**	**0.167**	**40.85**
□(.),p(global)	8	52.71	6.15	0.013	0.046	31.38

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.33. *Detection models for the Woodhouse's toad May, 2011.* Twelve models were tested for adult detection. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult detection, Woodhouse's toad (8,4, n=40)						
□(.),p(air temperature)	**3**	**60.55**	**0.00**	**0.456**	**1.000**	**53.88**
□(.),p(water temperature)	**3**	**60.66**	**0.11**	**0.432**	**0.946**	**53.99**
□(.),p(environmental conditions 1)	**5**	**64.79**	**4.25**	**0.055**	**0.120**	**53.03**
□(.),p(environmental conditions 1 and day)	6	65.22	4.67	0.044	0.097	50.67
□(.),p(day)	3	68.62	8.07	0.008	0.018	61.95
□(.),p(global)	10	72.16	11.61	0.001	0.003	44.57
□(.),p(.)	2	71.94	11.40	0.002	0.003	67.62
□(.),p(time of day)	3	73.51	12.96	0.001	0.002	66.84
□(.),p(wind speed)	3	73.95	13.40	0.001	0.001	67.28
□(.),p(moonshine)	3	74.08	13.53	0.001	0.001	67.41
□(.),p(wetland size)	4	76.10	15.56	0.000	0.000	66.96

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.34. *Adult detection parameter estimates April, 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	time	water	moon	small	medium
Western chorus frog (23, 7, n=42)								
□(.),p(environmental conditions 1 and day)	4	0.375	-28.98 ± 9.34		44.02 ± 27.75			
□(.),p(global)	8	0.330	-46.23 ± 16.28	-3.15 ± 19.80	-88.48 ± 36.25	-2.49 ± 3.03	4.34 ± 1.91	7.65 ± 2.99
□(.),p(day)	3	0.277	-23.40 ± 7.68					
Northern cricket frog (6,14, n=42)								
□(.),p(environmental conditions 1 and day)	4	0.382	24.81 ± 11.98		65.87 ± 43.22			
□(.),p(environmental conditions 2)	4	0.299			67.51 ± 35.85	4.44 ± 1.87		
□(.),p(day)	3	0.261	22.38 ± 9.59					
□(.),p(moonshine)	3	0.037				3.42 ± 1.61		
Cope's gray treefrog (18,18, n=42)								
□(.),p(water temperature)	3	0.544			54.00 ± 23.34			
□(.),p(environmental conditions 2)	4	0.171			54.68 ± 23.37	0.41 ± 1.11		
□(.),p(environmental conditions 1 and day)	4	0.165	-1.32 ± 5.25		53.91 ± 23.41			

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.34, continued. *Adult detection parameter estimates April, 2010*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	time	water	moon	small	medium
Plains leopard frog (18,20, n=42)								
□(.),p(.)	2	0.311						
□(.),p(day)	3	0.155	3.76 ± 3.94					
□(.),p(time of day)	3	0.128		6.27 ± 10.70				
□(.),p(water temperature)	3	0.125			-1.38 ± 2.81			
□(.),p(moonshine)	3	0.099				-0.14 ± 0.92		
□(.),p(wetland size)	4	0.090					0.39 ± 1.41	-0.84 ± 1.32
□(.),p(environmental conditions 1 and day)	4	0.055	3.47 ± 3.93		9.95 ± 16.07			
□(.),p(environmental conditions 2)	4	0.037			11.10 ± 15.54	-0.11 ± 0.92		
Woodhouse's toad (13,4, n=42)								
□(.),p(day)	3	0.441	-17.97 ± 7.00					
□(.),p(moonshine)	3	0.275				-3.78 ± 1.60		
□(.),p(environmental conditions 1 and day)	4	0.161	-17.44 ± 7.65		17.76 ± 26.80			
□(.),p(environmental conditions 2)	4	0.088			10.74 ± 26.84	-3.69 ± 1.63		

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.35. *Adult detection parameter estimates May, 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	time	water	moon	small	medium
Western chorus frog (5,5, n=42)								
□(.),p(.)	2	0.309						
□(.),p(time of day)	3	0.215		12.52 ± 2.74				
□(.),p(water temperature)	3	0.125			-7.36 ± 10.02			
□(.),p(day)	3	0.119	-6.25 ± 9.51					
□(.),p(moonshine)	3	0.110				-0.71 ± 1.40		
□(.),p(wetland size)	4	0.047					1.14 ± 1.22	0.92 ± 1.29
Northern cricket frog (14,19, n=42)								
□(.),p(day)	3	0.263	20.79 ± 12.66					
□(.),p(water temperature)	3	0.258			25.30 ± 12.51			
□(.),p(moonshine)	3	0.145				2.39 ± 1.50		
□(.),p(.)	2	0.100						
□(.),p(environmental conditions 1 and day)	4	0.092	11.12 ± 21.20		14.50 ± 24.65			
□(.),p(environmental conditions 2)	4	0.078			22.39 ± 18.68	0.45 ± 2.08		
□(.),p(time of day)	3	0.053		12.83 ± 2.19				
Cope's gray treefrog (16,24, n=42)								
□(.),p(environmental conditions 1 and day)	4	0.452	117.00 ± 10.13		33.83 ± 20.71			
□(.),p(day)	3	0.419	124.13 ± 6.37					

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.35. *Adult detection parameter estimates May, 2010, continued.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day			time			water			moon			small			medium		
Plains leopard frog (6,19, n=42)																				
□(.),p(moonshine)	3	0.246										2.85	±	1.47						
□(.),p(day)	3	0.235	21.74	±	9.64															
□(.),p(wetland size)	4	0.158													1.79	±	0.81	0.74	±	0.90
□(.),p(environmental conditions 2)	4	0.081							11.35	±	21.05	2.63	±	1.68						
□(.),p(environmental conditions 1 and day)	4	0.074	20.00	±	11.80				9.24	±	21.90									
□(.),p(water temperature)	3	0.072							26.54	±	15.65									
□(.),p(global)	8	0.051	-10.31	±	14.87	14.47	±	4.68	13.40	±	12.96	2.29	±	2.15	2.23	±	0.99	0.70	±	1.01
□(.),p(time of day)	3	0.047				11.63	±	3.59												
□(.),p(.)	2	0.036																		
Woodhouse's toad (6,7, n=42)																				
□(.),p(.)	2	0.316																		
□(.),p(time of day)	3	0.239				27.60	±	9.97												
□(.),p(water temperature)	3	0.130							13.94	±	18.11									
□(.),p(day)	3	0.117	6.64	±	11.74															
□(.),p(moonshine)	3	0.108										0.69	±	1.65						
□(.),p(environmental conditions 2)	4	0.040							19.69	±	27.16	-0.69	±	2.53						
□(.),p(environmental conditions 1 and day)	4	0.038	-1.38	±	19.59				15.70	±	30.54									

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.36. *Adult detection parameter estimates June 2010*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	time	water	moon	small	medium
Northern cricket frog (19,16, n=36)								
□(.),p(environmental conditions 1 and day)	4	0.347	-10.18 ± 5.14		43.29 ± 15.40			
□(.),p(water temperature)	3	0.183	31.64 ± 14.26					
□(.),p(time of day)	3	0.151		24.75 ± 2.25				
□(.),p(.)	2	0.118						
□(.),p(day)	3	0.068	-6.01 ± 5.52					
□(.),p(environmental conditions 2)	4	0.055			33.20 ± 14.79	-0.32 ± 0.89		
□(.),p(global)	8	0.033	-20.39 ± 7.22	25.96 ± 7.10	63.68 ± 19.74	2.03 ± 1.44	1.06 ± 1.09	-0.69 ± 0.96
Cope's gray treefrog (15,20, n=36)								
□(.),p(moonshine)	3	0.306				2.27 ± 1.40		
□(.),p(environmental conditions 2)	4	0.205			-29.77 ± 20.46	2.78 ± 20.46		
□(.),p(.)	2	0.143						
□(.),p(time of day)	3	0.095		17.56 ± 2.26				
□(.),p(global)	8	0.050	-15.53 ± 8.01	32.28 ± 6.30	2.10 ± 23.07	6.42 ± 2.18	0.64 ± 1.15	-2.30 ± 1.11
□(.),p(day)	3	0.067	5.34 ± 6.19					
□(.),p(water temperature)	3	0.053			-14.02 ± 20.10			
□(.),p(wetland size)	4	0.044					-0.33 ± 1.08	-1.54 ± 1.03
□(.),p(environmental conditions 1 and day)	4	0.037	8.69 ± 6.72		-24.97 ± 19.94			

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.36. *Adult detection parameter estimates June, 2010, continued*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	time	water	moon	small	medium
Plains leopard frog (10,12, n=36)								
□(.),p(moonshine)	3	0.442				1.58 ± 0.87		
□(.),p(.)	2	0.183						
□(.),p(environmental conditions 2)	4	0.125			1.86 ± 13.68	1.53 ± 0.93		
□(.),p(water temperature)	3	0.080			9.59 ± 10.60			
□(.),p(day)	3	0.065	2.51 ± 4.32					
□(.),p(time of day)	3	0.058		-2.85 ± 7.18				
American bullfrog (6,11, n=36)								
□(.),p(moonshine)	3	0.451				1.78 ± 0.73		
□(.),p(environmental conditions 2)	4	0.207			12.49 ± 12.67	1.51 ± 0.77		
□(.),p(wetland size)	4	0.122					-1.35 ± 0.78	0.29 ± 0.66
□(.),p(day)	3	0.073	-6.21 ± 4.22					
□(.),p(.)	2	0.074						
□(.),p(time of day)	3	0.057		11.95 ± 6.21				
Woodhouse's toad (1,5, n=36)								
□(.),p(moonshine)	3	0.289				1.33 ± 1.08		
□(.),p(water temperature)	3	0.226			17.41 ± 19.78			
□(.),p(environmental conditions 1 + day	4	0.189	10.39 ± 9.40		7.74 ± 21.20			
□(.),p(time of day)	3	0.137		-0.72 ± 14.96				
□(.),p(environmental conditions 2)	4	0.097			11.32 ± 20.20	1.06 ± 1.15		
□(.),p(wetland size)	4	0.048					0.75 ± 1.19	0.64 ± 1.27

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.37. *Adult detection parameter estimates April, 2011*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	moon	time	water	wind	air	small	medium
Western chorus frog (30,27, n=42)										
□(.),p(moonshine)	3	0.229		-2.61 ± 1.56						
□(.),p(.)	2	0.148								
□(.),p(environmental conditions 1)	5	0.139				45.54 ± 22.43	0.78 ± 1.16	-37.40 ± 16.02		
□(.),p(air temperature)	3	0.125						-10.96 ± 7.99		
□(.),p(day)	3	0.070	-8.09 ± 9.17							
□(.),p(environmental conditions 2)	6	0.063		-1.69 ± 1.70		37.92 ± 25.03	0.55 ± 1.16	-33.83 ± 17.00		
□(.),p(wind speed)	3	0.057					0.77 ± 1.25			
□(.),p(environmental conditions 1and day)	6	0.049	-9.44 ± 12.18			36.24 ± 25.79	0.91 ± 1.17	-37.05 ± 16.62		
□(.),p(time of day)	3	0.048			2.41 ± 9.28					
□(.),p(water temperature)	3	0.047				1.59 ± 13.82				
□(.),p(wetland size)	4	0.025							0.94 ± 1.06	0.08 ± 1.11
Plains leopard frog (30,19, n=42)										
□(.),p(environmental conditions 1)	5	0.365				18.51 ± 17.41	-2.44 ± 1.05	17.72 ± 12.89		
□(.),p(environmental conditions 2)	6	0.244		1.89 ± 1.36		22.41 ± 19.06	-1.91 ± 1.10	9.99 ± 15.43		
□(.),p(water temperature)	3	0.164				35.28 ± 11.62				
□(.),p(environmental conditions 1and day)	6	0.095	2.30 ± 11.06			21.13 ± 21.48	-2.47 ± 1.06	16.94 ± 13.47		
□(.),p(air temperature)	3	0.091						22.59 ± 8.60		

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.38. *Adult detection parameter estimates May, 2011*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	moon	time	water	wind	air
Western chorus frog (7,11, n=40)								
□(.),p(air temperature)	3	0.309						-13.18 ± 6.80
□(.),p(water temperature)	3	0.250				-15.63 ± 9.05		
□(.),p(day)	3	0.116	17.71 ± 9.59					
□(.),p(.)	2	0.111						
□(.),p(moonshine)	3	0.069		1.13 ± 0.99				
□(.),p(wind speed)	3	0.042					-0.38 ± 0.64	
□(.),p(time of day)	3	0.036			3.33 ± 8.18			
□(.),p(environmental conditions 1)	5	0.032				10.70 ± 32.00	-0.53 ± 0.79	-21.17 ± 24.20
Northern cricket frog (17,16, n=40)								
□(.),p(water temperature)	3	0.629				29.04 ± 10.69		
□(.),p(environmental conditions 1 and day)	6	0.243	43.20 ± 14.92			41.73 ± 18.31	1.78 ± 0.88	-0.66 ± 10.73
□(.),p(environmental conditions 1)	5	0.065				35.76 ± 20.03	0.28 ± 0.67	-6.75 ± 12.43
Cope's gray treefrog (16,15, n=40)								
□(.),p(environmental conditions 1 and day)	6	0.689	53.67 ± 5.34			30.00 ± 16.55	0.11 ± 0.80	23.78 ± 11.68
□(.),p(water temperature)	3	0.102				30.38 ± 6.82		
□(.),p(environmental conditions 1)	5	0.075				24.64 ± 11.96	-1.03 ± 0.68	7.14 ± 7.11

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.38. *Adult detection parameter estimates May, 2011, continued.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	moon	time	water	wind	air	small	medium
Plains leopard frog (13,25, n=40)										
□(.),p(environmental conditions 1and day)	6	0.427	71.07 ± 8.98			44.26 ± 11.44	-0.24 ± 0.75	-3.10 ± 6.74		
□(.),p(environmental conditions 2)	6	0.289		3.69 ± 1.52		29.19 ± 16.21	-0.42 ± 0.88	-7.13 ± 9.84		
□(.),p(moonshine)	3	0.152		2.75 ± 1.10						
□(.),p(global)	10	0.043	27.08 ± 27.94	2.30 ± 1.95	-25.37 ± 10.08	38.97 ± 17.48	-0.85 ± 1.00	-5.93 ± 9.57	1.70 ± 1.05	0.62 ± 1.01
Woodhouse's toad (8,4, n=40)										
□(.),p(air temperature)	3	0.456						17.18 ± 5.17		
□(.),p(water temperature)	3	0.432				26.38 ± 8.07				
□(.),p(environmental conditions 1)	5	0.055				15.74 ± 15.36	0.17 0.69	7.64 ± 9.54		

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.39. *Adult detection parameter estimates June, 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	moon	time	water	wind	air	small	medium
Northern cricket frog (21,16, n=34)										
□(.),p(.)	2	0.244								
□(.),p(wetland size)	4	0.201							1.03 ± 0.64	-0.11 ± 0.63
□(.),p(water temperature)	3	0.121				8.39 ± 8.42				
□(.),p(moonshine)	3	0.107		1.21 ± 1.39						
□(.),p(day)	3	0.084	-4.93 ± 7.79							
□(.),p(air temperature)	3	0.077						2.06 ± 6.11		
□(.),p(time of day)	3	0.074			-1.39 ± 6.93					
□(.),p(wind speed)	3	0.073					0.07 ± 0.69			
Cope's gray treefrog (26,20, n=34)										
□(.),p(water temperature)	3	0.225				15.38 ± 8.99				
□(.),p(.)	2	0.173								
□(.),p(air temperature)	3	0.121						8.18 ± 6.62		
□(.),p(day)	3	0.105	-11.37 ± 6.25							
□(.),p(time of day)	3	0.099			-8.52 ± 4.75					
□(.),p(wind speed)	3	0.079					0.65 ± 0.77			
□(.),p(wetland size)	4	0.073							0.75 ± 0.67	-0.28 ± 0.63
□(.),p(moonshine)	3	0.062		0.76 ± 1.45						
□(.),p(environmental conditions 1)	5	0.035				19.42 ± 14.48	0.80 ± 0.78	-2.77 ± 10.42		

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.39. *Adult detection parameter estimates June, 2011, continued.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	moon	time	water	wind	air	small	medium
Plains leopard frog (12,12, n=34)										
□(.),p(.)	2	0.259								
□(.),p(moonshine)	3	0.203		3.00 ± 2.47						
□(.),p(day)	3	0.100	-7.03 ± 13.57							
□(.),p(time of day)	3	0.096			-5.79 ± 15.76					
□(.),p(water temperature)	3	0.095				6.07 ± 12.45				
□(.),p(wind speed)	3	0.087					-0.26 ± 0.96			
□(.),p(air temperature)	3	0.085						1.17 ± 7.88		
□(.),p(wetland size)	4	0.057							0.52 ± 1.17	-0.66 ± 1.09
American bullfrog (11,7, n=34)										
□(.),p(.)	2	0.577								
□(.),p(water temperature)	3	0.325				10.03 ± 10.49				

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.40. *Tadpole detection parameter estimates April, 2010*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day			slope		
Western chorus frog (16,18, n=42)								
□(.),p(global)	4	0.984	63.13	±	23.16	-19.66	±	6.87
Plains leopard frog (17,14, n=42)								
□(.),p(slope)	3	0.599				-6.33	±	2.83
□(.),p(global)	4	0.178	1.20	±	10.60	-6.35	±	2.83
□(.),p(.)	2	0.170						
Woodhouse's toad (5,9, n=42)								
□(.),p(slope)	3	0.763				-18.79	±	6.87
□(.),p(global)	4	0.232	-3.37	±	12.30	-18.62	±	6.86

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.41. *Tadpole detection parameter estimates May, 2010*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day			slope		
Western chorus frog (18,14, n=42)								
□(.),p(day)	3	0.455	-27.73	±	6.52			
□(.),p(global)	4	0.261	-24.17	±	6.95	-6.42	±	3.34
□(.),p(.)	2	0.158						
□(.),p(slope)	3	0.126				-5.92	±	3.07
Cope's gray treefrog (6,6, n=42)								
□(.),p(day)	3	0.442	102.74	±	5.03			
□(.),p(slope)	3	0.256				-9.24	±	5.18
□(.),p(.)	2	0.168						
□(.),p(global)	4	0.133	93.66	±	5.28	-1.57	±	5.04
Plains leopard frog (21,20, n=42)								
□(.),p(slope)	3	0.610				-6.50	±	2.51
□(.),p(global)	4	0.180	-1.48	±	12.61	-6.69	±	2.97
□(.),p(.)	2	0.132						
□(.),p(day)	3	0.078	13.49	±	18.19			
Woodhouse's toad (6,4, n=42)								
□(.),p(day)	3	0.467	48.14	±	9.98			
□(.),p(global)	4	0.297	35.02	±	9.78	-8.77	±	6.47
□(.),p(slope)	3	0.223				-18.83	±	8.69
American bullfrog (4,3, n=42)								
□(.),p(.)	2	0.429						
□(.),p(day)	3	0.252	15.86	±	10.69			
□(.),p(slope)	3	0.178				8.87	±	7.71
□(.),p(global)	4	0.142	55.73	±	7.99	-22.7	±	8.79

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.42. *Tadpole detection parameter estimates June, 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day		slope	
Cope's gray treefrog (17,12, n=36)						
□(.),p(.)	2	0.497				
□(.),p(day)	3	0.221	6.23	6.54		
□(.),p(slope)	3	0.209			-3.76	4.45
□(.),p(global)	4	0.073	4.96	7.01	-2.82	4.70
Plains leopard frog (15,9, n=36)						
□(.),p(.)	2	0.321				
□(.),p(day)	3	0.297	12.50	7.27		
□(.),p(slope)	3	0.277			-6.39	5.05
□(.),p(global)	4	0.105	7.82	8.33	-3.86	5.51

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.43. *Tadpole detection parameter estimates April, 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day			time			water			slope			woody			herby		
Western chorus frog (3,6, n=42)																				
□(.),p(global)	8	0.865	-196.31	±	17.04	-84.63	±	10.31	-5.11	±	29.68	-8.85	±	10.80	-29.02	±	12.52	-0.94	±	7.41

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.44. *Tadpole detection parameter estimates May, 2011*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day	time	water	slope	woody	herby
Western chorus frog (13,16, n=40)								
□(.),p(water temperature and slope)	4	0.773			25.07 ± 9.27	-7.53 ± 3.38		
□(.),p(slope)	3	0.160				-8.85 ± 3.34		
Plains leopard frog (23,20, n=40)								
□(.),p(water temperature)	3	0.365			32.45 ± 11.06			
□(.),p(day)	3	0.253	36.07 ± 9.89					
□(.),p(water temperature and slope)	4	0.151			34.01 ± 10.95	-2.70 ± 2.48		
□(.),p(time of day)	3	0.084		8.09 ± 5.82				
□(.),p(.)	2	0.082						
□(.),p(aquatic vegetation)	4	0.037					-1.13 ± 2.52	2.94 ± 1.77
American bullfrog (4,5, n=40)								
□(.),p(slope)	3	0.496				20.74 ± 11.43		
□(.),p(time of day)	3	0.168		-12.31 ± 7.14				
□(.),p(water temperature and slope)	4	0.149			-2.95 ± 10.95	20.97 ± 11.74		
□(.),p(.)	2	0.101						

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.45. *Tadpole detection parameter estimates June, 2011*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	day			time			water			slope			woody			herby		
Western chorus frog (5,7, n=34)																				
□(.),p(water temperature and slope)	4	0.630							-73.17	±	15.68	-12.46	±	3.93						
□(.),p(time of day)	3	0.113				-22.47	±	10.47												
□(.),p(.)	2	0.088																		
Cope's gray treefrog (6,7, n=34)																				
□(.),p(water temperature)	3	0.629							786.80	±	9.72									
□(.),p(water temperature and slope)	4	0.174							848.74	±	10.36	1.75	±	7.27						
□(.),p(aquatic vegetation)	4	0.110													-5.57	±	9.13	-3.09	±	1.64
Plains leopard frog (25,27, n=34)																				
□(.),p(.)	2	0.239																		
□(.),p(time)	3	0.225				-22.35	±	56.42												
□(.),p(day)	3	0.149	17.05	±	1.25															
□(.),p(water temperature)	3	0.133							-23.58	±	23.59									
□(.),p(slope)	3	0.111										4.57	±	5.22						
□(.),p(aquatic vegetation)	4	0.079													-5.08	±	9.72	-4.35	±	4.24
□(.),p(water temperature and slope)	4	0.040							-19.08	±	34.74	1.54	±	7.87						
□(.),p(global)	8	0.024	23.74	±	10.72	-4.77	±	16.48	-8.73	±	34.25	-4.87	±	7.30	-0.69	±	5.96	3.63	±	1.89
American bullfrog (4,7, n=34)																				
□(.),p(slope)	3	0.577										15.30	±	6.11						
□(.),p(water temperature and slope)	4	0.325							38.88	±	22.24	16.21	±	5.19						

* The number of detections in survey 1and survey 2 and the number of sites sampled are shown parenthetically

Table 2.46. *Detection probabilities for adults and tadpoles.* The detection probability of the *null* model is reported for adult and larval anurans during three seasons in each of the years sampled, 2010 and 2011.

		2010		2011	
Species	Season	Adult	Tadpole	Adult	Tadpole
Western chorus frog (*Psuedacris triseriata*)	April	0.3955 (±0.2314)	0.8824 (±0.0584)	0.8421 (±0.0520)	0.4444 (±0.2066)
	May	0.2000 (±0.1697)	0.7500 (±0.0856)	0.3333 (±0.1434)	0.6207 (±0.1058)
	June	-	-	-	0.5000 (±0.1768)
Northern cricket frog (*Acris crepitans*)	April	0.5394 (±0.1379)	-	-	-
	May	0.7273 (±0.0875)	-	0.4125 (±0.0550)	-
	June	0.7429 (±0.0828)	-	0.5294 (±0.0605)	-
Cope's gray treefrog (*Hyla chrysoscelis*)	April	0.7482 (±0.0815)	-	-	-
	May	0.8000 (±0.0693)	0.6667 (±0.1571)	0.3875 (±0.0545)	-
	June	0.7429 (±0.0828)	0.5517 (±0.1111)	0.6471 (±0.0580)	0.9231 (±0.0767)
Plains leopard frog (*Lithobates blairi*)	April	0.6548 (±0.0903)	0.7097 (±0.0926)	0.6122 (±0.0820)	-
	May	0.3200 (±0.1210)	0.7805 (±0.0714)	0.5263 (±0.0983)	0.8837 (±0.0516)
	June	0.3636 (±0.1312)	0.5833 (±0.1198)	0.5833 (±0.1198)	0.9362 (±0.0368)
American bullfrog (*Lithobates catesbeiana*)	April	-	-	-	0.8571 (±0.1414)
	May	-	0.2857 (±0.2235)	-	0.4444 (±0.2066)
	June	0.2361 (±0.0501)	-	0.2500 (±0.0525)	0.5455 (±0.1811)
Woodhouse's toad (*Anaxyrus woodhousii*)	April	0.4668 (±0.1495)	0.5714 (±0.1581)	-	-
	May	0.6154 (±0.1588)	0.6000 (±0.1833)	0.1667 (±0.1459)	-
	June	0.0833 (±0.0326)[*]	-	-	-

[*] The probability of detection reported was from a null model that failed to converge and was removed from the model set.

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CHAPTER 3: AMPHIBIAN OCCUPANCY OF RESTORED WETLANDS IN THE MISSOURI RIVER FLOODPLAIN

INTRODUCTION

Global declines of amphibian species and loss of crucial wetland habitat have increased restoration efforts by government agencies seeking to mitigate losses incurred by the channelizing and damming of large rivers. The frequent lack of sufficient science-based monitoring threatens the success of restorations. Scientific monitoring programs can provide better insight into restoration characteristics and the habitat needs of species or taxa of interest. These insights can in turn inform management of current restorations, advance engineering of new restorations, and improve site selection.

The U.S. Army Corps of Engineers has been responsible for providing flood control and maintaining navigation along the Missouri River since the 1912 passing of the Missouri River Bank Stabilization and Navigation Act (U.S. Army Corps of Engineers 2006). The U.S. Army Corps of Engineers has channelized the lower and central portions of the river and installed dams to control water levels. They have also built levees at each of the major bends, to prevent flooding and to further ensure that water levels remain sufficient for navigation (U.S. Army Corps of Engineers 2006). In addition to providing flood control and economic benefits these measures have also contributed to the loss or degradation of floodplain wetlands. As of 2003, more than 211,000 hectares (522,000 acres) of Missouri River riparian habitat were lost as a result of the Bank Stabilization and Navigation Project (U.S. Army Corps of Engineers 2010). The loss of quality habitat and the consequential decline of riparian wetland-dependent species led to legislative action to aid in the restoration of lost habitat (U.S. Army Corps of Engineers 2006). In 1986 the U.S. Congress passed the Missouri River Mitigation Project which authorizes the purchase of 67,481 hectares (166,750 acres) along the Missouri River in Iowa, Nebraska, Kansas and Missouri. In Nebraska, the project aims to restore 10,785 hectares (26,652 acres) (U.S. Army Corps of Engineers 2006). These properties are being managed to preserve existing wetlands, as well as to create new mitigation wetlands. The objectives of the Missouri River Mitigation Project are to restore historic habitat and side-channels in the Missouri River floodplain and to provide or create habitat for fish, waterfowl, mammals and amphibians.

There are several methods used to restore wetlands. The approach used is dependent on the goals of the entity in charge of the restoration and the conditions and location of the wetlands. The loss of floodplain wetlands is usually a result of engineering structures created to prevent historically prevalent seasonal flooding. In riparian systems flood-prevention measures such as small levees are removed or perforated and land is allowed to flood seasonally. The floods scour and shape the landscape, introduce aquatic vegetation, and provide the necessary surface water to create ephemeral wetlands. When removal of flood control structures is not an option, the U.S. Army Corps of Engineers employs several engineering and management tools. Backwaters and chutes that have filled with sediment and debris are dredged to open the areas again. Dikes, chutes and levees may be notched to create aquatic habitat (Missouri River Recovery Program 2007). To discourage unwanted or invasive plants wetland managers may introduce aquatic plants to encourage the growth of a desirable wetland plant community. When flow-through or groundwater is insufficient pumps are used to maintain water levels (Missouri River Recovery Program 2007).

With agencies increasing efforts to restore degraded wetlands and create new mitigation wetlands, there is a growing need for monitoring and habitat analysis to assess the success of these efforts. Amphibian populations can be used as a metric of restoration success. They are sensitive to water quality and have been used as an indicator species (Welsh 1998). Amphibians also require standing water during some if not all of their life-history and are less motile than other wetland taxa such as water fowl (and therefore may be a truer indicator of persistent quality).

Site (or "patch") occupancy has emerged as an accepted metric for determining amphibian presence and persistence in wetlands (MacKenzie et al. 2002, Weir et al. 2005). Previous methods that attempted to extrapolate abundance from sampled data (chorus intensity index, transect-encounter methods) have proven too unreliable due to observer bias and differing detection probabilities, and have been largely discarded (Weir et al. 2005). Occupancy measures the presence or absence of a species over repeat visits and estimates the likelihood that a species exists at a site given an encounter history. Occupancy can also account for varying detection probabilities across species, sampling periods, or habitat patches. Site occupancy allows researchers to monitor large-scale restorations within a reasonable time-limit, while better reflecting the variable and dynamic nature of wetlands and the amphibians that occupy them.

To assess amphibian presence and restoration success in the Missouri River floodplain I monitored wetlands in three restored river bends for two years, 2010 and 2011. Monitoring efforts including recording the presence of adult and larval amphibians and measuring a variety of environmental and habitat variables that may impact detection and occupancy of amphibians. Herein I model occupancy parameters using characteristics of the sites as potential covariates. I use model selection to identify wetland characteristics that may be important to amphibian presence and restoration success in restored wetlands and provide recommendations for future monitoring efforts.

MATERIALS AND METHODS

Study Area

I selected wetlands in three river bends that have been restored by the U.S. Army Corps of Engineers, Hamburg Bend in Otoe County and Kansas Bend and Langdon Bend in Nemaha County in southeast Nebraska (Fig. 3.1). The Langdon Bend Mitigation Site consists of 529 hectares (1,308 acres) of former agricultural land purchased by the Corps. The restoration efforts at this site focused on reopening a historic side-channel, and creating shallow water habitat. To supplement rainwater fed wetlands at this site the Corps installed two water pumps designed to flood wetlands in autumn to provide habitat for migratory waterfowl. Restoration was completed in 2000 and the site is considered to be operational (U.S. Army Corps of Engineers 2006). The Kansas Bend Mitigation Site is located on 427 hectares (1,056 acres) purchased by the Corps. Privately owned farmland bisects the U.S. Army Corps of Engineers property. The goal of restoration efforts in the Kansas bend was to reopen two historic side-channels using the same methods utilized in the Langdon restoration. However, in the Kansas bend both channels are fully functional and connect to the main channel at both ends. The side-channels were reopened in 2004, and Nebraska Game and Parks has since assumed management of much of the site (U.S. Army Corps of Engineers 2006). The Hamburg Bend site consists of 637 hectares (1,576 acres) of former agricultural property purchased by the Corps. As with Kansas and Langdon bends, the majority of restoration efforts at this site were focused on restoring a historic side-channel. Hamburg bend was among the first restorations in Nebraska and work was completed in 1996 (U.S. Army Corps of Engineers 2006).

I used National Wetland Inventory and hydric soils GIS layers to preliminarily select sampling locations. Sites were then visited with a GPS unit to determine the state of the wetland. If additional wetlands not indicated in the GIS coverage were encountered, they were included in the study. Several wetland types were represented within each river bend, including: sloughs, irrigation ditches, seasonally flooded grasslands, emergent wetlands, forested wetlands, and agricultural wetlands. Land recently purchased by the U.S. Army Corps of Engineers or newly enrolled in the Natural Resource Conservation Service's Wetland Reserve Enhancement Program (a program that allows landowners to receive compensation for maintaining wetland habitat) still contained corn stubble and relatively bare soils, while other sites had well-established aquatic vegetation. Fifty five sites were initially selected across the three bends, although the actual number of sites fluctuated with seasonal flooding and drying (Tables 3.1 and 3.2).

Anuran Call Survey

I conducted surveys during three seasons, April. May, and June, and sampled each wetland holding water twice to allow for detection rates within seasons. Exceptions occurred when sites were flooded and wetlands were unreachable or wetland perimeters were undefinable. When this occurred, data were recorded at a safe point as close to the original site as possible. Call surveys are well established as a method to monitor and detect anuran species in wetlands (Van Gorp 1999, Genet and Sargent 2003). Most male anurans vocalize attraction calls during some or all of their breeding season. These vocalizations allow researchers to identify species present at a given wetland by conducting a simple call survey. Conducting separate surveys over a three month period captures seasonal variation in chorus assemblages. I began call surveys at least 30min after sunset and stood five to ten meters from the water's edge to avoid disturbing the chorus. I used a two minute acclimation period to allow any individuals disturbed by the approach to resume calling. The acclimation period was followed by a five minute call survey. I recorded the five minute survey on a digital recorder (Olympus DM-10) which I checked later for any missed or misidentified species (Lotz and Allen 2007). During the five minute listening period, all species heard were noted.

Biologists have been using call surveys to assess anuran presence, and in some cases abundance, for many years (Van Gorp 1999, Genet and Sargent 2003). During the breeding season male anurans vocalize attraction and territorial calls. Aural surveys can use these calls to identify species occupying a wetland. The North American Amphibian Monitoring Program run by U.S. Geological Survey, state agencies, and volunteers collects amphibian presence data around the country and in Canada and Mexico using anuran call surveys (Weir et al. 2005). To obtain encounter histories necessary for occupancy modeling my research team visited and surveyed all sites per season during three phenologically determined "seasons" in mid-April, mid-May, and mid-June. Using known phenology of expected species improves the likelihood of capturing seasonal variation in chorus assemblages. Call surveys did not start until at least 30min after sunset and were performed while standing five to ten meters from the water's edge to avoid disturbing the chorus. A two minute acclimation period to allow normal calling activity to resume was followed by a five minute call survey. A digital recorder (Olympus DM-10) was used to record surveys which were checked later for any missed or misidentified species (Lotz and Allen 2007). During the five minute listening period, all species heard are noted. Species heard outside the survey period were ignored.

Tadpole Dip-netting

Tadpole dip-netting was used to assess larval presence at the sites. This allows a measure of presence at a different life stage and provides a secondary method to catch rare or elusive anurans as well as salamanders. Some species are opportunistic breeders and only call and breed in short bursts following a rain event. Other species are relatively rare or otherwise have a low detection rate. Larval sampling offers an opportunity to catch any species that may have been missed during call surveys. Each site was dip-netted twice during each of the three seasons. In 2010, we attempted to sample the entire perimeter of the wetland, with sampling effort capped at one hour per site. We used a combination of visual detection and targeted sweeps to assess tadpole species present. To standardize sampling in 2011 we switched to a spatially defined sample. Beginning at the spot where call surveys were conducted we sampled 100m of shoreline on each side. A sweep was made every 10 meters along the 200m transect and all tadpoles were identified to species and returned to the wetland. We recorded only the species captured and did not count individuals. Each site was sampled independently by two researchers, usually on the same day. To avoid interference between the two samples, the second researcher waited at least 30 minutes for the water to clear and the tadpoles to return to the water's edge.

Covariates

Survey-specific covariates

Anuran calling behavior may be impacted by several environmental factors, and these were considered as potential detection covariates. Wind speed and air temperature were collected only during 2011. Water temperature and time were initially collected during call surveys but were later expanded to include collection during dip-netting. During call surveys and dip-netting we recorded: the day, time of day, water temperature, wind speed, air temperature and presence of precipitation. Moonshine increases visibility and may impact calling behavior of anurans, and was calculated as the product of cloud cover and moon phase. I obtained hourly cloud cover data for Omaha Eppley Airport and Falls City Municipal Airport from the National Oceanic and Atmospheric Administration's database. Eppley Airfield is located in Omaha, Nebraska north of Hamburg (the northernmost bend) and Falls City Municipal Airfield is located in Falls City, Nebraska and south of Langdon (the southernmost bend). To estimate cloud cover at my research bends I took the average of the hourly cloud cover reported at each airfield. To account for moonlight I used nightly moon phase date from the U.S. Naval Observatory. Moonshine was then calculated as % clear sky (1-%cloud cover) times the percent of the moon that is currently illuminated. All covariates were scaled to within 0 and 1 to enable disparately scaled covariates to be modeled together.

Site-specific covariates

Several habitat characteristics were measured and considered as potential covariates for the anuran occupancy. During tadpole sampling, the percentage of four categories of terrestrial vegetation (herbs and forbs, grass, shrubs and trees, and agriculture and bare ground) was estimated within 1m of the high water mark (or within 1m of the shoreline in the case of dynamic wetlands). Along the 200m of shoreline being sampled, a water depth measurement was taken 1m from the shoreline at 10m intervals. An average slope was calculated for each wetland. In 2011 every sweep of the dip-net was assigned a category of woody, herbaceous, or open water describing the habitat the dip-net penetrated. This was used to calculate a percentage of each aquatic habitat type present along the 200m transect. I estimated the size of each wetland as <0.83, 0.84-2.02, or >2.02 hectares (<2, 2.1-5, and >5.1 acres). I used ArcGIS to calculate the distance to the next nearest wetland. Finally I used the 2006 Land Cover layer to calculate the percentage of agriculture (row crops), field (grassland, hay meadow, and pasture), and forest within 500m of the sampling point. As with survey-specific covariates, all non-categorical site-specific covariates were scaled to within 0 and 1 to enable disparately scaled covariates to be modeled together.

Chytrid Prevention Measures

Although the Chytrid fungus has not been deemed a problem in Nebraska it poses a threat to amphibians world-wide (Bosch et al. 2001, Oullet et al. 2005) and precautions should be taken to prevent the spread. All tadpole dip-netting supplies were disinfected in a 5% bleach and water solution and scrubbed if necessary between wetlands (Department of Environment and Climate Change, Sydney).

Statistical Methods

A feature of occupancy modeling is the ability to account for imperfect detection with the incorporation of detection covariates. To accomplish this I used a two-stage approach. First, a series of candidate detection models were created to explain varying detection probabilities for each life stage; adults and tadpoles (Tables 3.3 and 3.4). The models $\psi(.)$,p(.), which contain an occupancy $\psi(.)$ component and a detection, or p(.) component were developed based on the work in MacKenzie et al. (2002). The models were tested using multi-model inference in Program PRESENCE (Hines 2006). The top model was selected to populate the detection, or p(.), portion of the occupancy models (Hellman, Chapter 2). Then, a model set was proposed to explain occupancy of a species (Table 3.5). The model set contained both a *null* and a *global* model. *Emergent vegetation* tests the impact of emergent aquatic vegetation on amphibian occupancy. *Slope* tests the impact of wetland slope on occupancy. *Distance to nearest wetland* tests the influence of proximity to other wetlands on occupancy. *Aquatic vegetation* proposes that the proportion of herbaceous and woody vegetation or open water may impact occupancy. *Bend* tests whether occupancy differences can be explained by variation between bends. *Wetland size* tests the relationship of small, medium, and large wetlands with occupancy. *Terrestrial vegetation* proposes that adjacent terrestrial vegetation (grasses, herbs/forbs, shrubs/trees and bare soil) may impact occupancy. *Land cover* tests the impact of land cover types (forest, field, and agriculture) on occupancy. *Connectivity* proposes that the relationship between wetland proximity and land cover types may impact occupancy at a site. *Vegetation* assesses the impacts of both terrestrial and aquatic vegetation on amphibian occupancy. The proposed occupancy models were then modified to include a species and life-stage specific detection model and tested using multi-model inference in Program PRESENCE. Due to the small sample size and large number of covariates in the model sets, I report the corrected AIC for all models. The confidence sets were selected as all models carrying ≥10% the weight of the top model. Due to the high uncertainty of occupancy modeling of species with limited encounter histories, I chose to exclude any species with less than 10% naïve occupancy within a given month from that month's analysis.

Models that failed to converge to greater than two significant figures or otherwise failed to run successfully (PRESENCE was often unable to calculate SEs of parameter estimates in potentially over-parameterized models) were deleted from analysis but are identified here. The inclusion of detection covariates increased the number of parameters in each model and the global model almost universally failed to run. A small sample size and the use of a corrected AIC biased model selection towards the most parsimonious of models. Models are presented in descending order of weight and untransformed parameter estimates are provided parenthetically. Naïve occupancies (raw proportion of sites occupied without accounting for imperfect detection) are reported in Table 3.35.

RESULTS

Western chorus frog (*Pseudacris triseriata*)

April 2010

Western chorus frogs were heard at 23 sites during the first survey and at seven sites during the second survey. The *global* model, *land cover* model, and *connectivity* model failed to run and were therefore not candidates for the confidence set. S*lope*

(β_{slope}= -7.219±3.184) was selected as the best model to explain adult occupancy (Table 3.6).

Western chorus frog tadpoles were captured at 16 sites during the first survey and at 18 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *land cover* ($\beta_{\%forest}$= 7.972±4.206, $\beta_{\%field}$= -47.418±23.404, and $\beta_{\%ag}$= 10.421±4.689), *connectivity* ($\beta_{distance}$= -0.174±2.363, $\beta_{\%forest}$= 7.885±4.371, $\beta_{\%field}$= -47.006±24.101, and $\beta_{\%ag}$= 10.328±4.863), *emergent vegetation* (β_{emerg_veg}= 1.851±1.069), *distance to nearest wetland* ($\beta_{distance}$= -3.27±2.106), and the *null* model (Table 3.6).

May 2010

Western chorus frogs were heard at five sites in both the first and second surveys. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *slope* (β_{slope}= -6180.192±902946.602), the *null* model, and *distance to nearest wetland* ($\beta_{distance}$= -7.485±9.809) (Table 3.7).

Western chorus frog tadpoles were captured at 18 sites during the first survey and at 14 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *slope* (β_{slope}= -6.943±3.2), *distance to nearest wetland* ($\beta_{distance}$= -3.293±1.592), *emergent vegetation* (β_{emerg_veg}= 2.333±1.17), and the *null* (Table 3.7).

April 2011

Western chorus frogs were heard at 30 sites during the first survey and at 27 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *aquatic vegetation* (β_{woody}= -7.936±4.616 and β_{herby}= -2.687±4.47) and *emergent vegetation* (β_{emerg_veg}= 2.437±1.228) (Table 3.8).

Western chorus frog tadpoles were captured at three sites during the first survey and at six sites during the second survey. *Vegetation, connectivity, terrestrial vegetation, emergent vegetation, wetland size, bend,* the *null* model, and the *global* model failed to run and were therefore not candidates for the confidence set. The top model was *slope* (β_{slope}= 85.962±56.347) (Table 3.8).

May 2011

Western chorus frogs were heard at seven sites during the first survey and at 11 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *distance to nearest wetland* ($\beta_{distance}$= 2.737±1.525), the null model, *slope* (β_{slope}= 11.356±7.92), and *emergent vegetation* (β_{emerg_veg}= -0.611±0.804) (Table 3.9).

Western chorus frog tadpoles were captured at 13 sites during the first survey and at 16 sites during the second survey. *Vegetation* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *slope* (β_{slope}= 46.566±34.928), *bend* ($\beta_{Hamburg}$= -2.839±1.358 and β_{Kansas}= 0.011±1.281), the *null* model, and *distance to nearest wetland* ($\beta_{distance}$= 13.273±12.133) (Table 3.9).

June 2011

Western chorus frog tadpoles were captured at five sites during the first survey and at seven sites during the second survey. *Aquatic vegetation, terrestrial vegetation, connectivity, land cover, vegetation, wetland size,* and the *global* model failed to run and were therefore not candidates for the confidence set. The remaining models were all plausible. The models were the *null* model, *emergent vegetation* (β_{emerg_veg}= -33.561±17.884), *distance to nearest wetland* ($\beta_{distance}$= -1.531±1.515), *slope* (β_{slope}= -3.946±7.411), and *bend* ($\beta_{Hamburg}$= 26.154±383546.877 and β_{Kansas}= 1.497±1.779) (Table 3.10).

Northern cricket frog (*Acris crepitans*)

April 2010

Northern cricket frogs were heard at six sites during the first survey and at 14 sites during the second survey. *Land cover* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *emergent vegetation* (β_{emerg_veg}= 2.773±1.146) and *slope* (β_{slope}= -6.862±3.718) (Table 3.11).

May 2010

Northern cricket frogs were heard at 14 sites during the first survey and at 19 sites during the second survey. The global model failed to converge and was therefore not a candidate for the confidence set. The top models were *slope* (β_{slope}= -5.341±2.566), the *null* model, *terrestrial vegetation* (β_{grass}= -2.498±2.16, $\beta_{herbs/forbs}$= 5.493±3.628, and $\beta_{shrubs/trees}$= -2.092±2.491) and *distance to nearest wetland* ($\beta_{distance}$= -0.983±1.001) (Table 3.12).

June 2010

Northern cricket frogs were heard at 19 sites during the first survey and at 16 sites during the second survey. The top models were the *null* model, *distance to nearest wetland* ($\beta_{distance}$= -1.483±1.99), *emergent vegetation* (β_{emerg_veg}= 0.763±1.319), *slope* (β_{slope}= -0.98±6.006) and *bend* ($\beta_{Hamburg}$= -1.66±1.424 and β_{Kansas}= -0.361±1.428) (Table 3.13).

May 2011

Northern cricket frogs were heard at 17 sites during the first survey and at 16 sites during the second survey. *Connectivity, vegetation, land cover, bend,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *distance to nearest wetland* ($\beta_{distance}$= -356.414±96427.071), *emergent vegetation* (β_{emerg_veg}= 2.145±1.104), *terrestrial vegetation* (β_{grass}= -20.608±11.476, $\beta_{herbs/forbs}$= -15.018±11.616, and $\beta_{shrubs/trees}$= -23.051±11.788), *slope* (β_{slope}= -4.043±2.24), and the *null* model (Table 3.14).

June 2011

Northern cricket frogs were heard calling from 21 sites during the first survey and 16 sites during the second survey. *Distance to nearest wetland, land cover, connectivity,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were the *null* model, *emergent vegetation* (β_{emerg_veg}= 27.625±562090.36), *slope* (β_{slope}= -10.433±14.291), *wetland size* (β_{small}= 31.8±1966211.25 and β_{medium}= 23.319±184323.751), and *bend* ($\beta_{Hamburg}$= 0.7±3.335 and β_{Kansas}= 23.969±124326.214) (Table 3.15).

Cope's gray treefrog (*Hyla chrysoscelis*)

April 2010

Cope's gray treefrogs were heard at 18 sites in each of the surveys. The *global* model failed to run and was therefore not a candidate for the confidence set. The top model was *slope* (β_{slope}= -15.048±5.617) (Table 3.16).

May 2010

Cope's gray treefrogs were heard at 16 sites during the first survey and at 24 sites during the second survey. The top models were *slope* (β_{slope}= -6.499±2.555) and *emergent vegetation* (β_{emerg_veg}= 1.706±0.892) (Table 3.17).

Cope's gray treefrog tadpoles were captured at six sites during both the first and second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *wetland size*(β_{small}= 310.613±0.707 and β_{medium}= 308.778±1.106), *emergent vegetation* (β_{emerg_veg}= 371.524±0.583), the *null* model, *bend* ($\beta_{Hamburg}$= 26.493±502774.722 and β_{Kansas}= 2.163±1.191), *distance to nearest wetland* ($\beta_{distance}$= -2.002±1.769), and *slope* (β_{slope}= -3.561±3.392) (Table 3.17).

June 2010

Cope's gray treefrogs were heard at 15 sites during the first survey and at 20 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *land cover* ($\beta_{\%forest}$= 10.087±8.283, $\beta_{\%field}$= -226.776±139.486, and $\beta_{\%ag}$= 2.449±1.942) and *connectivity*

($\beta_{distance}$= 0.476±1.704, $\beta_{\%forest}$= 10.253±8.041, $\beta_{\%field}$= -245.113±156.981, and $\beta_{\%ag}$= 2.825±2.447) (Table 3.18).

Cope's gray treefrog tadpoles were captured at 17 sites during the first survey and 12 sites during the second survey. *Land cover* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *bend* ($\beta_{Hamburg}$= -0.207±1.109 and β_{Kansas}= 25.561±416009.973), *distance to nearest wetland* ($\beta_{distance}$= -2.293±1.455), *emergent vegetation* (β_{emerg_veg}= 1.923±1.324), the *null* model, *slope* (β_{slope}= -4.461±6.636), and *connectivity* ($\beta_{distance}$= -2.267±1.657, $\beta_{\%forest}$= 9.776±7.23, $\beta_{\%field}$= -44.998±36.112, and $\beta_{\%ag}$= 3.728±3.609) (Table 3.18).

May 2011

Cope's gray treefrogs were heard at 16 sites during the first survey and at 15 sites during the second survey. *Aquatic vegetation, connectivity, wetland size, bend, vegetation, land cover, slope,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were the *null* model, *emergent vegetation* (β_{emerg_veg}= 27.369±348319.801), and *distance to nearest wetland* ($\beta_{distance}$= 4.89±10.16) (Table 3.19).

June 2011

Cope's gray treefrogs were heard at 26 sites during the first survey and at 20 sites during the second survey. *Emergent vegetation, distance to nearest wetland, wetland size, bend, aquatic vegetation, terrestrial vegetation,* and *land cover* failed to run and were therefore not candidates for the confidence set. The top models were the *null* model and *slope* (β_{slope}= -16.294±11.004) (Table 3.20).

Cope's gray treefrog tadpoles were captured at six sites during the first survey and at seven sites during the second survey. *Emergent vegetation, bend,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *terrestrial vegetation* (β_{grass}= 1816.179±1.458, $\beta_{herbs/forbs}$= 1822.915±1.81, and $\beta_{shrubs/trees}$= 1817.602±3.308), *aquatic vegetation* (β_{woody}= 7.559±25.836 and β_{herby}= 4.007±2.379), the *null* model, *slope* (β_{slope}= -4.657±3.679), *distance to nearest wetland* ($\beta_{distance}$= -1.519±1.428), and *wetland size* (β_{small}= 0.371±1.046 and β_{medium}= -1.487±1.274) (Table 3.20).

Plains leopard frog (*Lithobates blairi*)

April 2010

Plains leopard frogs were heard at 18 sites during the first survey and at 20 sites during the second survey. *Connectivity* and the *global* model failed to run and were therefore not candidates for the confidence set. The top model was *slope* (β_{slope}= -32.695±17.654) (Table 3.21).

Plains leopard frog tadpoles were captured at 17 sites during the first survey and at 14 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *land cover* ($\beta_{\%forest}$= 3.639±7.566, $\beta_{\%field}$= -2881.337±47532920.49, and $\beta_{\%ag}$= 0.888±2.443) and *connectivity* ($\beta_{distance}$= 2.314±3.963, $\beta_{\%forest}$ = 5.969±12.256, $\beta_{\%field}$= -2833.551±21789575.066, and $\beta_{\%ag}$= 1.855±3.587) (Table 3.21).

May 2010

Plains leopard frogs were heard at six sites during the first survey and at 19 sites during the second survey. *Distance to nearest wetland, connectivity, land cover,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *slope* (β_{slope}= -9.285±5.215), *wetland size* (β_{small}= 5.147±19.652 and β_{medium}= 0.792±1.201), and *terrestrial vegetation* (β_{grass}= -0.965±2.771, $\beta_{herbs/forbs}$= 9.678±6.575, and $\beta_{shrubs/trees}$= -5.733±3.546) (Table 3.22).

Plains leopard frog tadpoles were captured at 21 sites during the first survey and at 20 sites during the second survey. The top models were the *null* model, *terrestrial vegetation* (β_{grass}= -2.636±2.197, $\beta_{herbs/forbs}$= 6.352±3.588, and $\beta_{shrubs/trees}$= 0.572±2.776), *distance to nearest wetland* ($\beta_{distance}$= -1.316±1.21), *emergent vegetation* (β_{emerg_veg}= 0.661±1.099), *slope* (β_{slope}= -2.313±3.992), *bend* ($\beta_{Hamburg}$= -0.738±1 and β_{Kansas}= 0.36±0.978), and *wetland size* (β_{small}= 0.682±1.085 and β_{medium}= 0.202±1.148) (Table 3.22).

June 2010

Plains leopard frogs were heard at ten sites during the first survey and at 12 sites during the second survey. *Connectivity, wetland size,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were the *null* model, *terrestrial vegetation* (β_{grass}= -7.52±9.997, $\beta_{herbs/forbs}$= 7.413±13.692, and $\beta_{shrubs/trees}$= -9.04±9.943), *emergent vegetation* (β_{emerg_veg}= 1.004±1.67), *distance to nearest wetland* ($\beta_{distance}$= 0.855±1.845) and *slope* (β_{slope}= 2.358±7.958) (Table 3.23).

Plains leopard frog tadpoles were captured at 15 sites during the first survey and at nine sites during the second survey. *Connectivity* and the *global* model failed to run and were therefore not candidates for the confidence set. The top model was *land cover* ($\beta_{\%forest}$= 19.746±15.325, $\beta_{\%field}$= -1244.488±2307.129, and $\beta_{\%ag}$= 34.621±30.688) (Table 3.23).

April 2011

Plains leopard frogs were heard at 30 sites during the first survey and at 19 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *distance to nearest wetland* ($\beta_{distance}$= -2.509±1.33), *slope* (β_{slope}= -3.987±2.431), the *null* model, *emergent vegetation* (β_{emerg_veg}= 1.519±1.178), *aquatic vegetation* (β_{woody}= -1.246±2.853 and β_{herby}= 1.984±3.422) and *bend* ($\beta_{Hamburg}$= -1.948±1.455 and β_{Kansas}= -0.483±1.532) (Table 3.24).

May 2011

Plains leopard frogs were heard at 13 sites during the first survey and at 25 sites during the second survey. *Vegetation* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were the *null* model, *bend* ($\beta_{Hamburg}$= -20.169±3.784 and β_{Kansas}= -19.408±3.797), *slope* (β_{slope}= -2.967±2.081), *distance to nearest wetland* ($\beta_{distance}$= 0.198±0.961), *emergent vegetation* (β_{emerg_veg}= -0.09±0.78), *terrestrial vegetation* (β_{grass}= -9.777±8.664, $\beta_{herbs/forbs}$= -8.062±8.943, and $\beta_{shrubs/trees}$= -12.466±8.78) and *aquatic vegetation* (β_{woody}= -1.196±2.552 and β_{herby}= 1.413±1.468) (Table 3.25).

Plains leopard frog tadpoles were captured at 23 sites during the first survey and at 20 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *slope* (β_{slope}= -2.922±1.898), the *null* model, *distance to nearest wetland* ($\beta_{distance}$= 2.089±1.446), *wetland size* (β_{small}= 2.203±1.097 and β_{medium}= 1.493±1.057), *bend* ($\beta_{Hamburg}$= 25.503±553083.676 and β_{Kansas}= -0.982±0.95), *emergent vegetation* (β_{emerg_veg}= 0.008±0.777), *land cover* ($\beta_{\%forest}$= -4.363±3.735, $\beta_{\%field}$= 2739.547±33019408.14, and $\beta_{\%ag}$= -0.32±1.711), and *aquatic vegetation* (β_{woody}= -1.368±2.937 and β_{herby}= 0.841±1.431) (Table 3.25).

June 2011

Plains leopard frogs were heard at 12 sites during both the first and second surveys. *Vegetation* and the *global* model failed to run and were therefore not candidates for the confidence set. All of the remaining models were selected as plausible. The top models were the *null* model, *distance to nearest wetland* ($\beta_{distance}$= 1.657±3.757), *emergent vegetation* (β_{emerg_veg}= -0.304±0.888), *slope* (β_{slope}= -0.18±3.385), *aquatic vegetation* (β_{woody}= -10.131±10.524 and β_{herby}= -1.547±1.587), *bend* ($\beta_{Hamburg}$= -0.548±1.307 and β_{Kansas}= -0.857±1.133), *land cover* ($\beta_{\%forest}$= -2.835±3.248, $\beta_{\%field}$= 29.388±29.144, and $\beta_{\%ag}$= 1.417±2.099), and *terrestrial vegetation* (β_{grass}= -7.308±4.727, $\beta_{herbs/forbs}$= -6.354±4.709, and $\beta_{shrubs/trees}$= -10.799±6.371) (Table 3.26).

Plains leopard frog tadpoles were captured at 25 sites during the first survey and at 27 sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top model was *slope* (β_{slope}= -20.252±8.322) (Table 3.26).

American bullfrog (*Lithobates catesbeiana*)

May 2010

American bullfrog tadpoles were captured at four sites during the first survey and at three sites during the second survey. *Connectivity* and the *global* model failed tom run and were therefore not candidates for the confidence set. The top models were *emergent vegetation* (β_{emerg_veg}= 24.158±2.971), the *null* model, *distance to nearest wetland* ($\beta_{distance}$= 4.3±5.623), *terrestrial vegetation* (β_{grass}= 3285.948±2311.194, $\beta_{herbs/forbs}$= 542.202±637952.285, $\beta_{shrubs/trees}$= 2370.335±8537.769), *slope* (β_{slope}= 0.257±3.592), *bend* ($\beta_{Hamburg}$= -0.412±1.411 and β_{Kansas}= -1.941±1.539), and *wetland size* (β_{small}= -0.702±1.395 and β_{medium}= -1.399±1.673) (Table 3.27).

June 2010

American bullfrogs were heard at six sites during the first survey and at 11 sites during the second survey. *Land cover, wetland size, connectivity, slope,* and the *global* model failed to run and were therefore not candidates for the confidence set. The remaining models were all plausible. The top models were the *null* model, *distance to nearest wetland* ($\beta_{distance}$= -499.032±11695.46), *bend* ($\beta_{Hamburg}$= -25.938±3.979 and β_{Kansas}= -24.718±3.859), *emergent vegetation* (β_{emerg_veg}= 19.941±102448.797), and *terrestrial vegetation* (β_{grass}= 1876.942±186308.564, $\beta_{herbs/forbs}$= 16281.475±20.704, and $\beta_{shrubs/trees}$= -3080.962±910.888) (Table 3.28).

May 2011

American bullfrog tadpoles were captured at four sites during the first survey and at five sites during the second survey. The *global* model failed to run and was eliminated from consideration. The top models were *slope* (β_{slope}= -9.762±7.26), the *null* model, *bend* ($\beta_{Hamburg}$= 25.761±15.009 and β_{Kansas}= 25.822±15.005), *distance to nearest wetland* ($\beta_{distance}$= -1.098±1.244), and *emergent vegetation* (β_{emerg_veg}= -0.05±0.912) (Table 3.29).

June 2011

American bullfrogs were heard at 11 sites during the first survey and at seven sites during the second survey. *Aquatic vegetation, terrestrial vegetation, land cover, vegetation, distance to nearest wetland, connectivity, bend,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were the *null* model, *emergent vegetation* (β_{emerg_veg}= 26.571±372254.054), *wetland size* (β_{ssmall}= 24.683±140213.782 and β_{medium}= 1.516±1.804), and *slope* (β_{slope}= 7.480±201499.173) (Table 3.30).

American bullfrog tadpoles were captured at four sites during the first survey and at five sites during the second survey. *Connectivity, vegetation,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *bend* ($\beta_{Hamburg}$= -20.546±8546.148 and β_{Kansas}= 17.606±14799.237), *land cover* ($\beta_{\%forest}$= 5.509±7.281, $\beta_{\%field}$= 10.93±36.688, and β_{slope}= 15.661±12.787), the *null* model, and *wetland size* (β_{small}= -3.457±2.886 and β_{medium}= -1.948±2.781) (Table 3.30).

Woodhouse's toad (*Anaxyrus woodhousii*)

April 2010

Woodhouse's toads were heard at 13 sites during the first survey and at four sites during the second survey. The *global* model failed to run and was therefore not a candidate for the confidence set. The top models were *slope* (β_{slope}= -11.163±4.712) and *terrestrial vegetation* (β_{grass}= -4.205±2.192, $\beta_{herbs/forbs}$= -8.692±4.351, and $\beta_{shrubs/trees}$= -2.652±2.642) (Table 3.31).

Woodhouse's toad tadpoles were captured at five sites during the first survey and at nine sites during the second survey. *Wetland size, land cover, connectivity,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *distance to nearest wetland* ($\beta_{distance}$= 11.364±11.194), *emergent vegetation* (β_{emerg_veg}= 6.233±74.157), the *null* model, and *slope* (β_{slope}= -12.375±11.235) (Table 3.31).

May 2010

Woodhouse's toads were heard at six sites during the first survey and at seven sites during the second survey. *Wetland size* and the *global* model failed to run and were therefore not candidates for the confidence set. The top model was *slope* (β_{slope}= -20.274±9.553) (Table 3.32).

Woodhouse's toad tadpoles were captured at six sites during the first survey and at four sites during the second survey. *Terrestrial vegetation, land cover, bend,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were the *null* model, *slope* (β_{slope}= -28.455±5.452), *distance to nearest wetland* ($\beta_{distance}$= -0.822±1.691), *emergent vegetation* (β_{emerg_veg}= -0.566±1.176), and *wetland size* (β_{small}= -0.308±1.293 and β_{medium}= 1.547±1.603) (Table 3.32).

June 2010

Woodhouse's toads were heard at one site during the first survey and at five sites during the second survey. *Emergent vegetation, connectivity, bend, land cover,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *terrestrial vegetation* (β_{grass}= -12.855±7.683, $\beta_{herbs/forbs}$= -11.335±8.476, and $\beta_{shrubs/trees}$= -10.686±7.166), the *null* model, *distance to nearest wetland* ($\beta_{distance}$= 5.222±10.714), and *slope* (β_{slope}= 6.24±6.832) (Table 3.33).

May 2011

Woodhouse's toads were heard at eight sites during the first survey and at four sites during the second survey. *Land cover, terrestrial vegetation, slope, connectivity, aquatic vegetation, vegetation,* and the *global* model failed to run and were therefore not candidates for the confidence set. The top models were *emergent vegetation* (β_{emerg_veg}= -245.575±19.398), the *null* model, and *distance to nearest wetland* ($\beta_{distance}$= 3.081±2.819) (Table 3.34).

DISCUSSION

Western chorus frog (*Pseudacris triseriata*)

Western chorus frogs are small-bodied short-dispersing anurans that tend to be fairly cosmopolitan in site choice. However, their small size and high risk of predation from fish and other amphibians is likely to decrease their selection of, and success in, deep steep-sided wetlands (Conant and Collins 1998). The selection of *slope* in seven of the nine confidence sets seems to support this. This relationship is even more compelling when considering that *slope* was the top model for adult occupancy in April and May, 2010 and for tadpoles in May, 2010 and April and May, 2011 during the height of the chorus frog's breeding season. Although the slope or grade of a wetland is likely to impact occupancy of chorus frogs, the plausibility of the *null* model in six confidence sets and as the top model in June, 2011 may weaken any inference that can be drawn. The limited dispersal capabilities of Western chorus frogs may also explain the presence of *land cover* and *distance to nearest wetland* in several confidence sets. However, land cover was examined at a broad scale (500m) and chorus frogs interact with the environment at a small enough scale that a measure of micro-habitat or between-patch vegetation may be needed.

Northern cricket frog (*Acris crepitans*)

Northern cricket frogs, like Western chorus frogs, are small bodied and inhabit shallow water. Northern cricket frog occupancy in the Missouri River floodplain may be limited by available shallow water habitat and their ability to disperse to new wetlands. *Distance to nearest wetland* was selected in three of the five months in which occupancy was modeled. *Slope* was selected in all five confidence sets and was the top model in May, 2010. Cricket frogs attach their eggs to stems of vegetation in shallow water (Conant and Collins 1998) and *emergent vegetation* was selected in four of the five confidence sets and is the top model in April, 2010.

Cope's gray treefrog (*Hyla chrysoscelis*)

Cope's gray treefrogs occupancy may be influenced by *slope* as it appears in six of the eight confidence sets and as a top model twice, but the *null* model was also selected five times and was the top model for adult occupancy in May and June, 2011. It is interesting to note that neither *terrestrial vegetation* nor *land cover* appear in six of the eight confidence sets, despite the tendency of treefrogs to advertise while perched on the underside of broad leaves, small branches, and trunks of trees, or even while grasping the thin stems of common grasses. The selection of *terrestrial vegetation* as the most plausible tadpole occupancy model in June, 2011 and of *land cover* in June, 2010 however, suggests that treefrog occupancy may be responding to the structure of vegetation adjacent to the wetland and in the surrounding landscape, but the parameter estimates say little about the nature of this relationship.

Plains leopard frog (*Lithobates blairi*)

Plains leopard frogs are terrestrial long-range dispersers that will move far from water during the non-breeding season. Although leopard frogs are more successful in deeper or steeper sided wetlands than their smaller-bodied counterparts, they are more commonly found in shallow waters as indicated by the selection of *slope* in eight of the eleven confidence sets and as the top model four times. The vagility of leopard frogs would suggest that occupancy would be best explained by vegetation cover and land-use at large spatial scales. However, *terrestrial vegetation* appears in fewer than half of the confidence sets and never carries more than 19% of the weight. *Land cover* is the top model for tadpoles in both April and June of 2010, but only appears twice more and carries less than 4% of the weight each time. The lack of consistent support, coupled with the appearance of the null in six confidence sets and as the top model in four, makes inferring much about the relationship between leopard frogs and vegetation at any scale.

American bullfrog (*Lithobates catesbeiana*)

Little can be inferred from the models about what drives occupancy of American bullfrogs. This is due in part to limited encounter histories (small sample sizes) and in part to the frequent plausibility of the *null* model. It is likely that sampling occurred too early in the season to capture the height of bullfrog mating season. Bullfrogs are also considered to be invasive in many areas of North America and are generalists that thrive in a variety of environments and can utilize myriad food sources. Although bullfrog tadpoles can be preyed upon by fish, bullfrogs are voracious eaters and are known to consume anything they can swallow. It is likely that the abundant food sources available in deeper bodies of water offset predation risks. Therefore it was surprising to see *slope* selected in three of the five confidence sets, and as the top model for tadpoles in May, 2011. However, there is the possibility that steep-sided wetlands suffered from a tadpole sampling bias as they were more difficult to dip-net.

Woodhouse's toad (*Anaxyrus woodhousii*)

The *null* model was selected in every month (and all but two confidence sets) for which there were sufficient detections to model Woodhouse's toad occupancy. Although the frequency of the *null* weakens inference, the weight of *slope* in both April and May, 2010 suggests that Woodhouse's toads are most likely to occupy shallow, often ephemeral wetlands.

Management implications

The success of a wetland restoration depends largely on the forethought of site selection. The location of a wetland, the site characteristics, and the proximity to other wetlands all play a role in amphibian occupancy. Of the 44 selected model sets, *slope* was selected 35 times, 15 times as a top model (12 times with a wt >0.500). The relationship of slope to occupancy was almost universally negative, indicating that selecting shallow pre-existing sites or grading the slopes of constructed wetlands will lead to greater success of restorations. This is compatible with the management of wetlands for migratory waterfowl, but in conflict with the needs of many native fishes. As is often the case, agencies may need to select and manage sites for a range of habitat characteristics to satisfy a range of conservation needs. However, it is important to note that the *null* model was selected 30 times and appeared as the top model 13 times (twice with a wt >0.500) Although the relationship between occupancy and slope seems pretty clear, the frequency of selection and occasional dominance of the *null* model makes inference beyond slope difficult. This may be a function of a sample size that was reduced by flooding in the latter half of both years. It could also indicate a failure to ask the right questions, or a failure to measure the right covariates.

Alternatively, the lack of clear habitat covariates of occupancy across the six amphibian species may be an indicator not of poorly chosen models or a lack of robust data. It may be that the species inhabiting wetlands require a diversity of habitat characteristics. The difference in niches and habitat requirements of species and functional groups is often what provides a level of resilience to an ecosystem. Managing for a variety of wetland types representing a large range of microhabitats and hydroperiods may allow the wetland complex to thrive in the often stochastic environment of a floodplain. Acquiring and managing nearby upland wetlands could be another management strategy to improve the connectivity of the region and provide habitat during occasional large scale flood events like that seen in 2011.

Despite the lack of strong inference from many of the candidate models, some conclusions can be draw that will inform future assessment strategies. First, timing is important. I monitored and modeled each species during three phenologically determined time spans. This allowed for a near census of species occupying the restorations. However, occupancy in a wetland is difficult to define as there are species that exhibit very different levels of dependency on standing water. There are obligate occupants who live in the water year round like the American Bullfrog, while most toads emerge following a large rain event, breed in shallow, often very ephemeral, pools of water and then return to largely terrestrial lives. Choosing species of interest, such as the declining Northern cricket frog, and targeting the peak of their respective breeding seasons may be a better approach. Although this would be difficult with rare species or opportunistic breeders, the detections for these species are often so low as to minimize the value of modeling occupancy indicators for them anyway.

Wetlands are complex systems; floodplain wetlands are further complicated by seasonal and sometimes historic flooding. Floodplain wetland restorations are crucial to the persistence of many declining taxa, but creating and managing restorations requires an understanding of how the system works and what factors contribute to success. If amphibian presence at a wetland can be an indicator of wetland function and restoration success, amphibian persistence at a wetland or within a complex may be an even better indicator. Continued monitoring at restored wetland complexes may provide a better picture of system resilience and the physical characteristics that drive wetland function. Managers and monitors alike must be careful not to rely too heavily on the wealth of information that exists for upland wetlands. As seen in 2010 and even more so in 2011, riparian systems and floodplain wetlands are inherently stochastic and the landscape can vary dramatically from year to year or even from week to week. Our management approach needs to incorporate the dynamics of this system.

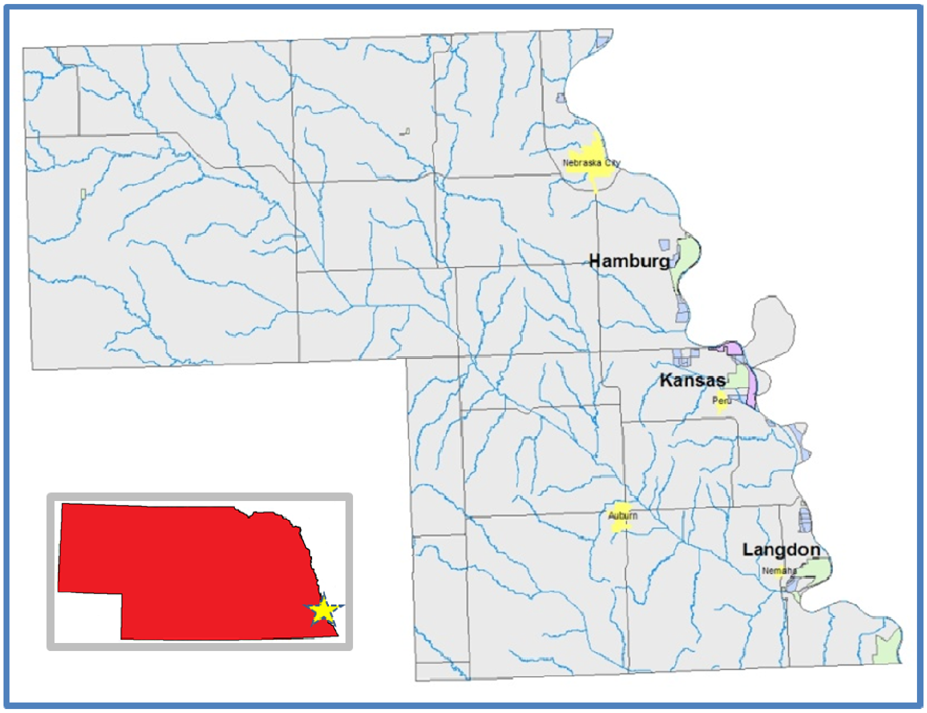

Figure 3.1. *Research bends*. Amphibian occupancy of three restored Missouri River bends was assessed. Fifty five wetland sites representing a variety of wetland types were selected across the three bends. Research sites were located in Hamburg bend (River mile 557) in Otoe County, and Kansas (River mile 548) and Langdon (River mile 534) bends in Nemaha County in southeast Nebraska along the lower Missouri River.

Table 3.1. *Research Sites, Hamburg and Langdon Bends.* Three restored river bends along the Missouri River (river mile 557-528) in southeast Nebraska were selected to assess amphibian occupancy as a metric for wetland success. Wetlands were selected in ArcMap as intersections of hydric soils and National Wetland Inventory polygons. Initial selections were visited to assess current status and additional wetlands encountered while in the bends were included in the study. Sites selected represented a variety of engineering categories used the U.S. Army Corps of Engineers. Each wetland was assigned a site number, the wetland type was determined, and a GPS location was taken.

Name	Wetland Type	Latitude	Longitude
Hamburg Research Sites			
H9	Tributary	40.59478	-95.77416
H11	Scour Hole	40.60105	-95.77130
H12	Tributary	40.60559	-95.79135
H14	Tributary	40.58963	-95.78448
H15F	Ephemeral, unfarmed	40.58395	-95.78078
H15S	Tributary	40.58444	-95.78220
H34	Ephemeral, farmed	40.53872	-95.78388
H59	Ground Fed Permanent	40.57660	-95.78010
H64	Ditch	40.54506	-95.77943
H65N	Ditch	40.54155	-95.78173
H65S	Ditch	40.54160	-95.78172
Langdon Research Sites			
L37	Ground Fed Permanent	40.32483	-95.65586
L39	Ephemeral, farmed	40.33432	-95.63966
L43	Ground Fed Permanent	40.33962	-95.65435
L44	Ditch	40.34520	-95.65708
L46	Ditch	40.33448	-95.66757
L51N	Ephemeral, unfarmed	40.32288	-95.65952
L51S	Ephemeral, farmed	40.32279	-95.65964
L53	Backwater	40.32922	-95.64075
L54E	Ephemeral, unfarmed	40.34186	-95.64357
L54W	Ground Fed Permanent	40.34156	-95.64455
L55E	Ditch	40.34013	-95.65951
L55W	Ditch	40.33957	-95.66021
L70	Backwater	40.34894	-95.63411

Table 3.2. *Research Sites, Kansas Bend.* Three restored river bends along the Missouri River (river mile 557-528) in southeast Nebraska were selected to assess amphibian occupancy as a metric for wetland success. Wetlands were selected in ArcMap as intersections of hydric soils and National Wetland Inventory polygons. Initial selections were visited to assess current status and additional wetlands encountered while in the bends were included in the study. Sites selected represented a variety of engineering categories used the U.S. Army Corps of Engineers. Each wetland was assigned a site number, the wetland type was determined, and a GPS location was taken.

Name	Wetland Type	Latitude	Longitude
Kansas Research Sites			
K2	Ephemeral, unfarmed	40.48175	-95.72298
K6	Ephemeral, unfarmed	40.48025	-95.71866
K7	Ground Fed Permanent	40.47885	-95.71381
K10	Ground Fed Permanent	40.48343	-95.71973
K23	Tributary	40.47711	-95.71013
K24	Tributary	40.47371	-95.70198
K25	Impoundment	40.48340	-95.70690
K27	Impoundment	40.47732	-95.70813
K30	Ephemeral, unfarmed	40.50184	-95.70430
K32	Ground Fed Permanent	40.51362	-95.71594
K56I	Ditch	40.49219	-95.70470
K56O	Ephemeral, unfarmed	40.49229	-95.70358
K57N	Ditch	40.50857	-95.70990
K57S	Ephemeral, unfarmed	40.50821	-95.71032
K66	Impoundment	40.49382	-95.71946
K67F	Impoundment	40.49458	-95.72079
K67S	Tributary	40.49426	-95.72108
K68	Tributary	40.48308	-95.71446
K69	Impoundment	40.49425	-95.72041
K71	Tributary	40.49408	-95.72070

Table 3.3. *Candidate adult detection models*. Models were created based on the work of MacKenzie (2001) and used *a priori* selection of covariates that may impact detection of adult anurans. Covariates were survey-specific (water temperature, air temperature, wind speed, moonshine, time of day, day of year) or site-specific (wetland size). MacKenzie's occupancy model allows the incorporation of detection covariates. To test detection alone, the occupancy, or □ half of the equation, was held as the *null* model for occupancy (occupancy was assumed to be independent of the covariates).

Name	Model	# of parameters
Null	□(.), p(.)	2
Day	□(.), p(Day[1])	3
Moonshine	□(.), p(Moonshine[2])	3
Time of Day	□(.), p(Time[3])	3
Water Temperature	□(.), p(Water Temp[4])	3
*Air Temperature	□(.), p(Air Temp[5])	3
*Wind Speed	□(.), p(Wind Speed[5])	3
Wetland Size	□(.), p(<2.0ac[6] + 2.1-5.0ac[6])	4
*Environmental Conditions 1	□(.), p(Water Temp + Air Temp + Wind Speed)	5
*Environmental Conditions 1 and Day	□(.), p(Day + Water Temp + Air Temp + Wind Speed)	6
*Environmental Conditions 2	□(.), p(Moonshine + Water Temp + Air Temp + Wind Speed)	6
*Global	□(.), p(Day+ Moonshine + Time + Water Temp + Air Temp + Wind Speed + <2.0ac + 2.1-5.0ac)	11

* Models containing covariates not measured in 2010 (wind speed and air temperature) were modified to exclude missing covariates in 2010 analysis. In the event that the modified model was redundant with another model in the set one of the redundant models was dropped.

1. Day was represented as day since April 1.
2. Moonshine was calculated as the phase of moon * (1-%cloud cover). Cloud cover data was obtained from two airports, one north of the northernmost sites and one south of the southernmost sites. The average of the two airports' reported cloud cover was taken hourly.
3. Time was measured as the time of day at the start of the survey
4. Water temperature was measured at a depth of 4cm with an instant read probe thermometer.
5. Wind speed and air temperature were measured using a Kestrel anemometer.
6. Each wetland was visually assessed and assigned to a size category of small (<0.83ha or <2ac), medium (0.84-2.02ha or 2.1-5ac), or large (>2.02ha or 5.1ac).

Table 3.4. *Candidate tadpole detection models.* Models were created based on the work of MacKenzie (2001) and used *a priori* selection of covariates that may impact detection of larval anurans. Covariates were survey-specific (water temperature, time of day, day of year) or site-specific (slope, aquatic vegetation: % herbaceous, % woody, and % open). MacKenzie's occupancy model allows the incorporation of detection covariates. To test detection alone, the occupancy, or ψ half of the equation, was held as the *null* model for occupancy (occupancy was assumed to be independent of the covariates).

Name	Model	# of parameters
Null	ψ(.), p(.)	2
Day	ψ(.), p(Day[1])	3
*Time of Day	ψ(.), p(Time[2])	3
*Water Temperature	ψ(.), p(Water Temp[3])	3
Slope	ψ(.), p(%Slope[4] 0-1m)	3
*Aquatic Vegetation	ψ(.), p(% Herbaceous[5] + %Woody[5])	4
*Water Temperature + Slope	ψ(.), p(Water Temp + Slope)	4
*Global	ψ(.), p(Day + Time + Water Temp + %Slope + %Herbaceous +%Woody)	8

* Models containing covariates not measured in 2010 or not recorded during tadpole dip-netting (water temperature, time, and aquatic vegetation) were modified to exclude missing covariates in 2010 analysis. In the event that the modified model was redundant with another model in the set one of the redundant models was dropped.
1. Day was represented as day since April 1.
2. Time was the time of day at the beginning of the survey
3. Water temperature was measured at a depth of 4cm with an instant read probe thermometer.
4. Slope was calculated from water depth1m from the shoreline. Depth was measured at 20 1m intervals and averaged for a site.
5. Each dip-net sweep was designated as having passed through woody, herbaceous, or open water habitat. Percentages were calculated based on the total number of sweeps in a wetland (usually 20).

Table 3.5. *Candidate occupancy models.* Models were created based on the work of MacKenzie (2001) and used *a priori* selection of covariates that may impact occupancy of anurans. MacKenzie's occupancy model allows the incorporation of detection covariates. To test occupancy the top model selected for detection for each species, life stage, month, and year was incorporated in to the detection or *p* half of the model.

Name	Model	# of parameters
Null	□(.), p(.)	2+
Slope	□(%Slope[1] 0-1m), p(.)	3+
Emergent Vegetation	□(Emergent Veg[2]), p(.)	3+
Distance to Nearest Wetland	□(Distance to Nearest Wetland[3]), p(.)	3+
*Aquatic Vegetation	□(% Herbaceous[4] + %Woody[4]), p(.)	4+
Bend	□(Hamburg Bend[5] + Kansas Bend[5]), p(.)	4+
Wetland Size	□(small[6], <2.0ac + medium[6], 2.1-5.0ac), p(.)	4+
Terrestrial Vegetation	□(%Grass[7] + %Herbs/Forbs[7] + %Shrubs/Trees[7]), p(.)	5+
Land Cover	□(% Forest[8] + % Field[8] + %Agriculture[8]), p(.)	5+
Connectivity	□(Distance to Nearest Wetland + %Forest + %Field + %Agriculture), p(.)	6+
*Vegetation	□(%Grass + %Herbs/Forbs + %Shrubs/Trees + % Herbaceous + %Woody), p(.)	7+
*Global	□(Slope + Emergent Veg + Distance to Nearest Wetland + % Herbaceous + %Woody+ Hamburg Bend + Kansas Bend + <2.0ac + 2.1-5.0ac + %Grass + %Herbs/Forbs + %Shrubs/Trees + %Forest + %Field + %Agriculture), p(.)	17+

* Models containing aquatic vegetation (not measured in 2010) were modified in 2010 analysis. In the event that the modified model was redundant with another model in the set one of the redundant models was dropped. The number of parameters listed in the table indicates the number of parameters when the detection model is the null. The actual number of parameters varies within and across species, life stages, and months due to the independent selection of top detection models.
1. Slope was calculated from water depth1m from the shoreline. Depth was measured at 20 1m intervals and averaged for a site.
2. Presence or absence of emergent aquatic vegetation was noted.
3. Distance to nearest wetland was calculated in ArcMap as the distance between the closest of two survey points.
4. Each dip-net sweep was designated as having passed through woody, herbaceous, or open water habitat. Percentages were calculated based on the total number of sweeps in a wetland (usually 20).
5. A bend effect was included to test for variation in occupancy between bends.
6. Each wetland was visually assessed and assigned to a size category of small (<0.83ha or <2ac), medium (0.84-2.02ha or 2.1-5ac), or large (>2.02ha or 5.1ac).
7. The percentage of four terrestrial vegetation categories (grasses, hers/forbs, shrubs/trees, and bare ground) were visually estimated 1m from the high water mark along the length of the dip-netting transect. Transects varied by wetland size in 2010 and were 200m in 2011.
8. Land cover categories (%forest, %field, and %agriculture) were calculated within $1000m^2$ of the survey point.

Table 3.6. *Occupancy models for the western chorus frog in April, 2010*. Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, western chorus frog (23, 7, n=42; detection: environmental conditions 1 and day)						
□(slope),p(best)	**5**	**88.67**	**0.00**	**0.806**	**1.000**	**77.00**
□(.),p(best)	4	93.33	4.66	0.078	0.097	84.25
□(emergent vegetation),p(best)	5	94.56	5.89	0.042	0.053	82.89
□(wetland size),p(best)	6	95.47	6.80	0.027	0.033	81.07
□(distance to nearest wetland),p(best)	5	95.90	7.23	0.022	0.027	84.23
□(terrestrial vegetation),p(best)	7	96.56	7.89	0.016	0.019	79.27
□(bend),p(best)	6	97.68	9.01	0.009	0.011	83.28
Tadpole occupancy, western chorus frog (16,18, n=42; detection: global)						
□(land cover),p(best)	**7**	**71.30**	**0.00**	**0.549**	**1.000**	**54.01**
□(connectivity),p(best)	**8**	**74.36**	**3.06**	**0.119**	**0.217**	**54.00**
□(emergent vegetation),p(best)	**5**	**74.45**	**3.15**	**0.114**	**0.207**	**62.78**
□(distance to nearest wetland),p(best)	**5**	**74.79**	**3.49**	**0.096**	**0.175**	**63.12**
□(.),p(best)	**4**	**75.14**	**3.84**	**0.081**	**0.147**	**66.06**
□(slope),p(best)	5	77.60	6.30	0.024	0.043	65.93
□(wetland size),p(best)	6	79.70	8.40	0.008	0.015	65.30
□(bend),p(best)	6	79.78	8.48	0.008	0.014	65.38
□(terrestrial vegetation),p(best)	7	81.89	10.59	0.003	0.005	64.60

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.7. *Occupancy models for the western chorus frog in May, 2010.* Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, western chorus frog (5, 5, n=42; detection: null)						
□(slope),p(best)	**3**	**62.11**	**0.00**	**0.651**	**1.000**	**55.48**
□(.),p(best)	**2**	**65.32**	**3.21**	**0.131**	**0.201**	**61.01**
□(distance to nearest wetland),p(best)	**3**	**66.44**	**4.33**	**0.075**	**0.115**	**59.81**
□(emergent vegetation),p(best)	3	67.57	5.46	0.043	0.065	60.94
□(bend),p(best)	4	67.66	5.55	0.041	0.062	58.58
□(land cover),p(best)	5	68.93	6.82	0.022	0.033	57.26
□(wetland size),p(best)	4	69.28	7.17	0.018	0.028	60.20
□(terrestrial vegetation),p(best)	5	69.65	7.54	0.015	0.023	57.98
□(connectivity),p(best)	6	71.51	9.40	0.006	0.009	57.11
Tadpole occupancy, western chorus frog (18, 14, n=42; detection: day)						
□(slope),p(best)	**4**	**93.83**	**0.00**	**0.393**	**1.000**	**84.75**
□(distance to nearest wetland),p(best)	**4**	**94.36**	**0.53**	**0.302**	**0.767**	**85.28**
□(emergent vegetation),p(best)	**4**	**95.54**	**1.71**	**0.167**	**0.425**	**86.46**
□(.),p(best)	**3**	**98.33**	**4.50**	**0.041**	**0.105**	**91.70**
□(land cover.),p(best)	6	98.80	4.97	0.033	0.083	84.40
□(connectivity),p(best)	7	99.13	5.30	0.028	0.071	81.84
□(wetland size),p(best)	5	99.40	5.57	0.024	0.062	87.73
□(terrestrial vegetation),p(best)	6	101.44	7.61	0.009	0.022	87.04
□(bend),p(best)	5	103.25	9.42	0.004	0.009	91.58

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.8. *Occupancy models for the western chorus frog in April, 2011.* Twelve models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, western chorus frog (30, 27, n=42; detection: moonshine)						
□(aquatic vegetation),p(best)	**5**	**89.87**	**0.00**	**0.829**	**1.000**	**78.20**
□(emergent vegetation),p(best)	**4**	**94.21**	**4.34**	**0.095**	**0.114**	**85.13**
□(vegetation),p(best)	8	96.70	6.83	0.027	0.033	76.34
□(distance to nearest wetland),p(best)	4	97.80	7.93	0.016	0.019	88.72
□(.),p(best)	3	98.22	8.35	0.013	0.015	91.59
□(slope),p(best)	4	98.77	8.90	0.010	0.012	89.69
□(wetland size),p(best)	5	100.37	10.50	0.004	0.005	88.70
□(bend),p(best)	5	101.03	11.16	0.003	0.004	89.36
□(land cover),p(best)	6	102.28	12.41	0.002	0.002	87.88
□(connectivity),p(best)	7	102.90	13.03	0.001	0.002	85.61
□(terrestrial vegetation),p(best)	6	103.85	13.98	0.001	0.001	89.45
Tadpole occupancy, western chorus frog (3, 6, n=42; detection: global)						
□(slope),p(best)	**9**	**43.48**	**0.00**	**0.962**	**1.000**	**19.86**
□(distance to nearest wetland),p(best)	9	50.69	7.21	0.026	0.027	27.06
□(aquatic vegetation),p(best)	10	52.93	9.45	0.009	0.009	25.83
□(land cover),p(best)	11	55.01	11.53	0.003	0.003	24.21

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.9. *Occupancy models for the western chorus frog in May, 2011.* Twelve models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, western chorus frog (7, 11, n=40; detection: air temperature)						
(distance to nearest wetland),p(best)	**4**	**85.05**	**0.00**	**0.491**	**1.000**	**75.91**
(.),p(best)	**3**	**86.86**	**1.81**	**0.198**	**0.405**	**80.19**
(slope),p(best)	**4**	**87.91**	**2.86**	**0.117**	**0.239**	**78.77**
(emergent vegetation),p(best)	**4**	**88.73**	**3.68**	**0.078**	**0.159**	**79.59**
(wetland size),p(best)	5	90.51	5.46	0.032	0.065	78.75
(bend),p(best)	5	90.69	5.64	0.029	0.060	78.93
(aquatic vegetation),p(best)	5	91.01	5.96	0.025	0.051	79.25
(connectivity),p(best)	7	91.44	6.39	0.020	0.041	73.94
(land cover),p(best)	6	94.39	9.34	0.005	0.009	79.84
(terrestrial vegetation),p(best)	6	94.47	9.42	0.004	0.009	79.92
(vegetation),p(best)	8	98.53	13.48	0.001	0.001	77.88
Tadpole occupancy, western chorus frog (13, 16, n=40; detection: water temperature and slope)						
(slope),p(best)	**5**	**88.32**	**0.00**	**0.517**	**1.000**	**76.56**
(bend),p(best)	**6**	**91.00**	**2.68**	**0.135**	**0.262**	**76.45**
(.),p(best)	**4**	**91.10**	**2.78**	**0.129**	**0.249**	**81.96**
(distance to nearest wetland),p(best)	**5**	**91.41**	**3.09**	**0.110**	**0.213**	**79.65**
(emergent vegetation),p(best)	5	93.67	5.35	0.036	0.069	81.91
(land cover),p(best)	7	94.30	5.98	0.026	0.050	76.80
(wetland size),p(best)	6	95.01	6.69	0.018	0.035	80.46
(terrestrial vegetation),p(best)	7	96.18	7.86	0.010	0.020	78.68
(aquatic vegetation),p(best)	6	96.26	7.94	0.010	0.019	81.71
(connectivity),p(best)	8	96.36	8.04	0.009	0.018	75.71

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.10. *Occupancy models for the western chorus frog in June, 2011.* Twelve models were proposed to explain occupancy of larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Tadpole occupancy, western chorus frog (5,7, n=34; detection: water temperature and slope)						
□(.),p(best)	**4**	**59.45**	**0.00**	**0.428**	**1.000**	**50.07**
□(emergent vegetation),p(best)	**5**	**61.01**	**1.56**	**0.196**	**0.458**	**48.87**
□(distance to nearest wetland),p(best)	**5**	**61.26**	**1.81**	**0.173**	**0.405**	**49.12**
□(slope),p(best)	**5**	**61.95**	**2.50**	**0.123**	**0.287**	**49.81**
□(bend),p(best)	**6**	**62.81**	**3.36**	**0.080**	**0.186**	**47.70**

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.11. *Occupancy models for the Northern cricket frog in April, 2010.* Ten models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Northern cricket frog (6, 14, n=42: detection: environmental conditions 1 and day)						
□(emergent vegetation),p(best)	**5**	**74.52**	**0.00**	**0.807**	**1.000**	**62.85**
□(slope),p(best)	**5**	**78.24**	**3.72**	**0.126**	**0.156**	**66.57**
□(.),p(best)	4	81.07	6.55	0.031	0.038	71.99
□(connectivity),p(best)	8	82.31	7.79	0.016	0.020	61.95
□(distance to nearest wetland),p(best)	5	83.04	8.52	0.011	0.014	71.37
□(bend),p(best)	6	84.48	9.96	0.006	0.007	70.08
□(wetland size),p(best)	6	86.05	11.53	0.003	0.003	71.65
□(terrestrial vegetation),p(best)	7	87.13	12.61	0.002	0.002	69.84

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.12. *Occupancy models for the Northern cricket frog in May, 2010.* Ten models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, northern cricket frog (14, 19, n=42; detection: day)						
□(slope),p(best)	**4**	**98.66**	**0.00**	**0.554**	**1.000**	**89.58**
□(.),p(best)	**3**	**101.76**	**3.10**	**0.118**	**0.212**	**95.13**
□(terrestrial vegetation),p(best)	**6**	**101.82**	**3.16**	**0.114**	**0.206**	**87.42**
□(distance to nearest wetland),p(best)	**4**	**103.19**	**4.53**	**0.058**	**0.104**	**94.11**
□(emergent vegetation),p(best)	4	103.54	4.88	0.048	0.087	94.46
□(land cover.),p(best)	6	104.00	5.34	0.038	0.069	89.60
□(bend),p(best)	5	104.04	5.38	0.038	0.068	92.37
□(wetland size),p(best)	5	105.19	6.53	0.021	0.038	93.52
□(connectivity),p(best)	7	106.54	7.88	0.011	0.019	89.25

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.13. *Occupancy models for the Northern cricket frog in June, 2010.* Ten models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, northern cricket frog (19, 16, n=36; detection: environmental conditions 1 and day)						
□(.),p(best)	**4**	**92.57**	**0.00**	**0.447**	**1.000**	**83.28**
□(distance to nearest wetland),p(best)	**5**	**94.53**	**1.96**	**0.168**	**0.375**	**82.53**
□(emergent vegetation),p(best)	**5**	**94.96**	**2.39**	**0.135**	**0.303**	**82.96**
□(slope),p(best)	**5**	**95.25**	**2.68**	**0.117**	**0.262**	**83.25**
□(bend),p(best)	**6**	**96.90**	**4.33**	**0.051**	**0.115**	**82.00**
□(wetland size),p(best)	6	97.56	4.99	0.037	0.083	82.66
□(terrestrial vegetation),p(best)	7	98.45	5.88	0.024	0.053	80.45
□(land cover),p(best)	7	99.10	6.53	0.017	0.038	81.10
□(connectivity),p(best)	8	102.08	9.51	0.004	0.009	80.75
□(global),p(best)	17	134.19	41.62	0.000	0.000	66.19

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.14. *Occupancy models for the Northern cricket frog in May, 2011*. Twelve models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, northern cricket frog (17,16, n=40; detection: water temperature)						
□(distance to nearest wetland),p(best)	**4**	**98.50**	**0.00**	**0.280**	**1.000**	**89.36**
□(emergent vegetation),p(best)	**4**	**98.53**	**0.03**	**0.276**	**0.985**	**89.39**
□(terrestrial vegetation),p(best)	**6**	**98.85**	**0.35**	**0.235**	**0.840**	**84.30**
□(slope),p(best)	**4**	**100.38**	**1.88**	**0.109**	**0.391**	**91.24**
□(.),p(best)	**3**	**101.37**	**2.87**	**0.067**	**0.238**	**94.70**
□(aquatic vegetation),p(best)	5	103.27	4.77	0.026	0.092	91.51
□(wetland size),p(best)	5	105.81	7.31	0.007	0.026	94.05

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.15. *Occupancy models for the Northern cricket frog in June, 2011.* Twelve models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, northern cricket frog (21,16, n=34; detection: null)						
□(.),p(best)	**2**	**98.42**	**0.00**	**0.435**	**1.000**	**94.03**
□(emergent vegetation),p(best)	**3**	**99.40**	**0.98**	**0.267**	**0.613**	**92.60**
□(slope),p(best)	**3**	**100.64**	**2.22**	**0.143**	**0.330**	**93.84**
□(wetland size),p(best)	**4**	**102.69**	**4.27**	**0.051**	**0.118**	**93.31**
□(bend),p(best)	**4**	**102.87**	**4.45**	**0.047**	**0.108**	**93.49**
□(aquatic vegetation),p(best)	4	103.41	4.99	0.036	0.083	94.03
□(terrestrial vegetation),p(best)	5	104.64	6.22	0.019	0.045	92.50
□(vegetation),p(best)	7	109.92	11.50	0.001	0.003	91.61

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.16. *Occupancy models for the Cope's gray treefrog in April, 2010.* Ten models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Cope's gray treefrog (18,18, n=42; detection: water temperature)						
□(slope),p(best)	**4**	**85.36**	**0.00**	**0.998**	**1.000**	**76.28**
□(.),p(best)	3	100.20	14.84	0.001	0.001	93.57
□(distance to nearest wetland),p(best)	4	100.42	15.06	0.001	0.001	91.34
□(wetland size),p(best)	5	102.05	16.69	0.000	0.000	90.38
□(emergent vegetation),p(best)	4	102.20	16.84	0.000	0.000	93.12
□(bend),p(best)	5	103.54	18.18	0.000	0.000	91.87
□(terrestrial vegetation),p(best)	6	104.76	19.40	0.000	0.000	90.36
□(land cover),p(best)	6	107.36	22.00	0.000	0.000	92.96
□(connectivity),p(best)	7	108.01	22.65	0.000	0.000	90.72

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.17. *Occupancy models for the Cope's gray treefrog in May, 2010.* Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Cope's gray treefrog (16, 24, n=42; detection: environmental conditions 1 and day)						
□(slope),p(best)	**5**	**83.32**	**0.00**	**0.827**	**1.000**	**71.65**
□(emergent vegetation),p(best)	**5**	**87.77**	**4.45**	**0.089**	**0.108**	**76.10**
□(.),p(best)	4	89.40	6.08	0.040	0.048	80.32
□(wetland size),p(best)	6	90.57	7.25	0.022	0.027	76.17
□(distance to nearest wetland),p(best)	5	91.51	8.19	0.014	0.017	79.84
□(bend),p(best)	6	93.77	10.45	0.005	0.005	79.37
□(terrestrial vegetation),p(best)	7	95.40	12.08	0.002	0.002	78.11
□(land cover),p(best)	7	96.10	12.78	0.001	0.002	78.81
□(connectivity),p(best)	8	98.93	15.61	0.000	0.000	78.57
□(global),p(best)	17	119.21	35.89	0.000	0.000	59.71
Tadpole occupancy, Cope's gray treefrog(6, 6, n=42; detection: day)						
□(wetland size),p(best)	**5**	**56.67**	**0.00**	**0.474**	**1.000**	**45.00**
□(emergent vegetation),p(best)	**4**	**58.16**	**1.49**	**0.225**	**0.475**	**49.08**
□(.),p(best)	**3**	**59.91**	**3.24**	**0.094**	**0.198**	**53.28**
□(bend),p(best)	**5**	**60.14**	**3.47**	**0.084**	**0.176**	**48.47**
□(distance to nearest wetland),p(best)	**4**	**60.80**	**4.13**	**0.060**	**0.127**	**51.72**
□(slope),p(best)	**4**	**61.07**	**4.40**	**0.053**	**0.111**	**51.99**
□(terrestrial vegetation),p(best)	6	66.08	9.41	0.004	0.009	51.68
□(land cover.),p(best)	6	66.08	9.41	0.004	0.009	51.68
□(connectivity),p(best)	7	67.79	11.12	0.002	0.004	50.50

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.18. *Occupancy models for the Cope's gray treefrog in June, 2010.* Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Cope's gray treefrog (15, 20, n=36; detection: moonshine)						
□(land cover),p(best)	**6**	**87.23**	**0.00**	**0.728**	**1.000**	**72.33**
□(connectivity),p(best)	**7**	**90.25**	**3.02**	**0.161**	**0.221**	**72.25**
□(.),p(best)	3	93.20	5.97	0.037	0.051	86.45
□(emergent vegetation),p(best)	4	93.22	5.99	0.036	0.050	83.93
□(distance to nearest wetland),p(best)	4	95.36	8.13	0.013	0.017	86.07
□(slope),p(best)	4	95.56	8.33	0.011	0.016	86.27
□(bend),p(best)	5	96.36	9.13	0.008	0.010	84.36
□(terrestrial vegetation),p(best)	6	97.66	10.43	0.004	0.005	82.76
□(wetland size),p(best)	5	98.05	10.82	0.003	0.005	86.05
Tadpole occupancy, Cope's gray treefrog (17, 12, n=36; detection: null)						
□(bend),p(best)	**4**	**97.56**	**0.00**	**0.318**	**1.000**	**88.27**
□(distance to nearest wetland),p(best)	**3**	**98.23**	**0.67**	**0.228**	**0.715**	**91.48**
□(emergent vegetation),p(best)	**3**	**98.45**	**0.89**	**0.204**	**0.641**	**91.70**
□(.),p(best)	**2**	**99.19**	**1.63**	**0.141**	**0.443**	**94.83**
□(slope),p(best)	**3**	**101.15**	**3.59**	**0.053**	**0.166**	**94.40**
□(connectivity),p(best)	**6**	**101.87**	**4.31**	**0.037**	**0.116**	**86.97**
□(wetland size),p(best)	4	103.83	6.27	0.014	0.044	94.54
□(terrestrial vegetation),p(best)	5	105.84	8.28	0.005	0.016	93.84

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.19. *Occupancy models for the Cope's gray treefrog in May, 2011.* Twelve models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Cope's gray treefrog (16,15, n=40; detection: environmental conditions 1 and day)						
□(.),p(best)	**6**	**81.55**	**0.00**	**0.630**	**1.000**	**67.00**
□(emergent vegetation),p(best)	**7**	**83.68**	**2.13**	**0.217**	**0.345**	**66.18**
□(distance to nearest wetland),p(best)	**7**	**84.45**	**2.90**	**0.148**	**0.235**	**66.95**
□(terrestrial vegetation),p(best)	9	91.00	9.45	0.006	0.009	67.00

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.20. *Occupancy models for the Cope's gray treefrog in June, 2011.* Twelve models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Cope's gray treefrog (26,20, n=34; detection: water temperature)						
□(.),p(best)	**3**	**92.09**	**0.00**	**0.626**	**1.000**	**85.29**
□(slope),p(best)	**4**	**93.14**	**1.05**	**0.371**	**0.592**	**83.76**
□(connectivity),p(best)	7	102.85	10.76	0.003	0.005	84.54
□(vegetation),p(best)	8	107.05	14.96	0.000	0.001	85.29
□(global),p(best)	18	157.71	65.62	0.000	0.000	76.11
Tadpole occupancy, Cope's gray treefrog (6,7, n=34; detection: water temperature)						
□(terrestrial vegetation),p(best)	**6**	**39.38**	**0.00**	**0.354**	**1.000**	**24.27**
□(aquatic vegetation),p(best)	**5**	**40.62**	**1.24**	**0.190**	**0.538**	**28.48**
□(.),p(best)	**3**	**40.85**	**1.47**	**0.170**	**0.480**	**34.05**
□(slope),p(best)	**4**	**41.75**	**2.37**	**0.108**	**0.306**	**32.37**
□(distance to nearest wetland),p(best)	**4**	**41.93**	**2.55**	**0.099**	**0.279**	**32.55**
□(wetland size),p(best)	**5**	**43.59**	**4.21**	**0.043**	**0.122**	**31.45**
□(vegetation),p(best)	8	44.55	5.17	0.027	0.075	22.79
□(land cover),p(best)	6	47.46	8.08	0.006	0.018	32.35
□(connectivity),p(best)	7	49.18	9.80	0.003	0.007	30.87

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.21. *Occupancy models for the Plains leopard frog in April, 2010.* Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, plains leopard frog (18, 20, n=42; detection: null)						
□(slope),p(best)	**3**	**101.19**	**0.00**	**0.961**	**1.000**	**94.56**
□(emergent vegetation),p(best)	3	109.61	8.42	0.014	0.015	102.98
□(terrestrial vegetation),p(best)	5	110.11	8.92	0.011	0.012	98.44
□(wetland size),p(best)	4	111.43	10.24	0.006	0.006	102.35
□(distance to nearest wetland),p(best)	3	111.57	10.38	0.005	0.006	104.94
□(.),p(best)	2	113.37	12.18	0.002	0.002	109.06
□(bend),p(best)	4	117.76	16.57	0.000	0.000	108.68
□(land cover),p(best)	5	119.17	17.98	0.000	0.000	107.50
Tadpole occupancy, plains leopard frog (17,14, n=42; detection: slope)						
□(land cover),p(best)	**6**	**91.00**	**0.00**	**0.753**	**1.000**	**76.60**
□(connectivity),p(best)	**7**	**93.44**	**2.44**	**0.222**	**0.295**	**76.15**
□(.),p(best)	3	99.92	8.92	0.009	0.012	93.29
□(emergent vegetation),p(best)	4	100.59	9.59	0.006	0.008	91.51
□(distance to nearest wetland),p(best)	4	102.23	11.23	0.003	0.004	93.15
□(slope),p(best)	4	102.24	11.24	0.003	0.004	93.16
□(terrestrial vegetation),p(best)	6	103.40	12.40	0.002	0.002	89.00
□(wetland size),p(best)	5	103.90	12.90	0.001	0.002	92.23
□(bend),p(best)	5	104.23	13.23	0.001	0.001	92.56

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.22. *Occupancy models for the Plains leopard frog in May, 2010.* Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, plains leopard frog (6, 19, n=42; detection: moonshine)						
□(slope),p(best)	**4**	**97.76**	**0.00**	**0.570**	**1.000**	**88.68**
□(wetland size),p(best)	**5**	**99.47**	**1.71**	**0.243**	**0.425**	**87.80**
□(terrestrial vegetation),p(best)	**6**	**102.14**	**4.38**	**0.064**	**0.112**	**87.74**
□(bend),p(best)	5	102.47	4.71	0.054	0.095	90.80
□(.),p(best)	3	102.68	4.92	0.049	0.085	96.05
□(emergent vegetation),p(best)	4	104.43	6.67	0.020	0.036	95.35
Tadpole occupancy, plains leopard frog (21, 20, n=42; detection: slope)						
□(.),p(best)	**3**	**103.08**	**0.00**	**0.323**	**1.000**	**96.45**
□(terrestrial vegetation),p(best)	**6**	**104.17**	**1.09**	**0.187**	**0.580**	**89.77**
□(distance to nearest wetland),p(best)	**4**	**104.50**	**1.42**	**0.159**	**0.492**	**95.42**
□(emergent vegetation),p(best)	**4**	**105.21**	**2.13**	**0.111**	**0.345**	**96.13**
□(slope),p(best)	**4**	**105.30**	**2.22**	**0.107**	**0.330**	**96.22**
□(bend),p(best)	**5**	**106.76**	**3.68**	**0.051**	**0.159**	**95.09**
□(wetland size),p(best)	**5**	**107.66**	**4.58**	**0.033**	**0.101**	**95.99**
□(land cover),p(best)	6	108.44	5.36	0.022	0.069	94.04
□(connectivity),p(best)	7	110.84	7.76	0.007	0.021	93.55
□(global),p(best)	16	137.67	34.59	0.000	0.000	83.91

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.23. *Occupancy models for the Plains leopard frog in June, 2010.* Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, plains leopard frog (10, 12, n=36; detection: moonshine)						
□(.),p(best)	**3**	**90.98**	**0.00**	**0.390**	**1.000**	**84.23**
□(terrestrial vegetation),p(best)	**6**	**92.57**	**1.59**	**0.176**	**0.452**	**77.67**
□(emergent vegetation),p(best)	**4**	**93.09**	**2.11**	**0.136**	**0.348**	**83.80**
□(distance to nearest wetland),p(best)	**4**	**93.25**	**2.27**	**0.125**	**0.321**	**83.96**
□(slope),p(best)	**4**	**93.43**	**2.45**	**0.115**	**0.294**	**84.14**
□(bend),p(best)	5	95.82	4.84	0.035	0.089	83.82
□(land cover),p(best)	6	96.56	5.58	0.024	0.061	81.66
Tadpole occupancy, plains leopard frog (15, 9, n=36; detection: null)						
□(land cover),p(best)	**5**	**81.19**	**0.00**	**0.957**	**1.000**	**69.19**
□(distance to nearest wetland),p(best)	3	88.89	7.70	0.020	0.021	82.14
□(emergent vegetation),p(best)	3	90.84	9.65	0.008	0.008	84.09
□(.),p(best)	2	91.05	9.86	0.007	0.007	86.69
□(slope),p(best)	3	92.32	11.13	0.004	0.004	85.57
□(bend),p(best)	4	93.67	12.48	0.002	0.002	84.38
□(terrestrial vegetation),p(best)	5	93.87	12.68	0.002	0.002	81.87
□(wetland size),p(best)	4	95.53	14.34	0.001	0.001	86.24

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.24. *Occupancy models for the Plains leopard frog in April, 2011*. Twelve models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, plains leopard frog (30, 19, n=42; detection: environmental conditions 1)						
□(distance to nearest wetland),p(best)	**6**	**106.38**	**0.00**	**0.398**	**1.000**	**91.98**
□(slope),p(best)	**6**	**108.28**	**1.90**	**0.154**	**0.387**	**93.88**
□(.),p(best)	**5**	**108.49**	**2.11**	**0.139**	**0.348**	**96.82**
□(emergent vegetation),p(best)	**6**	**108.84**	**2.46**	**0.116**	**0.292**	**94.44**
□(aquatic vegetation),p(best)	**7**	**109.55**	**3.17**	**0.082**	**0.205**	**92.26**
□(bend),p(best)	**7**	**110.81**	**4.43**	**0.043**	**0.109**	**93.52**
□(wetland size),p(best)	7	111.55	5.17	0.030	0.075	94.26
□(connectivity),p(best)	9	112.42	6.04	0.019	0.049	88.80
□(land cover),p(best)	8	113.25	6.87	0.013	0.032	92.89
□(terrestrial vegetation),p(best)	8	115.18	8.80	0.005	0.012	94.82
□(vegetation),p(best)	10	117.51	11.13	0.002	0.004	90.41

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.25. *Occupancy models for the Plains leopard frog in May, 2011.* Twelve models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, plains leopard frog (13,25, n=40; detection: environmental conditions 1 and day)						
(.),p(best)	**6**	**106.07**	**0.00**	**0.281**	**1.000**	**91.52**
(bend),p(best)	**8**	**106.29**	**0.22**	**0.251**	**0.896**	**85.64**
(slope),p(best)	**7**	**106.74**	**0.67**	**0.201**	**0.715**	**89.24**
(distance to nearest wetland),p(best)	**7**	**108.97**	**2.90**	**0.066**	**0.235**	**91.47**
(emergent vegetation),p(best)	**7**	**109.00**	**2.93**	**0.065**	**0.231**	**91.50**
(terrestrial vegetation),p(best)	**9**	**109.75**	**3.68**	**0.045**	**0.159**	**85.75**
(aquatic vegetation),p(best)	**8**	**109.80**	**3.73**	**0.044**	**0.155**	**89.15**
(wetland size),p(best)	8	111.01	4.94	0.024	0.085	90.36
(land cover),p(best)	9	111.29	5.22	0.021	0.074	87.29
(connectivity),p(best)	10	114.56	8.49	0.004	0.014	86.97
Tadpole occupancy, plains leopard frog (23,20, n=40; detection: water temperature)						
(slope),p(best)	**4**	**86.61**	**0.00**	**0.202**	**1.000**	**77.47**
(.),p(best)	**3**	**86.68**	**0.07**	**0.195**	**0.966**	**80.01**
(distance to nearest wetland),p(best)	**4**	**86.78**	**0.17**	**0.186**	**0.919**	**77.64**
(wetland size),p(best)	**5**	**86.96**	**0.35**	**0.170**	**0.840**	**75.20**
(bend),p(best)	**5**	**87.86**	**1.25**	**0.108**	**0.535**	**76.10**
(emergent vegetation),p(best)	**4**	**89.15**	**2.54**	**0.057**	**0.281**	**80.01**
(land cover),p(best)	**6**	**90.54**	**3.93**	**0.028**	**0.140**	**75.99**
(aquatic vegetation),p(best)	**5**	**90.94**	**4.33**	**0.023**	**0.115**	**79.18**
(terrestrial vegetation),p(best)	6	91.50	4.89	0.018	0.087	76.95
(connectivity),p(best)	7	92.17	5.56	0.013	0.062	74.67
(vegetation),p(best)	8	96.26	9.65	0.002	0.008	75.61

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.26. *Occupancy models for the Plains leopard frog in June, 2011.* Twelve models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, plains leopard frog (12,12, n=34; detection: null)						
□(.),p(best)	**2**	**88.42**	**0.00**	**0.362**	**1.000**	**84.03**
□(distance to nearest wetland),p(best)	**3**	**90.11**	**1.69**	**0.155**	**0.430**	**83.31**
□(emergent vegetation),p(best)	**3**	**90.71**	**2.29**	**0.115**	**0.318**	**83.91**
□(slope),p(best)	**3**	**90.83**	**2.41**	**0.108**	**0.300**	**84.03**
□(aquatic vegetation),p(best)	**4**	**91.16**	**2.74**	**0.092**	**0.254**	**81.78**
□(bend),p(best)	**4**	**92.76**	**4.34**	**0.041**	**0.114**	**83.38**
□(land cover),p(best)	**5**	**92.95**	**4.53**	**0.038**	**0.104**	**80.81**
□(terrestrial vegetation),p(best)	**5**	**93.00**	**4.58**	**0.037**	**0.101**	**80.86**
□(wetland size),p(best)	4	93.22	4.80	0.033	0.091	83.84
□(connectivity),p(best)	6	94.33	5.91	0.019	0.052	79.22
Tadpole occupancy, plains leopard frog (25,27, n=34; detection: null)						
□(slope),p(best)	**3**	**53.94**	**0.00**	**0.993**	**1.000**	**47.14**
□(.),p(best)	2	66.19	12.25	0.002	0.002	61.80
□(wetland size),p(best)	4	66.69	12.75	0.002	0.002	57.31
□(emergent vegetation),p(best)	3	67.96	14.02	0.001	0.001	61.16
□(distance to nearest wetland),p(best)	3	68.46	14.52	0.001	0.001	61.66
□(aquatic vegetation),p(best)	4	68.68	14.74	0.001	0.001	59.30
□(bend),p(best)	4	70.47	16.53	0.000	0.000	61.09
□(land cover),p(best)	5	70.65	16.71	0.000	0.000	58.51
□(terrestrial vegetation),p(best)	5	70.76	16.82	0.000	0.000	58.62
□(connectivity),p(best)	6	73.54	19.60	0.000	0.000	58.43
□(vegetation),p(best)	7	75.34	21.40	0.000	0.000	57.03

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.27. *Occupancy models for the American bullfrog in May, 2010.* Ten models were proposed to explain occupancy of larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Tadpole occupancy, American bullfrog (4, 3, n=42; detection: null)						
□(emergent vegetation),p(best)	**3**	**50.66**	**0.00**	**0.319**	**1.000**	**44.03**
□(.),p(best)	**2**	**51.10**	**0.44**	**0.256**	**0.803**	**46.79**
□(distance to nearest wetland),p(best)	**3**	**52.22**	**1.56**	**0.146**	**0.458**	**45.59**
□(terrestrial vegetation),p(best)	**5**	**53.32**	**2.66**	**0.084**	**0.265**	**41.65**
□(slope),p(best)	**3**	**53.41**	**2.75**	**0.081**	**0.253**	**46.78**
□(bend),p(best)	**4**	**53.62**	**2.96**	**0.073**	**0.228**	**44.54**
□(wetland size),p(best)	**4**	**55.06**	**4.40**	**0.035**	**0.111**	**45.98**
□(land cover),p(best)	5	58.33	7.67	0.007	0.022	46.66

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.28. *Occupancy models for the American bullfrog in June, 2010.* Ten models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, American bullfrog (6, 11, n=36; detection: moonshine)						
□(.),p(best)	**3**	**79.45**	**0.00**	**0.382**	**1.000**	**72.70**
□(distance to nearest wetland),p(best)	**4**	**80.61**	**1.16**	**0.214**	**0.560**	**71.32**
□(bend),p(best)	**5**	**80.69**	**1.24**	**0.205**	**0.538**	**68.69**
□(emergent vegetation),p(best)	**4**	**81.99**	**2.54**	**0.107**	**0.281**	**72.70**
□(terrestrial vegetation),p(best)	**6**	**82.29**	**2.84**	**0.092**	**0.242**	**67.39**

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.29. *Occupancy models for the American bullfrog in May, 2011.* Twelve models were proposed to explain occupancy of larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Tadpole occupancy, American bullfrog (4,5, n=40; detection: slope)						
□(slope),p(best)	**4**	**51.78**	**0.00**	**0.462**	**1.000**	**42.64**
□(.),p(best)	**3**	**53.55**	**1.77**	**0.191**	**0.413**	**46.88**
□(bend),p(best)	**5**	**54.60**	**2.82**	**0.113**	**0.244**	**42.84**
□(distance to nearest wetland),p(best)	**4**	**55.11**	**3.33**	**0.087**	**0.189**	**45.97**
□(emergent vegetation),p(best)	**4**	**56.02**	**4.24**	**0.056**	**0.120**	**46.88**
□(aquatic vegetation),p(best)	5	57.84	6.06	0.022	0.048	46.08
□(terrestrial vegetation),p(best)	6	58.08	6.30	0.020	0.043	43.53
□(wetland size),p(best)	5	58.34	6.56	0.017	0.038	46.58
□(vegetation),p(best)	8	58.58	6.80	0.015	0.033	37.93
□(land cover),p(best)	6	59.28	7.50	0.011	0.024	44.73
□(connectivity),p(best)	7	60.50	8.72	0.006	0.013	43.00

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.30. *Occupancy models for the American bullfrog in June, 2011.* Twelve models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, American bullfrog (11,7, n=34; detection: null)						
□(.),p(best)	**2**	**80.87**	**0.00**	**0.463**	**1.000**	**76.48**
□(emergent vegetation),p(best)	**3**	**82.20**	**1.33**	**0.238**	**0.514**	**75.40**
□(wetland size),p(best)	**4**	**82.99**	**2.12**	**0.160**	**0.347**	**73.61**
□(slope),p(best)	**3**	**83.28**	**2.41**	**0.139**	**0.300**	**76.48**
Tadpole occupancy, American bullfrog (4,7, n=34; detection: slope)						
□(bend),p(best)	**5**	**49.78**	**0.00**	**0.475**	**1.000**	**37.64**
□(land cover),p(best)	**6**	**52.06**	**2.28**	**0.152**	**0.320**	**36.95**
□(.),p(best)	**3**	**52.08**	**2.30**	**0.151**	**0.317**	**45.28**
□(wetland size),p(best)	**5**	**53.59**	**3.81**	**0.071**	**0.149**	**41.45**
□(emergent vegetation),p(best)	4	54.64	4.86	0.042	0.088	45.26
□(distance to nearest wetland),p(best)	4	54.66	4.88	0.041	0.087	45.28
□(slope),p(best)	4	54.66	4.88	0.041	0.087	45.28
□(aquatic vegetation),p(best)	5	56.56	6.78	0.016	0.034	44.42
□(terrestrial vegetation),p(best)	6	57.35	7.57	0.011	0.023	42.24

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.31. *Occupancy models for the Woodhouse's toad in April, 2010.* Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Woodhouse's toad (13, 4, n=42: detection: day)						
□(slope),p(best)	**4**	**70.21**	**0.00**	**0.795**	**1.000**	**61.13**
□(terrestrial vegetation),p(best)	**6**	**74.43**	**4.22**	**0.096**	**0.121**	**60.03**
□(bend),p(best)	5	76.64	6.43	0.032	0.040	64.97
□(.),p(best)	3	77.16	6.95	0.025	0.031	70.53
□(land cover.),p(best)	6	77.29	7.08	0.023	0.029	62.89
□(distance to nearest wetland),p(best)	4	78.68	8.47	0.012	0.015	69.60
□(emergent vegetation),p(best)	4	79.52	9.31	0.008	0.010	70.44
□(connectivity),p(best)	7	79.70	9.49	0.007	0.009	62.41
□(wetland size),p(best)	5	81.74	11.53	0.003	0.003	70.07
Tadpole occupancy, Woodhouse's toad (5,9, n=42; detection: slope)						
□(distance to nearest wetland),p(best)	**4**	**59.12**	**0.00**	**0.448**	**1.000**	**50.04**
□(emergent vegetation),p(best)	**4**	**60.03**	**0.91**	**0.284**	**0.634**	**50.95**
□(.),p(best)	**3**	**61.32**	**2.20**	**0.149**	**0.333**	**54.69**
□(slope),p(best)	**4**	**63.04**	**3.92**	**0.063**	**0.141**	**53.96**
□(terrestrial vegetation),p(best)	6	63.88	4.76	0.042	0.093	49.48
□(bend),p(best)	5	66.08	6.96	0.014	0.031	54.41

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.32. *Occupancy models for the Woodhouse's toad in May, 2010.* Ten models were proposed to explain occupancy of adult and larval anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Woodhouse's toad (6, 7, n=42; detection: null)						
□(slope),p(best)	**3**	**56.22**	**0.00**	**0.989**	**1.000**	**49.59**
□(.),p(best)	2	67.25	11.03	0.004	0.004	62.94
□(terrestrial vegetation),p(best)	5	68.33	12.11	0.002	0.002	56.66
□(emergent vegetation),p(best)	3	69.50	13.28	0.001	0.001	62.87
□(distance to nearest wetland),p(best)	3	69.52	13.30	0.001	0.001	62.89
□(bend),p(best)	4	70.20	13.98	0.001	0.001	61.12
□(land cover),p(best)	5	70.54	14.32	0.001	0.001	58.87
□(connectivity),p(best)	6	73.15	16.93	0.000	0.000	58.75
Tadpole occupancy, Woodhouse's toad (6, 4, n=42; detection: day)						
□(.),p(best)	**3**	**50.10**	**0.00**	**0.357**	**1.000**	**43.47**
□(slope),p(best)	**4**	**50.34**	**0.24**	**0.317**	**0.887**	**41.26**
□(distance to nearest wetland),p(best)	**4**	**52.30**	**2.20**	**0.119**	**0.333**	**43.22**
□(emergent vegetation),p(best)	**4**	**52.31**	**2.21**	**0.118**	**0.331**	**43.23**
□(wetland size),p(best)	**5**	**53.21**	**3.11**	**0.075**	**0.211**	**41.54**
□(connectivity),p(best)	7	56.60	6.50	0.014	0.039	39.31

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.33. Occupancy models for the Woodhouse's toad in June, 2010. Ten models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Woodhouse's toad (1, 5, n=36; detection: moonshine)						
□(terrestrial vegetation),p(best)	**6**	**44.70**	**0.00**	**0.570**	**1.000**	**29.80**
□(.),p(best)	**3**	**46.56**	**1.86**	**0.225**	**0.395**	**39.81**
□(distance to nearest wetland),p(best)	**4**	**48.15**	**3.45**	**0.102**	**0.178**	**38.86**
□(slope),p(best)	**4**	**48.57**	**3.87**	**0.082**	**0.144**	**39.28**
□(wetland size),p(best)	5	51.30	6.60	0.021	0.037	39.30

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.34. *Occupancy models for the Woodhouse's toad in May, 2011.* Twelve models were proposed to explain occupancy of adult anurans. Models that failed to converge or would not run successfully are not shown. Models carrying ≥10% the weight of the top model were selected as the confidence set (shown in bold).

Model	K	AICc	Δ	w	l	-2l
Adult occupancy, Woodhouse's toad (8,4, n=40; detection: air temperature)						
□(emergent vegetation),p(best)	**4**	**57.67**	**0.00**	**0.682**	**1.000**	**48.53**
□(.),p(best)	**3**	**60.55**	**2.88**	**0.162**	**0.237**	**53.88**
□(distance to nearest wetland),p(best)	**4**	**61.85**	**4.18**	**0.084**	**0.124**	**52.71**
□(wetland size),p(best)	5	63.16	5.49	0.044	0.064	51.40
□(bend),p(best)	5	64.06	6.39	0.028	0.041	52.30

* The number of detections in survey 1and survey 2, the number of sites sampled, and the detection model used to model occupancy are shown parenthetically.

Table 3.35. *Parameter estimates for selected occupancy models for Western chorus frogs in 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

						Land Cover		
Model	K	w	Slope	Emergent Vegetation	Distance to Nearest Wetland	% Forest	% Field	% Agriculture
April, 2010								
Adult occupancy, western chorus frog (23, 7, n=42; detection: environmental conditions 1 and day)								
ψ(slope),p(best)	5	0.806	-7.22±3.18					
Tadpole occupancy, western chorus frog (16,18, n=42; detection: global)								
ψ(land cover),p(best)	7	0.549				7.97±4.21	-47.42±23.4	10.42±4.69
ψ(connectivity),p(best)	8	0.119			-0.17±2.36	7.89±4.37	-47.01±24.1	10.33±4.86
ψ(emergent vegetation),p(best)	5	0.114		1.85±1.07				
ψ(distance to nearest wetland),p(best)	5	0.096			-3.27±2.11			
ψ(.),p(best)	4	0.081						
May, 2010								
Adult occupancy, western chorus frog (5, 5, n=42; detection: null)								
ψ(slope),p(best)	3	0.651	-6180.19±902946.6					
ψ(.),p(best)	2	0.131						
ψ(distance to nearest wetland),p(best)	3	0.075			-7.49±9.81			
Tadpole occupancy, western chorus frog (18, 14, n=42; detection: day)								
ψ(slope),p(best)	4	0.393	-6.94±3.2					
ψ(distance to nearest wetland),p(best)	4	0.302			-3.29±1.59			
ψ(emergent vegetation),p(best)	4	0.167		2.33±1.17				
ψ(.),p(best)	3	0.041						

Table 3.36. *Parameter estimates for selected occupancy models for Western chorus frogs in 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	Slope	Emergent Vegetation	Distance to Nearest Wetland	Aquatic Vegetation: % Herby	Aquatic Vegetation: % Woody	Bend: Hamburg	Bend: Kansas
April, 2011									
Adult occupancy, western chorus frog (30, 27, n=42; detection: moonshine)									
ψ(aquatic vegetation),p(best)	5	0.829				-2.69±4.47	-7.94±4.62		
ψ(emergent vegetation),p(best)	4	0.095		2.44±1.23					
Tadpole occupancy, western chorus frog (3, 6, n=42; detection: global)									
ψ(slope),p(best)	9	0.962	85.96±56.35						
May, 2011									
Adult occupancy, western chorus frog (7, 11, n=40; detection: air									
ψ(distance to nearest wetland),p(best)	4	0.491			2.74±1.53				
ψ(.),p(best)	3	0.198							
ψ(slope),p(best)	4	0.117	11.36±7.92						
ψ(emergent vegetation),p(best)	4	0.078		-0.61±0.8					
Tadpole occupancy, western chorus frog (13, 16, n=40; detection: water temperature and slope)									
ψ(slope),p(best)	5	0.517	46.57±34.93						
ψ(bend),p(best)	6	0.135						-2.84±1.36	0.01±1.28
ψ(.),p(best)	4	0.129							
ψ(distance to nearest wetland),p(best)	5	0.110			13.27±12.13				
June, 2011									
Tadpole occupancy, western chorus frog (5,7, n=34; detection: water temperature and slope)									
ψ(.),p(best)	4	0.428							
ψ(emergent vegetation),p(best)	5	0.196		-33.56±17.88					
ψ(distance to nearest wetland),p(best)	5	0.173			-1.53±1.52				
ψ(slope),p(best)	5	0.123		-3.95±7.41					
ψ(bend),p(best)	6	0.080						26.15±383546.88	1.5±1.78

Table 3.37. *Parameter estimates for selected occupancy models for Northern cricket frogs in 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

						Bend		Terrestrial Vegetation		
Model	K	w	Slope	Emergent Vegetation	Distance to Nearest	Hamburg	Kansas	Grasses	Herbs/ forbs	Shrubs/ trees
April, 2010										
Adult occupancy, Northern cricket frog (6, 14, n=42: detection: environmental conditions 1 and day)										
ψ(emergent vegetation),p(best)	5	0.807		2.77±1.15						
ψ(slope),p(best)	5	0.126	-6.86±3.72							
May, 2010										
Adult occupancy, northern cricket frog (14, 19, n=42; detection: day)										
ψ(slope),p(best)	4	0.554	-5.34±2.57							
ψ(.),p(best)	3	0.118								
ψ(terrestrial vegetation),p(best)	6	0.114						-2.5±2.16	5.49±3.63	-2.09±2.49
ψ(distance to nearest wetland),p(best)	4	0.058			-0.98±1.0					
June, 2010										
Adult occupancy, northern cricket frog (19, 16, n=36; detection: environmental conditions 1 and day)										
ψ(.),p(best)	4	0.447								
ψ(distance to nearest wetland),p(best)	5	0.168			-1.48±1.99					
ψ(emergent vegetation),p(best)	5	0.135		0.76±1.32						
ψ(slope),p(best)	5	0.117	-0.98±6.01							
ψ(bend),p(best)	6	0.051				-1.66±1.42	-0.36±1.43			

Table 3.38. *Parameter estimates for selected occupancy models for Northern cricket frogs in 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	Slope	Emergent Vegetation	Distance to Nearest Wetland	Bend Hamburg	Bend Kansas
May, 2011							
Adult occupancy, northern cricket frog (17,16, n=40; detection: water temperature)							
(distance to nearest wetland),p(best)	4	0.280			- 356.41±96427.07		
(emergent vegetation),p(best)	4	0.276		2.15±1.1			
(terrestrial vegetation),p(best)	6	0.235					
(slope),p(best)	4	0.109	-4.04±2.24				
(.),p(best)	3	0.067					
June, 2011							
Adult occupancy, northern cricket frog (21,16, n=34; detection: null)							
(.),p(best)	2	0.435					
(emergent vegetation),p(best)	3	0.267		27.63±562090.36			
(slope),p(best)	3	0.143	- 10.43±14.29				
(wetland size),p(best)	4	0.051					
(bend),p(best)	4	0.047				0.7±3.34	23.99±124326.21

Table 3.38, continued. *Parameter estimates for selected occupancy models for Northern cricket frogs in 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

			Wetland Size		Terrestrial Vegetation		
Model	K	w	Small	Medium	Grasses	Herbs/ forbs	Shrubs/ trees
May, 2011							
Adult occupancy, northern cricket frog (17,16, n=40; detection: water temperature)							
(distance to nearest wetland),p(best)	4	0.280					
(emergent vegetation),p(best)	4	0.276					
(terrestrial vegetation),p(best)	6	0.235			-20.61±11.48	-15.02±11.62	-23.05±11.79
(slope),p(best)	4	0.109					
(.),p(best)	3	0.067					
June, 2011							
Adult occupancy, northern cricket frog (21,16, n=34; detection: null)							
(.),p(best)	2	0.435					
(emergent vegetation),p(best)	3	0.267					
(slope),p(best)	3	0.143					
(wetland size),p(best)	4	0.051	31.8±1966211.25	23.32±184323.75			
(bend),p(best)	4	0.047					

Table 3.39. *Parameter estimates for selected occupancy models for Cope's gray treefrogs in 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	Slope	Emergent Vegetation	Distance to Nearest Wetland	Bend Hamburg	 Kansas
April, 2010							
Adult occupancy, Cope's gray treefrog (18,18, n=42; detection: water							
(slope),p(best)	4	0.998	-15.05±5.62				
May, 2010							
Adult occupancy, Cope's gray treefrog (16, 24, n=42; detection: envirc							
(slope),p(best)	5	0.827	-6.5±2.56				
(emergent vegetation),p(best)	5	0.089		1.71±0.89			
Tadpole occupancy, Cope's gray treefrog(6, 6, n=42; detection: day)							
(wetland size),p(best)	5	0.474					
(emergent vegetation),p(best)	4	0.225		371.52±0.58			
(.),p(best)	3	0.094					
(bend),p(best)	5	0.084				26.49±502774.72	2.16±1.19
(distance to nearest wetland),p(best)	4	0.060			-2.0±1.77		
(slope),p(best)	4	0.053	-3.56±3.39				
June, 2010							
Adult occupancy, Cope's gray treefrog (15, 20, n=36; detection: moon							
(land cover),p(best)	6	0.728					
(connectivity),p(best)	7	0.161			0.48±1.7		
Tadpole occupancy, Cope's gray treefrog (17, 12, n=36; detection: nu							
(bend),p(best)	4	0.318				-0.21±1.11	25.56±416009.97
(distance to nearest wetland),p(best)	3	0.228			-2.29±1.46		
(emergent vegetation),p(best)	3	0.204		1.92±1.32			
(.),p(best)	2	0.141					
(slope),p(best)	3	0.053	-4.46±6.64				
(connectivity),p(best)	6	0.037			-2.27±1.66		

Table 3.39, continued. *Parameter estimates for selected occupancy models for Cope's gray treefrogs in 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

			Wetland Size		Land Cover		
Model	K	w	Small	Medium	% Forest	% Field	% Agriculture
April, 2010							
Adult occupancy, Cope's gray treefrog (18,18, n=42; detection: water							
⍰(slope),p(best)	4	0.998					
May, 2010							
Adult occupancy, Cope's gray treefrog (16, 24, n=42; detection: envir							
⍰(slope),p(best)	5	0.827					
⍰(emergent vegetation),p(best)	5	0.089					
Tadpole occupancy, Cope's gray treefrog(6, 6, n=42; detection: day)							
⍰(wetland size),p(best)	5	0.474	310.61±0.71	308.78±1.12			
⍰(emergent vegetation),p(best)	4	0.225					
⍰(.),p(best)	3	0.094					
⍰(bend),p(best)	5	0.084					
⍰(distance to nearest wetland),p(best)	4	0.060					
⍰(slope),p(best)	4	0.053					
June, 2010							
Adult occupancy, Cope's gray treefrog (15, 20, n=36; detection: moon							
⍰(land cover),p(best)	6	0.728			10.09±8.28	-226.78±139.49	2.45±1.94
⍰(connectivity),p(best)	7	0.161			10.25±8.04	-245.11±156.98	2.83±2.45
Tadpole occupancy, Cope's gray treefrog (17, 12, n=36; detection: nu							
⍰(bend),p(best)	4	0.318					
⍰(distance to nearest wetland),p(best)	3	0.228					
⍰(emergent vegetation),p(best)	3	0.204					
⍰(.),p(best)	2	0.141					
⍰(slope),p(best)	3	0.053					
⍰(connectivity),p(best)	6	0.037			9.78±7.23	-45±36.11	3.73±3.61

Table 3.40. *Parameter estimates for selected occupancy models for Cope's gray treefrogs in 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

						Aquatic Vegetation	
Model	K	w	Slope	Emergent Vegetation	Distance to Nearest Wetland	% Herbaceous	% Woody
May, 2011							
Adult occupancy, Cope's gray treefrog (16,15, n=40; detection: enviro							
?(.),p(best)	6	0.630					
?(emergent vegetation),p(best)	7	0.217		27.37±348319.8			
?(distance to nearest wetland),p(best)	7	0.148			4.89±10.16		
June, 2011							
Adult occupancy, Cope's gray treefrog (26,20, n=34; detection: water							
?(.),p(best)	3	0.626					
?(slope),p(best)	4	0.371	-16.29±11.0				
Tadpole occupancy, Cope's gray treefrog (6,7, n=34; detection: water temperature)							
?(terrestrial vegetation),p(best)	6	0.354					
?(aquatic vegetation),p(best)	5	0.190				4.01±2.38	7.56±25.84
?(.),p(best)	3	0.170					
?(slope),p(best)	4	0.108	-4.66±3.68				
?(distance to nearest wetland),p(best)	4	0.099			-1.52±1.43		
?(wetland size),p(best)	5	0.043					

Table 3.40, continued. *Parameter estimates for selected occupancy models for Cope's gray treefrogs in 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

			Wetland Size		Terrestrial Vegetation		
Model	K	w	Small	Medium	Grasses	Herbs/ forbs	Shrubs/ trees
May, 2011							
Adult occupancy, Cope's gray treefrog (16,15, n=40; detection: enviro							
?(.),p(best)	6	0.630					
?(emergent vegetation),p(best)	7	0.217					
?(distance to nearest wetland),p(best)	7	0.148					
June, 2011							
Adult occupancy, Cope's gray treefrog (26,20, n=34; detection: water							
?(.),p(best)	3	0.626					
?(slope),p(best)	4	0.371					
Tadpole occupancy, Cope's gray treefrog (6,7, n=34; detection: water temperature)							
?(terrestrial vegetation),p(best)	6	0.354			1816.18±1.46	1822.92±1.81	1817.6±3.31
?(aquatic vegetation),p(best)	5	0.190					
?(.),p(best)	3	0.170					
?(slope),p(best)	4	0.108					
?(distance to nearest wetland),p(best)	4	0.099					
?(wetland size),p(best)	5	0.043	0.37±1.05	-1.49±1.27			

Table 3.41. *Parameter estimates for selected occupancy models for Plains leopard frogs in 2010*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	Slope	Emergent Vegetation	Distance to Nearest Wetland	Bend: Hamburg	Bend: Kansas	Wetland Size: Small	Wetland Size: Medium
April, 2010									
Adult occupancy, plains leopard frog (18, 20, n=42; detection: null)									
⍰(slope),p(best)	3	0.961	-32.7±17.65						
Tadpole occupancy, plains leopard frog (17,14, n=42; detection: slo									
⍰(land cover),p(best)	6	0.753							
⍰(connectivity),p(best)	7	0.222							
May, 2010									
Adult occupancy, plains leopard frog (6, 19, n=42; detection: moonsl									
⍰(slope),p(best)	4	0.570	-9.29±5.22						
⍰(wetland size),p(best)	5	0.243						5.15±19.65	0.79±1.2
⍰(terrestrial vegetation),p(best)	6	0.064							
Tadpole occupancy, plains leopard frog (21, 20, n=42; detection: slo									
⍰(.),p(best)	3	0.323							
⍰(terrestrial vegetation),p(best)	6	0.187							
⍰(distance to nearest wetland),p(best)	4	0.159		-1.32±1.21					
⍰(emergent vegetation),p(best)	4	0.111		0.66±1.1					
⍰(slope),p(best)	4	0.107	-2.31±4						
⍰(bend),p(best)	5	0.051				-0.74±1	0.36±0.98		
⍰(wetland size),p(best)	5	0.033						0.68±1.09	0.2±1.15
June, 2010									
Adult occupancy, plains leopard frog (10, 12, n=36; detection: moon:									
⍰(.),p(best)	3	0.390							
⍰(terrestrial vegetation),p(best)	6	0.176							
⍰(emergent vegetation),p(best)	4	0.136		1.0±1.67					
⍰(distance to nearest wetland),p(best)	4	0.125			0.86±1.85				
⍰(slope),p(best)	4	0.115	2.36±7.96						
Tadpole occupancy, plains leopard frog (15, 9, n=36; detection: null									
⍰(land cover),p(best)	5	0.957							

Table 3.41, continued. *Parameter estimates for selected occupancy models for Plains leopard frogs in 2010*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	Terrestrial Vegetation: Grasses	Terrestrial Vegetation: Herbs/ forbs	Terrestrial Vegetation: Shrubs/ trees	Land Cover: % Forest	Land Cover: % Field	Land Cover: % Agriculture
April, 2010							
Adult occupancy, plains leopard frog (18, 20, n=42; detection: null)							
▯(slope),p(best)	3						
Tadpole occupancy, plains leopard frog (17,14, n=42; detection: slope)							
▯(land cover),p(best)	6				3.64±7.57	-2881.337±47532920.49	0.89±2.44
▯(connectivity),p(best)	7				5.97±12.27	-2833.55±21789575.07	1.86±3.59
May, 2010							
Adult occupancy, plains leopard frog (6, 19, n=42; detection: moonshin							
▯(slope),p(best)	4						
▯(wetland size),p(best)	5						
▯(terrestrial vegetation),p(best)	6	-0.97±2.77	9.68±6.58	-5.73±3.55			
Tadpole occupancy, plains leopard frog (21, 20, n=42; detection: slope)							
▯(.),p(best)	3						
▯(terrestrial vegetation),p(best)	6	-2.64±2.2	6.35±3.59	0.57±2.78			
▯(distance to nearest wetland),p(best)	4						
▯(emergent vegetation),p(best)	4						
▯(slope),p(best)	4						
▯(bend),p(best)	5						
▯(wetland size),p(best)	5						
June, 2010							
Adult occupancy, plains leopard frog (10, 12, n=36; detection: moonshi							
▯(.),p(best)	3						
▯(terrestrial vegetation),p(best)	6	-7.52±10	7.41±13.69	-9.04±9.94			
▯(emergent vegetation),p(best)	4						
▯(distance to nearest wetland),p(best)	4						
▯(slope),p(best)	4						
Tadpole occupancy, plains leopard frog (15, 9, n=36; detection: null)							
▯(land cover),p(best)	5				19.75±15.33	-1244.49±2307.13	34.62±30.69

Table 3.42. *Parameter estimates for selected occupancy models for Plains leopard frogs in 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

					Distance	Aquatic Vegetation		Bend	
				Emergent	to Nearest				
Model	K	w	Slope	Vegetation	Wetland	% Herby	% Woody	Hamburg	Kansas
April, 2011									
Adult occupancy, plains leopard frog (30, 19, n=42; detection: enviro									
ψ(distance to nearest wetland),p(best)	6	0.398			-2.51±1.33				
ψ(slope),p(best)	6	0.154	-3.99±2.43						
ψ(.),p(best)	5	0.139							
ψ(emergent vegetation),p(best)	6	0.116		1.52±1.18					
ψ(aquatic vegetation),p(best)	7	0.082				1.99±3.42	-1.25±2.86		
ψ(bend),p(best)	7	0.043						-1.95±1.46	-0.48±1.53
May, 2011									
Adult occupancy, plains leopard frog (13,25, n=40; detection: enviro									
ψ(.),p(best)	6	0.281							
ψ(bend),p(best)	8	0.251						-20.17±3.78	-19.41±3.8
ψ(slope),p(best)	7	0.201	-2.97±2.08						
ψ(distance to nearest wetland),p(best)	7	0.066			0.2±0.97				
ψ(emergent vegetation),p(best)	7	0.065		-0.09±0.78					
ψ(terrestrial vegetation),p(best)	9	0.045							
ψ(aquatic vegetation),p(best)	8	0.044				1.41±1.47	-1.2±2.55		
Tadpole occupancy, plains leopard frog (23,20, n=40; detection: wat									
ψ(slope),p(best)	4	0.202	-2.92±1.9						
ψ(.),p(best)	3	0.195							
ψ(distance to nearest wetland),p(best)	4	0.186			2.09±1.45				
ψ(wetland size),p(best)	5	0.170							
ψ(bend),p(best)	5	0.108						25.5±553083.68	-0.98±0.95
ψ(emergent vegetation),p(best)	4	0.057		0.01±0.78					
ψ(land cover),p(best)	6	0.028							
ψ(aquatic vegetation),p(best)	5	0.023				0.84±1.43	-1.37±2.94		
June, 2011									
Adult occupancy, plains leopard frog (12,12, n=34; detection: null)									
ψ(.),p(best)	2	0.362							
ψ(distance to nearest wetland),p(best)	3	0.155			1.66±3.76				
ψ(emergent vegetation),p(best)	3	0.115		-0.3±0.89					
ψ(slope),p(best)	3	0.108	-0.18±3.39						
ψ(aquatic vegetation),p(best)	4	0.092				-1.55±1.59	10.13±10.52		
ψ(bend),p(best)	4	0.041						-0.55±1.31	-0.86±1.13
ψ(land cover),p(best)	5	0.038							
ψ(terrestrial vegetation),p(best)	5	0.037							
Tadpole occupancy, plains leopard frog (25,27, n=34; detection: null)									
ψ(slope),p(best)	3	0.993	-20.25±8.32						

Table 3.42, continued. *Parameter estimates for selected occupancy models for Plains leopard frogs in 2011*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

		Wetland Size		Terrestrial Vegetation			Land Cover		
Model	K	Small	Medium	Grasses	Herbs/ forbs	Shrubs/ trees	% Forest	% Field	% Agriculture
April, 2011									
Adult occupancy, plains leopard frog (30, 19, n=42; detection: enviro									
?(distance to nearest wetland),p(best)	6								
?(slope),p(best)	6								
?(.),p(best)	5								
?(emergent vegetation),p(best)	6								
?(aquatic vegetation),p(best)	7								
?(bend),p(best)	7								
May, 2011									
Adult occupancy, plains leopard frog (13,25, n=40; detection: enviroı									
?(.),p(best)	6								
?(bend),p(best)	8								
?(slope),p(best)	7								
?(distance to nearest wetland),p(best)	7								
?(emergent vegetation),p(best)	7								
?(terrestrial vegetation),p(best)	9			-9.78±8.67	-8.06±8.94	-12.47±8.78			
?(aquatic vegetation),p(best)	8								
Tadpole occupancy, plains leopard frog (23,20, n=40; detection: wat									
?(slope),p(best)	4								
?(.),p(best)	3								
?(distance to nearest wetland),p(best)	4								
?(wetland size),p(best)	5	2.2±1.1	1.49±1.06						
?(bend),p(best)	5								
?(emergent vegetation),p(best)	4								
?(land cover),p(best)	6						-4.36±3.74	2739.55±33019408.14	-0.32±1.71
?(aquatic vegetation),p(best)	5								
June, 2011									
Adult occupancy, plains leopard frog (12,12, n=34; detection: null)									
?(.),p(best)	2								
?(distance to nearest wetland),p(best)	3								
?(emergent vegetation),p(best)	3								
?(slope),p(best)	3								
?(aquatic vegetation),p(best)	4								
?(bend),p(best)	4								
?(land cover),p(best)	5						-2.84±3.25	29.39±29.14	1.42±2.1
?(terrestrial vegetation),p(best)	5			-7.31±4.73	-6.35±4.71	-10.8±6.37			
Tadpole occupancy, plains leopard frog (25,27, n=34; detection: null)									
?(slope),p(best)	3								

Table 3.43. *Parameter estimates for selected occupancy models for American bullfrogs in 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	Slope	Emergent Vegetation	Distance to Nearest Wetland	Bend: Hamburg	Bend: Kansas
May, 2010							
Tadpole occupancy, American bullfrog (4, 3, n=42; detection: null)							
(emergent vegetation),p(best)	3	0.319		24.16±2.97			
(.),p(best)	2	0.256					
(distance to nearest wetland),p(best)	3	0.146			4.3±5.62		
(terrestrial vegetation),p(best)	5	0.084					
(slope),p(best)	3	0.081	0.26±3.59				
(bend),p(best)	4	0.073				-0.41±1.41	-1.94±1.54
(wetland size),p(best)	4	0.035					
June, 2010							
Adult occupancy, American bullfrog (6, 11, n=36; detection: moonshi							
(.),p(best)	3	0.382					
(distance to nearest wetland),p(best)	4	0.214			-499.032±11695.46		
(bend),p(best)	5	0.205				-25.94±3.98	-24.72±3.86
(emergent vegetation),p(best)	4	0.107		19.94±102448.8			
(terrestrial vegetation),p(best)	6	0.092					

Table 3.43, continued. *Parameter estimates for selected occupancy models for American bullfrogs in 2010.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

			Wetland Size		Terrestrial Vegetation		
Model	K	w	Small	Medium	Grasses	Herbs/ forbs	Shrubs/ trees
May, 2010							
Tadpole occupancy, American bullfrog (4, 3, n=42; detection: null)							
ψ(emergent vegetation),p(best)	3	0.319					
ψ(.),p(best)	2	0.256					
ψ(distance to nearest wetland),p(best)	3	0.146					
ψ(terrestrial vegetation),p(best)	5	0.084			3285.95±2311.19	542.2±637952.29	2370.34±8537.77
ψ(slope),p(best)	3	0.081					
ψ(bend),p(best)	4	0.073					
ψ(wetland size),p(best)	4	0.035	-0.7±1.7	1.4±1.67			
June, 2010							
Adult occupancy, American bullfrog (6, 11, n=36; detection: moonshi							
ψ(.),p(best)	3	0.382					
ψ(distance to nearest wetland),p(best)	4	0.214					
ψ(bend),p(best)	5	0.205					
ψ(emergent vegetation),p(best)	4	0.107					
ψ(terrestrial vegetation),p(best)	6	0.092			1876.94±186308.56	16281.48±20.7	-3080.96±910.89

Table 3.44. *Parameter estimates for selected occupancy models for American bullfrogs in 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

Model	K	w	Slope	Emergent Vegetation	Distance to Nearest Wetland	Bend Hamburg	Bend Kansas
May, 2011							
Tadpole occupancy, American bullfrog (4,5, n=40; detection: slope)							
?(slope),p(best)	4	0.462	-9.76±7.26				
?(.),p(best)	3	0.191					
?(bend),p(best)	5	0.113				25.76±15.01	25.82±15.01
?(distance to nearest wetland),p(best)	4	0.087			-1.1±1.24		
?(emergent vegetation),p(best)	4	0.056		-0.05±0.91			
June, 2011							
Adult occupancy, American bullfrog (11,7, n=34; detection: null)							
?(.),p(best)	2	0.463					
?(emergent vegetation),p(best)	3	0.238		26.57±372254.05			
?(wetland size),p(best)	4	0.160					
?(slope),p(best)	3	0.139	7.48±201499.17				
Tadpole occupancy, American bullfrog (4,7, n=34; detection: slope)							
?(bend),p(best)	5	0.475				-20.55±8546.15	17.61±14799.24
?(land cover),p(best)	6	0.152					
?(.),p(best)	3	0.151					
?(wetland size),p(best)	5	0.071					

Table 3.44, continued. *Parameter estimates for selected occupancy models for American bullfrogs in 2011.* Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

			Wetland Size		Land Cover		
Model	K	w	Small	Medium	% Forest	% Field	% Agriculture
May, 2011							
Tadpole occupancy, American bullfrog (4,5, n=40; detection: slope)							
ψ(slope),p(best)	4	0.462					
ψ(.),p(best)	3	0.191					
ψ(bend),p(best)	5	0.113					
ψ(distance to nearest wetland),p(best)	4	0.087					
ψ(emergent vegetation),p(best)	4	0.056					
June, 2011							
Adult occupancy, American bullfrog (11,7, n=34; detection: null)							
ψ(.),p(best)	2	0.463					
ψ(emergent vegetation),p(best)	3	0.238					
ψ(wetland size),p(best)	4	0.160	24.68±140213.78	1.52±1.8			
ψ(slope),p(best)	3	0.139					
Tadpole occupancy, American bullfrog (4,7, n=34; detection: slope)							
ψ(bend),p(best)	5	0.475					
ψ(land cover),p(best)	6	0.152			5.51±7.28	10.93±36.69	15.66±12.79
ψ(.),p(best)	3	0.151					
ψ(wetland size),p(best)	5	0.071	-3.46±2.89	-1.95±2.78			

Table 3.45. *Parameter estimates for selected occupancy models for Woodhouse's toads in 2010 and 2011*. Parameter estimates of covariates included in selected models (models containing ≥10% the weight of the top model).

					Distance to	Wetland Size		Terrestrial Vegetation		
				Emergent	Nearest					
Model	K	w	Slope	Vegetation	Wetland	Small	Medium	Grasses	Herbs/forbs	Shrubs/trees
April, 2010										
Adult occupancy, Woodhouse's toad (13, 4, n=42: detection: day)										
ψ(slope),p(best)	4	0.795	-11.16±4.71							
ψ(terrestrial vegetation),p(best)	6	0.096						-4.21±2.19	-8.69±4.35	-2.65±2.64
Tadpole occupancy, Woodhouse's toad (5,9, n=42; detection: slope)										
ψ(distance to nearest wetland),p(best)	4	0.448			11.36±11.19					
ψ(emergent vegetation),p(best)	4	0.284		6.23±74.16						
ψ(.),p(best)	3	0.149								
ψ(slope),p(best)	4	0.063	-12.38±11.24							
May, 2010										
Adult occupancy, Woodhouse's toad (6, 7, n=42; dete										
ψ(slope),p(best)	3	0.989	-20.27±9.55							
Tadpole occupancy, Woodhouse's toad (6, 4, n=42; d										
ψ(.),p(best)	3	0.357								
ψ(slope),p(best)	4	0.317	-28.46±5.45							
ψ(distance to nearest wetland),p(best)	4	0.119			-0.82±1.69					
ψ(emergent vegetation),p(best)	4	0.118		-0.57±1.18						
ψ(wetland size),p(best)	5	0.075				-0.308±1.29	1.55±1.6			
June, 2010										
Adult occupancy, Woodhouse's toad (1, 5, n=36; dete										
ψ(terrestrial vegetation),p(best)	6	0.570						-12.86±7.68	-11.34±8.48	-10.69±7.17
ψ(.),p(best)	3	0.225								
ψ(distance to nearest wetland),p(best)	4	0.102			5.22±10.71					
ψ(slope),p(best)	4	0.082	6.24±6.83							
May, 2011										
Adult occupancy, Woodhouse's toad (8,4, n=40; dete										
ψ(emergent vegetation),p(best)	4	0.682		-245.58±19.4						
ψ(.),p(best)	3	0.162								
ψ(distance to nearest wetland),p(best)	4	0.084			3.08±2.82					

Table 3.46. *Naïve occupancy for adults and tadpoles.* Naïve occupancy is the proportion of sites occupied assuming perfect detection. Naïve occupancy is reported for adult and larval anurans during three seasons in each of the years sampled, 2010 and 2011.

		Naïve occupancy			
		Adult		Tadpole	
Species	Season	2010	2011	2010	2011
Western chorus frog (*Psuedacris triseriata*)	April	0.571	0.786	0.452	0.167
	May	0.214	0.375	0.476	0.500
	June	-	-	-	0.265
Northern cricket frog (*Acris crepitans*)	April	0.357	-	-	-
	May	0.500	0.675	-	-
	June	0.611	0.824	-	-
Cope's gray treefrog (*Hyla chrysoscelis*)	April	0.548	-	-	-
	May	0.571	0.700	0.191	-
	June	0.611	0.912	0.583	0.206
Plains leopard frog (*Lithobates blairi*)	April	0.619	0.810	0.476	-
	May	0.500	0.700	0.595	0.600
	June	0.500	0.500	0.472	0.735
American bullfrog (*Lithobates catesbeiana*)	April	-	-	-	0.095
	May	-	-	0.143	0.175
	June	0.417	0.441	-	0.235
Woodhouse's toad (*Anaxyrus woodhousii*)	April	0.310	-	0.238	-
	May	0.214	0.275	0.167	-
	June	0.167	-	-	-

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CHAPTER 4: FUNCTIONAL CONNECTIVITY OF RESTORED WETLANDS IN THE MISSOURI RIVER FLOODPLAIN

INTRODUCTION

Fragmentation of formerly extensive landscapes negatively impacts plant and animal populations by limiting dispersal of propagules or juveniles, restricting gene flow between extant groups, and reducing resilience to disturbance such as drought or land use change (Hitchings and Beebee 1997, Cushman 2006, Thrush et al. 2008, Olds et al. 2012). Remediation of the negative effects of fragmentation is often the focus of conservation programs that seek to protect or create corridors for dispersal between patches of habitat (Haas 1994, Beier and Noss 2008). In some cases fragmentation is driven by anthropogenic forces and formerly connected habitat such as remnant prairie now exists in a larger matrix of agriculture or development (Jaeger 2000, Wade et al. 2003). Other habitats however, such as wetlands, naturally exist as discrete patches. Regardless of the cause, fragmented habitat patches are often connected by ecological processes and the movement of species, and have an aggregate function. For wetlands, aggregate function is captured by the concept of wetland complexes. Some amphibian populations display characteristics of metapopulation dynamics within wetland complexes, dispersing from patch to patch and experiencing patch-wide extinctions and recolonizations (Marsh and Trenham 2001, Semlitsch and Bodie 2001, Smith and Green 2005).

Connectivity among patches can be either physical or functional. Physical connectivity is often the focus of conservation biologists and implies actual physical connectedness between sites, which is often achieved by maintaining or creating corridors. Functional connectivity is an organism-specific measure that is based on dispersal capability and can occur between patches that are not physically connected (Crooks and Sanjayan 2006). Connectivity of a landscape is reduced by loss or degradation of the habitat patches, or changes to the landscape that must be crossed to travel between patches. Floodplain wetlands are lost or degraded by flood control measures that isolate wetlands from seasonal overland flow. Upland wetlands and wetlands protected by levees have fertile soil rich with organic material and are often drained and farmed. Wetlands in the Missouri River floodplain declined 39 percent between 1890 and 1980 (Hesse et al. 1988). An additional 250,000ha (633,500ac) were lost between 1986 and 1997 (Dahl 2000). In an attempt to counter these losses and restore riparian and floodplain habitat the Missouri River Fish and Wildlife Mitigation Project was created. Through this project the U.S. Army Corps of Engineers is restoring more than 64,000ha (160,000ac) of wetland and shallow water habitat along the Lower Missouri River (U.S. Army Corps of Engineers 2006).

Habitat loss and fragmentation, climate change, and disease have been linked to both global and local declines of amphibians (Lanoo et al. 1994, Semlitsch 2003, Collins and Holliday 2005). Along the Missouri River damning and channelization of the river and the creation of flood control structures have prevented or diminished spring flooding that was historically crucial to the creation and maintenance of floodplain wetlands (Hesse et al. 1988). As the number and variety of wetlands decreased so too did the connectivity of the bend. Current restoration efforts have focused on creating or improving wetland habitat. However, if the spatial distribution of wetlands is not conducive to movement between patches the amphibian community may not be resilient to disturbance. The Missouri River floodplain underwent a historic flood in 2011 and a historic drought in 2012. It remains to be seen how amphibian populations were affected by these stressors but it is likely that the impacts of catastrophic events could be buffered, and resilience of the system increased, by improving connectedness of the complexes (Olds et al. 2012). Increasing or maintaining connectivity may be crucial to the continued success of these restorations.

I assessed the functional connectivity for amphibians of three restored Missouri River bend to determine connectedness of wetlands within complexes, connectedness between wetland complexes, and to identify isolated wetlands and wetlands crucial to maintaining overall connectivity. I evaluated overall connectedness using three dispersal distances to represent average dispersal capabilities of amphibians found in the region. I calculated the number of connections each wetland created (wetlands within the dispersal distance) and an average for each complex. I then simulated the random "loss" of 15% of the wetlands at each complex to determine the impacts of wetland loss on connectivity. Finally, I created connectivity maps of the wetlands under three dispersal scenarios and identified wetlands that are isolated and those that play a crucial role in connectivity. Assessing connectedness for wetlands crucial to maintaining connectivity and identifying connectivity "gaps" will help managers improve the effectiveness of wetland restorations along the Missouri River.

METHODS

Study Area

The Missouri River extends from headwaters in Montana to the confluence near St. Louis, Missouri where it empties into the Mississippi River. The Missouri River watershed drains nearly one-sixth of the mainland United States. (Figure 4.1; CERC 2009). The Lower Missouri River stretching from Sioux City, Iowa, to the Mississippi, is the most channelized and managed section of the Missouri River and is the focus of current restoration projects by the U.S. Army Corps of Engineers (Figure 4.2; Galat et al. 1998). My study utilized three Missouri River bends between river mile 557 and 528 located within southeast Nebraska. Hamburg Bend (Federal levee R573) is located southeast of Nebraska City in Otoe County, Nebraska at river mile 557. This bend is largely grasslands, wetlands, and riparian forest and is the location of the Nebraska City Station, a coal-burning power plant. Hamburg has undergone restoration including the dredging of historic side-channels and the purchase and subsequent retirement of farmland. Kansas Bend (federal levee R562) is located east of Peru in Nemaha County, Nebraska between river mile 548.9 and 541.5. Kansas is the largest of the bends and exists as a mix of row crops, wetlands, grasslands, and riparian forest (mostly cottonwood). Kansas has also undergone restoration including the dredging of two historic side channels. Langdon Bend (federal levee R548) is located east of Nemaha in Nemaha County, Nebraska between river mile 534.4 and 528.3. Langdon is the location of Cooper Nuclear Station and is primarily grasslands, wetlands, and riparian forest with minimal agriculture.

Site Selection

I selected fifty wetlands from three wetland complexes along the Missouri River in southeast Nebraska (Tables 4.1 and 4.2). Each complex is located in a river bend that has been the focus of restoration efforts. I identified potential wetlands in ArcMap as any intersection of hydric soils in the Soil Survey Geographic (SSURGO) Database layer and wetland polygons identified by National Wetland Inventory. Once I obtained coordinates for all potential wetlands I located the sites on foot and determined if they were currently functioning wetlands. I included all wetlands that held water and could be safely reached at night. Although a near census of wetlands is desirable for functional connectivity analysis oftentimes the smallest wetlands do not appear in the National Wetland Inventory dataset. Small wetlands may be crucial to the overall connectivity of a complex and I included smaller wetlands found during reconnaissance of the complexes. Each wetland was represented in ArcMap as a GPS point at which amphibian call surveys were performed for a portion of a larger Missouri River wetland study. I estimated the size of each wetland and assigned it to a category of small (0-2ac; <0.83 hectares), medium (2.1-5ac; 0.84-2.02 hectares), or large (>5.1ac; >2.02 hectares). The median value for each size range was selected and applied to the corresponding wetlands in ArcMap. Thus small wetlands were represented as a circle with an area of 1ac or $4047m^2$, medium wetlands with an area of 3.5ac or $14164m^2$, and large wetlands with an area of 7ac or $28328m^2$ (this value was chosen as a median estimate based on visual surveys of the largest wetlands).

Analysis

I assessed functional connectivity at scales appropriate for anurans. I chose three values that represent the average dispersal capabilities of short-range dispersers, medium-range dispersers, and long-range dispersers. Values chosen were based on the average dispersal reported in studies across a variety of terrain and do not represent maximum dispersal capabilities under ideal conditions (Smith and Green 2005). Small-bodied, semi-philopatric anurans such as Western chorus frogs (*Psuedacris triseriata*) and Northern cricket frogs (*Acris crepitans*) tend to disperse relatively short distances with an average of 200m (Burkett 1984, Kramer 1973). Medium bodied farther ranging toads (*Anaxyrus sp*.) and gray tree frogs (*Hyla chrysoscelis*) disperse an average of 500m (Johnson and Semlitsch 2003, Dole 1972) with the caveat that toads are highly terrestrial and can disperse much longer distances when necessary. The largest ranging amphibians are generally members of the *Lithobates* genus and will disperse an average distance of 1000m (Willis et al. 1956, Dole 1971). Using the selected wetlands I assessed simple functional connectivity at the three distances. I determined the connectivity of each wetland in ArcMap (using a visual count of wetlands within a spatial buffer) and calculated an average connectivity for each bend for short, medium, and long-range dispersers. To understand the impact of wetland loss on functional connectivity within a bend I randomly selected 15% of the wetlands for "removal". I then reassessed functional connectivity after the loss of these wetlands. I repeated this procedure 100 times as part of a Monte Carlo simulation and calculated average connectivity after wetland loss. Because a complex with high average connectivity could have an uneven distribution of connectivity I used maps to identify "hotspots" that may be more important to maintain connectivity as well as "gaps" where restoration activities may be best focused. To assess this I created spatial connectivity maps reflecting the three dispersal ranges and identified the hotspots and gaps in each wetland complex.

RESULTS

The river bends varied in the number of wetlands that were present and accessible. Langdon Bend contained 13 study wetlands, Hamburg 15, and Kansas 21. Kansas bend had the greatest average connectivity (1.24, 2.19, 4.48; for 200m, 500m, and 1000m respectively) at all three distances assessed (Table 4.3). Hamburg bend was moderately connected (0.38, 1.38, 2.75) and Langdon bend was the least connected (0.46, 1.38, 2.46) (Table 4.3).

At all dispersal distances Hamburg bend exists as three or more groups of wetlands that were not connected to each other (Figure 4.6). Kansas bend consists of two clusters of wetlands that are highly connected to one another but only minimally connected to the rest of the bend, and only at the highest dispersal range, with the remaining wetlands having little connectedness (Figure 4.7). Langdon bend has fewer average connections than Kansas or Hamburg, but there is one wetland that serves to connect many wetlands (Figure 4.8). None of the three bends were connected to one another at even the largest dispersal value.

There was a decrease in connectivity after random deletion of 15% of the wetlands at Hamburg (0.38, 1.38, 2.75 before; 0.32, 1.18, 2.32 after) (Table 4.4; Figure 4.3) and Langdon (0.46, 1.38, 2.46 before; 0.37, 1.13, 2.02 after) (Table 4.4; Figure 4.5). The connectivity of Kansas decreased for 200m and 500m dispersers (1.24, 2.19 before; 1.17, 2.08 after), but connectivity increased for long-range dispersers (4.48 before; 4.71 after) (Table 4.4; Figure 4.4).

DISCUSSION

Average connectivity was highest in the river bend with the most wetlands. Average connectivity predictably decreased after simulated wetland loss in all bends and at all dispersal ranges except for long-range dispersers in Kansas bend. This is most likely explained by the random deletion of poorly connected wetlands which would improve the overall score but would not actually increase the connectivity of the bend. This suggests that Kansas bend may have several wetlands that are functionally isolated or near isolated. Wetlands with seemingly few connections may still be crucial to conservation as they can maintain connectivity between different reaches of the river. The connectivity maps can be used by managers and engineers to identify crucial connectors or potential gaps that could be targeted for restoration to improve the connectivity of the bend. There are distinct locations within each of the three bends where a newly placed wetland would facilitate within-bend connectivity (indicated by star Figs. 4.6, 4.7, and 4.8).

Average connectivity can be used as an index of how connected a wetland is but the relative importance of a wetland has as much to do with the spatial arrangement of wetlands as it does with the total number of connections. To contribute to the connectivity of a complex a wetland must not only be a node of many connections, but it must also be centrally located to improve connectivity of the landscape. A highly connected wetland on the edge of a complex might be lost with little to no impact to overall connectivity. At none of the scales I tested were the complexes connected to one another. Although my analysis did not indicate connection between any of the bends I failed to capture many of the numerous irrigation canals and ditches that create a patchwork of semi-permanent water. These ditches may function as important patches and as a conduit for dispersal. Upland and off-bend wetlands may also improve connectivity between bends and are not accounted for in the analysis.

Of the eight species of amphibians I detected in the Missouri River bends during this study, at least one, the Northern cricket frog (*Acris crepitans*) has experienced noted declines throughout its range and along with the subspecies Blanchard's cricket frog (*Acris crepitans blanchardi*) is listed as endangered or as a species of concern in several states including Michigan, Minnesota, Wisconsin, and New York (Lanoo 2005). The Northern cricket frog is a short lived, small bodied, short-range disperser and populations may experience complete turnover every 16 months (Burkett 1984). A benefit of highly connected wetland complexes is the ability of organisms to disperse in a matrix of wetlands that represent a spectrum of suitability for species like the Northern cricket frog, allowing them to be more resilient to drought or localized habitat loss. Moderate flooding in the Missouri River floodplain in the summer of 2010 may have disrupted the breeding season of the Northern cricket frog. Major flooding, characterized by deep waters and swift overland flow, beginning in early May 2011 is likely to have severely limited successful breeding. The two flood years were then followed by a significant drought in 2011 in which many of the wetlands dried and the remaining wetlands were dominated by juvenile and first year American bullfrogs, a known predator of cricket frog eggs, tadpoles, and metamorphs (VanderHam, personal communication). If the population has experienced the expected decline due to these disturbances, it is even more crucial that a well-connected heterogeneous landscape exists when remaining pockets of cricket frogs began to disperse and re-establish in the complex.

To increase the function of the system, as well as the ability of the amphibian community to persist in such a stochastic environment, managers should focus conservation efforts on centrally located wetlands with the greatest number of connections, or other wetlands crucial to maintaining overall connectivity. Loss of these wetlands would greatly diminish connectivity of the bend, and as seen in Langdon bend may functionally divide the complex into separate clusters of wetlands. Furthermore, locations for new restorations should be chosen such that they increase overall connectedness of the complex. Using spatial connectivity maps could be the first step in the site selection process. As more managers and biologist are charged with maintaining connectivity of the landscape, better analyses are needed to identify spots of crucial conservation value as well as areas where restoration could greatly improve connectivity. Restoring or creating wetlands in connectivity gaps could improve the resilience of the wetland complex and lessen the need for engineering solutions in wetland management.

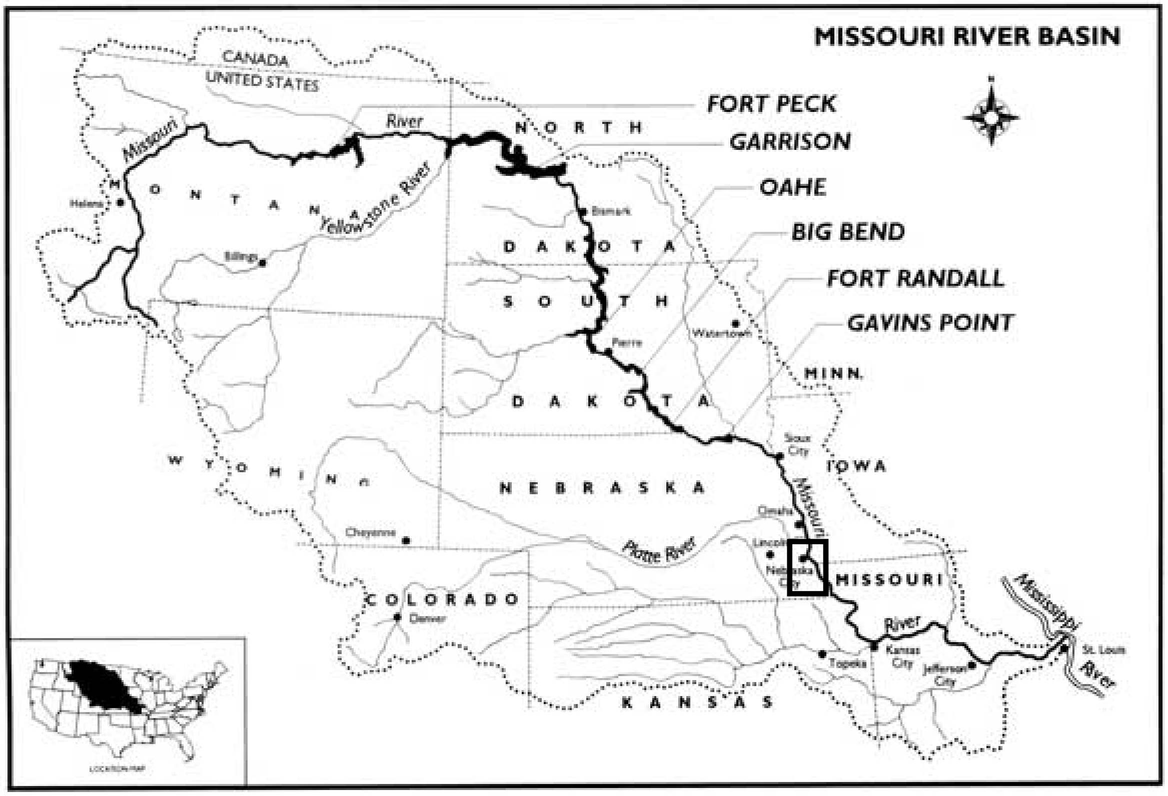

Figure 4.1. *The Missouri River watershed.* The watershed includes all or part of ten states and drains nearly one sixth of the continental U.S. My study area is indicated by the rectangle. Image used with the permission of the Missouri Department of Natural Resources, Water Resources Center.

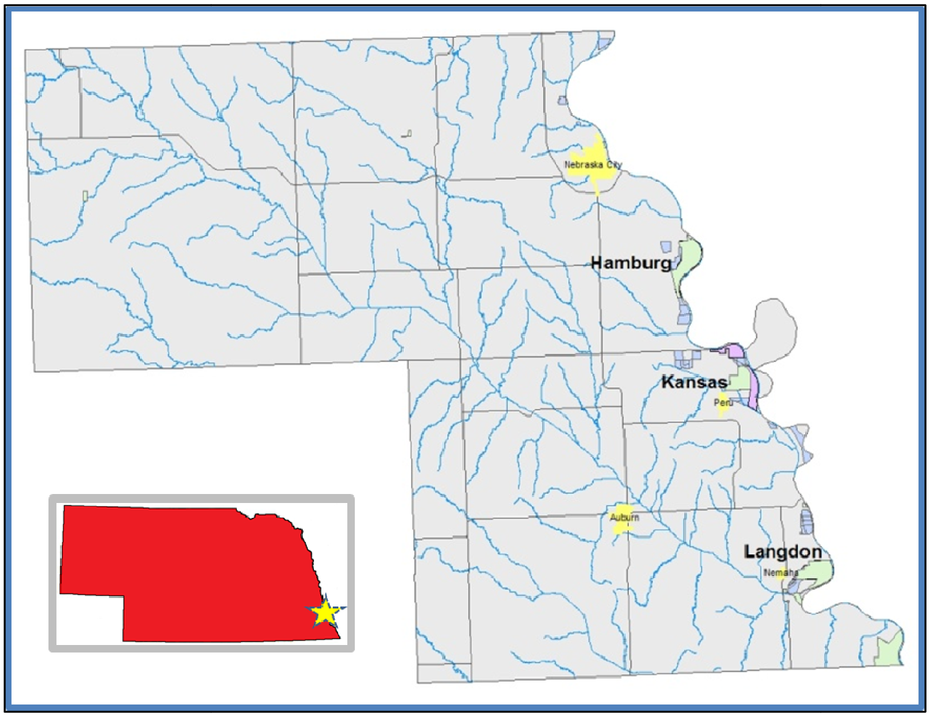

Figure 4.2. *Research bends.* Connectivity of three restored Missouri River bends was assessed. Fifty wetland sites representing a variety of wetland types were selected across the three bends. Research sites were located in Hamburg bend (River mile 557) in Otoe County, and Kansas (River mile 548) and Langdon (River mile 534) bends in Nemaha County in southeast Nebraska along the lower Missouri River.

Table 4.1. *Research sites in Hamburg and Langdon.* Three restored river bends along the Missouri River (river mile 557-528) in southeast Nebraska were selected to assess amphibian occupancy as a metric for wetland success. Wetlands were selected in ArcMap as intersections of hydric soils and National Wetland Inventory polygons. Initial selections were visited to assess current status and additional wetlands encountered while in the bends were included in the study. Sites selected represented a variety of engineering categories used the U.S. Army Corps of Engineers. Each wetland was assigned a site number, the wetland type was determined, and a GPS location was taken.

Name	Wetland Type	Latitude	Longitude
Hamburg Research Sites			
H9	Tributary	40.59478	-95.77416
H11	Scour Hole	40.60105	-95.77130
H12	Tributary	40.60559	-95.79135
H14	Tributary	40.58963	-95.78448
H15F	Ephemeral, unfarmed	40.58395	-95.78078
H15S	Tributary	40.58444	-95.78220
H34	Ephemeral, farmed	40.53872	-95.78388
H59	Ground Fed Permanent	40.57660	-95.78010
H64	Ditch	40.54506	-95.77943
H65N	Ditch	40.54155	-95.78173
H65S	Ditch	40.54160	-95.78172
Langdon Research Sites			
L37	Ground Fed Permanent	40.32483	-95.65586
L39	Ephemeral, farmed	40.33432	-95.63966
L43	Ground Fed Permanent	40.33962	-95.65435
L44	Ditch	40.34520	-95.65708
L46	Ditch	40.33448	-95.66757
L51N	Ephemeral, unfarmed	40.32288	-95.65952
L51S	Ephemeral, farmed	40.32279	-95.65964
L53	Backwater	40.32922	-95.64075
L54E	Ephemeral, unfarmed	40.34186	-95.64357
L54W	Ground Fed Permanent	40.34156	-95.64455
L55E	Ditch	40.34013	-95.65951
L55W	Ditch	40.33957	-95.66021
L70	Backwater	40.34894	-95.63411

Table 4.2. *Research sites in Kansas bend.* Three restored river bends along the Missouri River (river mile 557-528) in southeast Nebraska were selected to assess amphibian occupancy as a metric for wetland success. Wetlands were selected in ArcMap as intersections of hydric soils and National Wetland Inventory polygons. Initial selections were visited to assess current status and additional wetlands encountered while in the bends were included in the study. Sites selected represented a variety of engineering categories used the U.S. Army Corps of Engineers. Each wetland was assigned a site number, the wetland type was determined, and a GPS location was taken.

Name	Wetland Type	Latitude	Longitude
Kansas Research Sites			
K2	Ephemeral, unfarmed	40.48175	-95.72298
K6	Ephemeral, unfarmed	40.48025	-95.71866
K7	Ground Fed Permanent	40.47885	-95.71381
K10	Ground Fed Permanent	40.48343	-95.71973
K23	Tributary	40.47711	-95.71013
K24	Tributary	40.47371	-95.70198
K25	Impoundment	40.48340	-95.70690
K27	Impoundment	40.47732	-95.70813
K30	Ephemeral, unfarmed	40.50184	-95.70430
K32	Ground Fed Permanent	40.51362	-95.71594
K56I	Ditch	40.49219	-95.70470
K56O	Ephemeral, unfarmed	40.49229	-95.70358
K57N	Ditch	40.50857	-95.70990
K57S	Ephemeral, unfarmed	40.50821	-95.71032
K66	Impoundment	40.49382	-95.71946
K67F	Impoundment	40.49458	-95.72079
K67S	Tributary	40.49426	-95.72108
K68	Tributary	40.48308	-95.71446
K69	Impoundment	40.49425	-95.72041
K71	Tributary	40.49408	-95.72070

Table 4.3. *Average connectivity by bend.* The average connectivity is calculated as the sum total of connections divided by the number of wetlands. The average connectivity is reported for three dispersal categories.

	200m	500m	100m
Hamburg	0.38	1.38	2.75
Kansas	1.24	2.19	4.48
Langdon	0.46	1.38	2.46

Table 4.4. *Average connectivity by bend after a Monte Carlo simulation of random loss of 15% of the wetlands at each bend.* The average connectivity is calculated as the sum total of connections divided by the number of wetlands. The average connectivity is reported for three dispersal categories.

	# of sites	200m	500m	1000m
Hamburg (-2)	14	0.32 (0.29, 0.43)	1.18 (0.71, 1.57)	2.32 (1.86, 3.00)
Kansas (-3)	18	1.17 (0.67, 1.44)	2.08 (1.67, 2.56)	4.71 (4.39, 5.22)
Langdon (-2)	11	0.37 (0.18, 0.55)	1.13 (0.82, 1.64)	2.02 (1.55, 2.55)

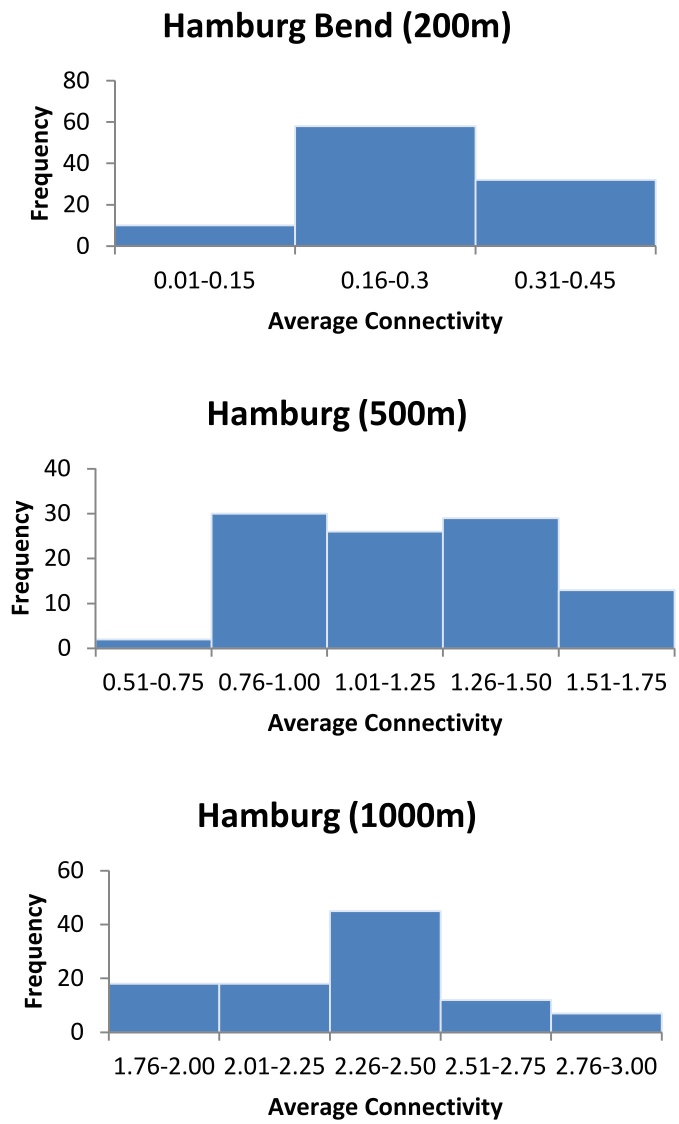

Figure 4.3. *Average connectivity of Hamburg bend after wetland loss.* Frequency of binned average connectivity values (average number of connections per individual wetland per bend) at 200m (initial connectivity 0.46), 500m (initial connectivity 1.38), and 1000m (initial connectivity 2.46) after Monte Carlo simulation of removal of 15% of the wetlands at each bend.

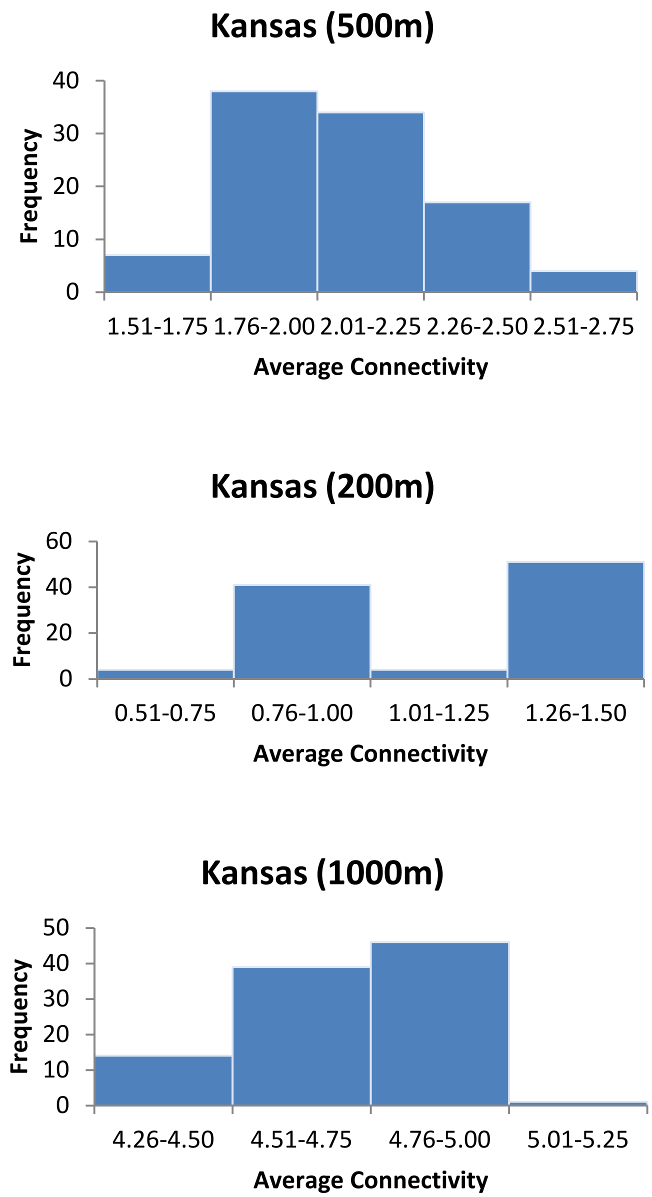

Figure 4.4. *Average connectivity of Kansas bend after wetland loss.* Frequency of binned average connectivity values (average number of connections per individual wetland per bend) at 200m (initial connectivity 0.46), 500m (initial connectivity 1.38), and 1000m (initial connectivity 2.46) after Monte Carlo simulation of removal of 15% of the wetlands at each bend.

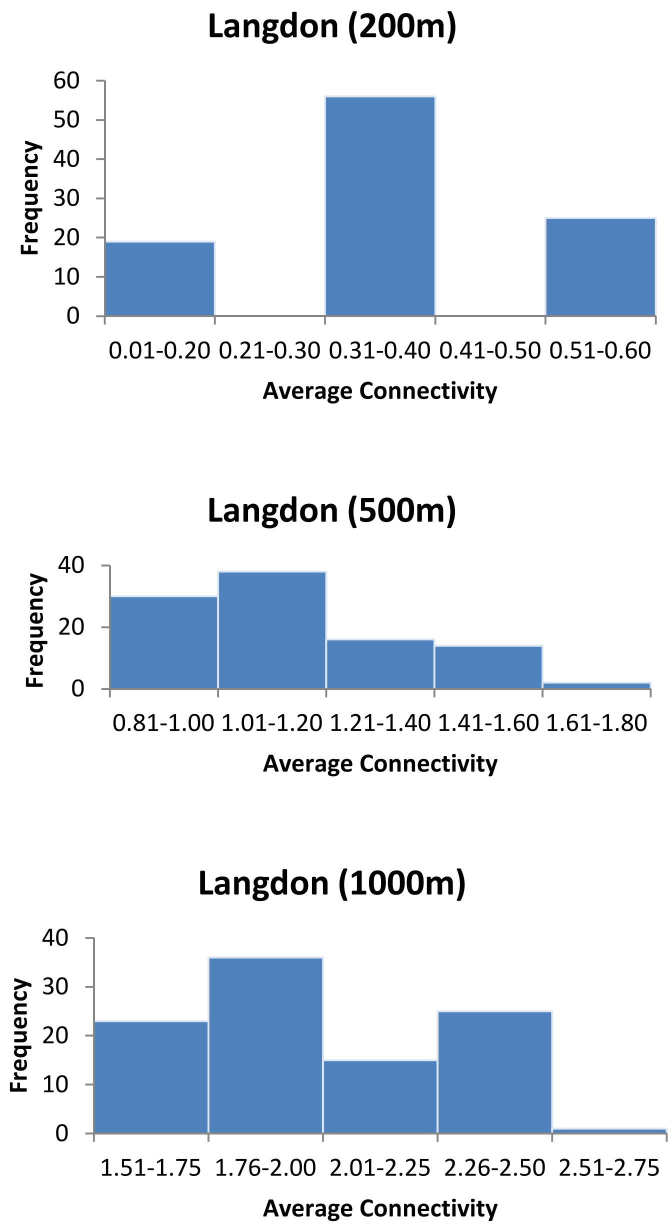

Figure 4.5. *Average connectivity of Langdon bend after wetland loss.* Frequency of binned average connectivity values (average number of connections per individual wetland per bend) at 200m (initial connectivity 0.46), 500m (initial connectivity 1.38), and 1000m (initial connectivity 2.46) after Monte Carlo simulation of removal of 15% of the wetlands at each bend.

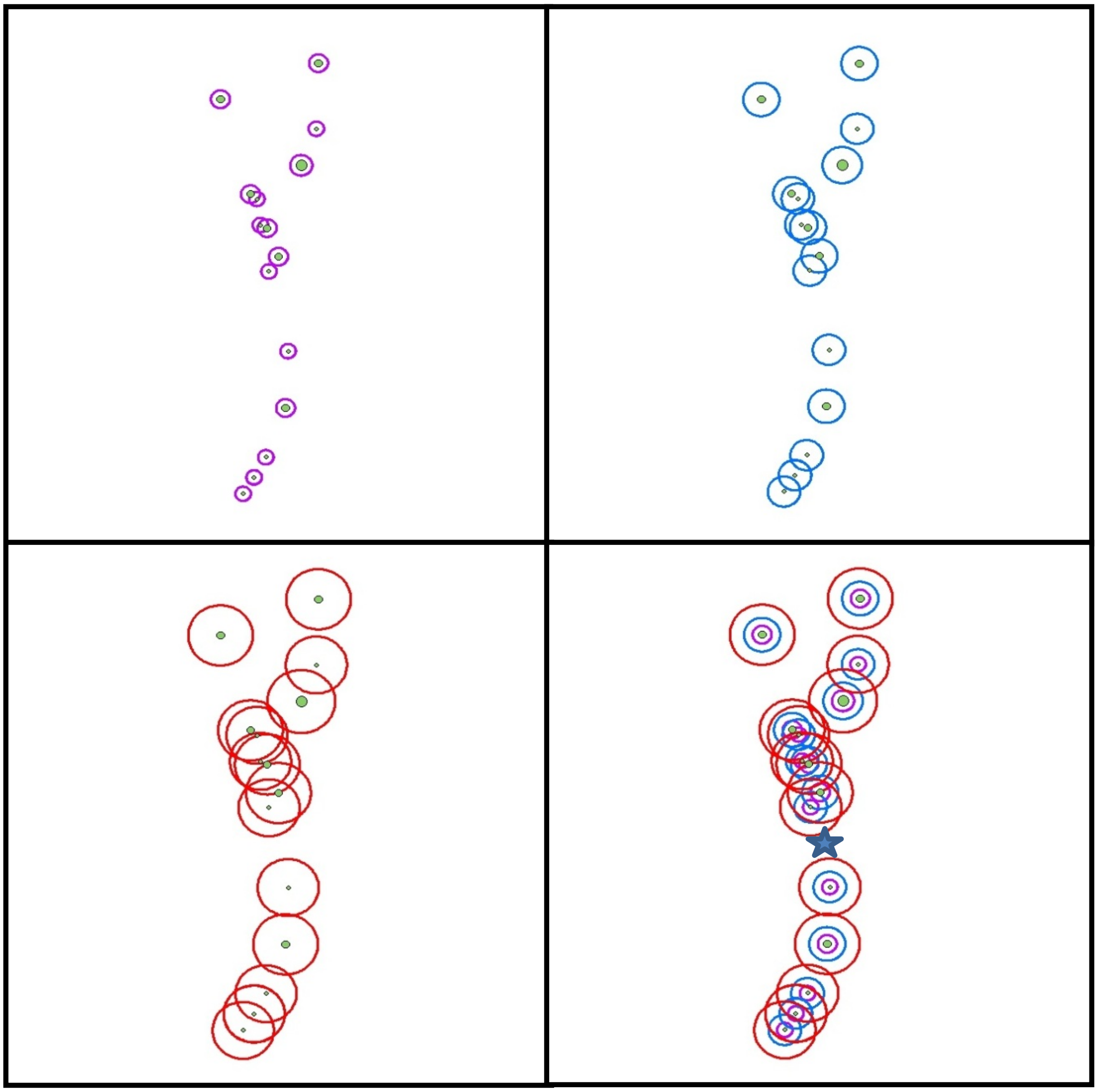

Figure 4.6. *Functional connectivity of research wetlands in Hamburg Bend.* The wetlands are represented by the green circles. Each ring represents 0.5 x the dispersal distance being assessed. Thus, if two rings overlap the wetlands are functionally connected. Functional connectivity at 200m (purple, upper left), 500m (blue, upper right), 1000m (red, lower left), and all three distances (lower right). The star indicates an ideal location for a new wetland restoration that would increase connectivity between reaches of the bend.

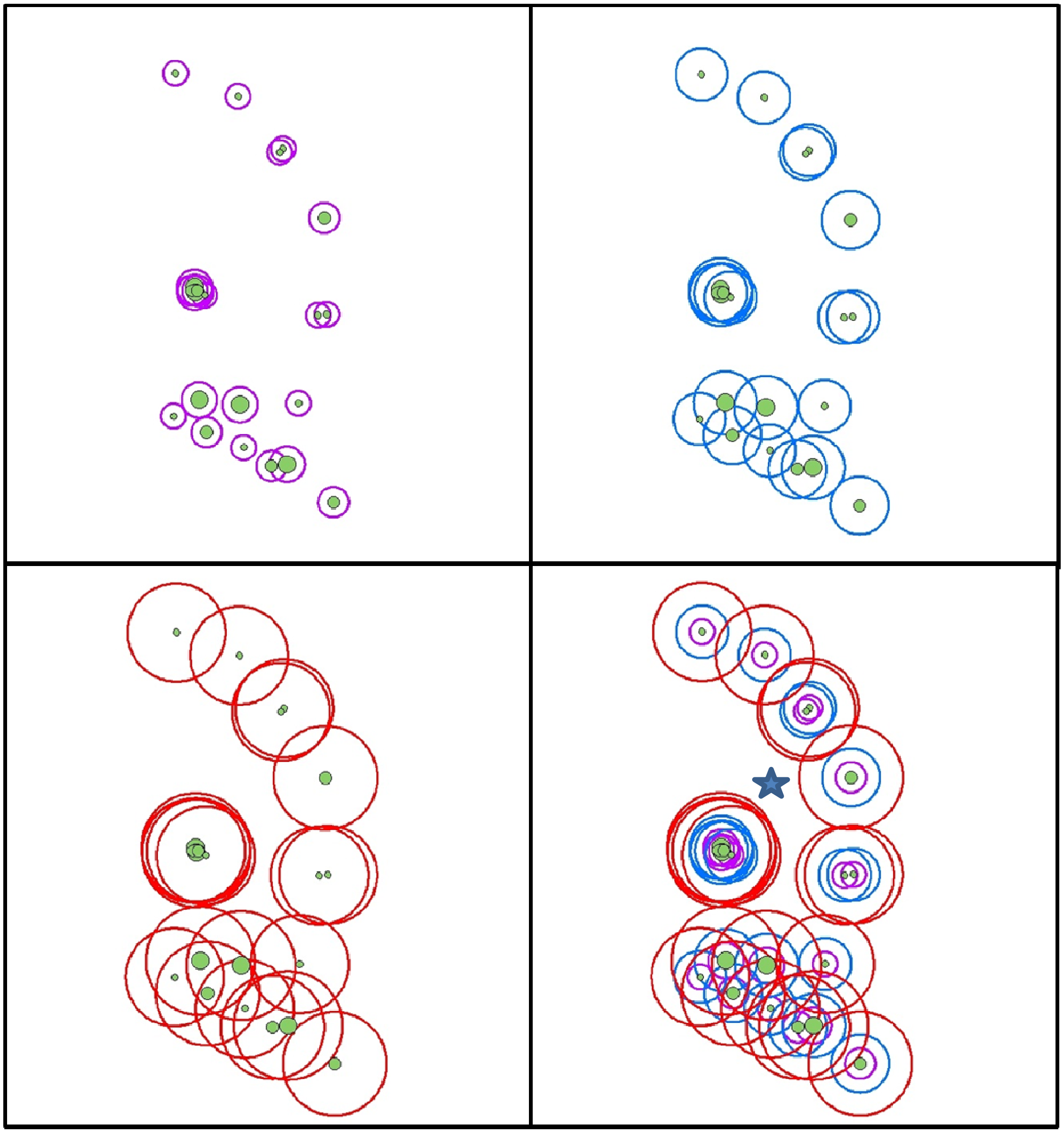

Figure 4.7. *Functional connectivity of research wetlands in Kansas Bend.* The wetlands are represented by the green circles. Each ring represents 0.5 x the dispersal distance being assessed. Thus, if two rings overlap the wetlands are functionally connected. Functional connectivity at 200m (purple, upper left), 500m (blue, upper right), 1000m (red, lower left), and all three distances (lower right). The star indicates an ideal location for a new wetland restoration that would increase connectivity between reaches of the bend.

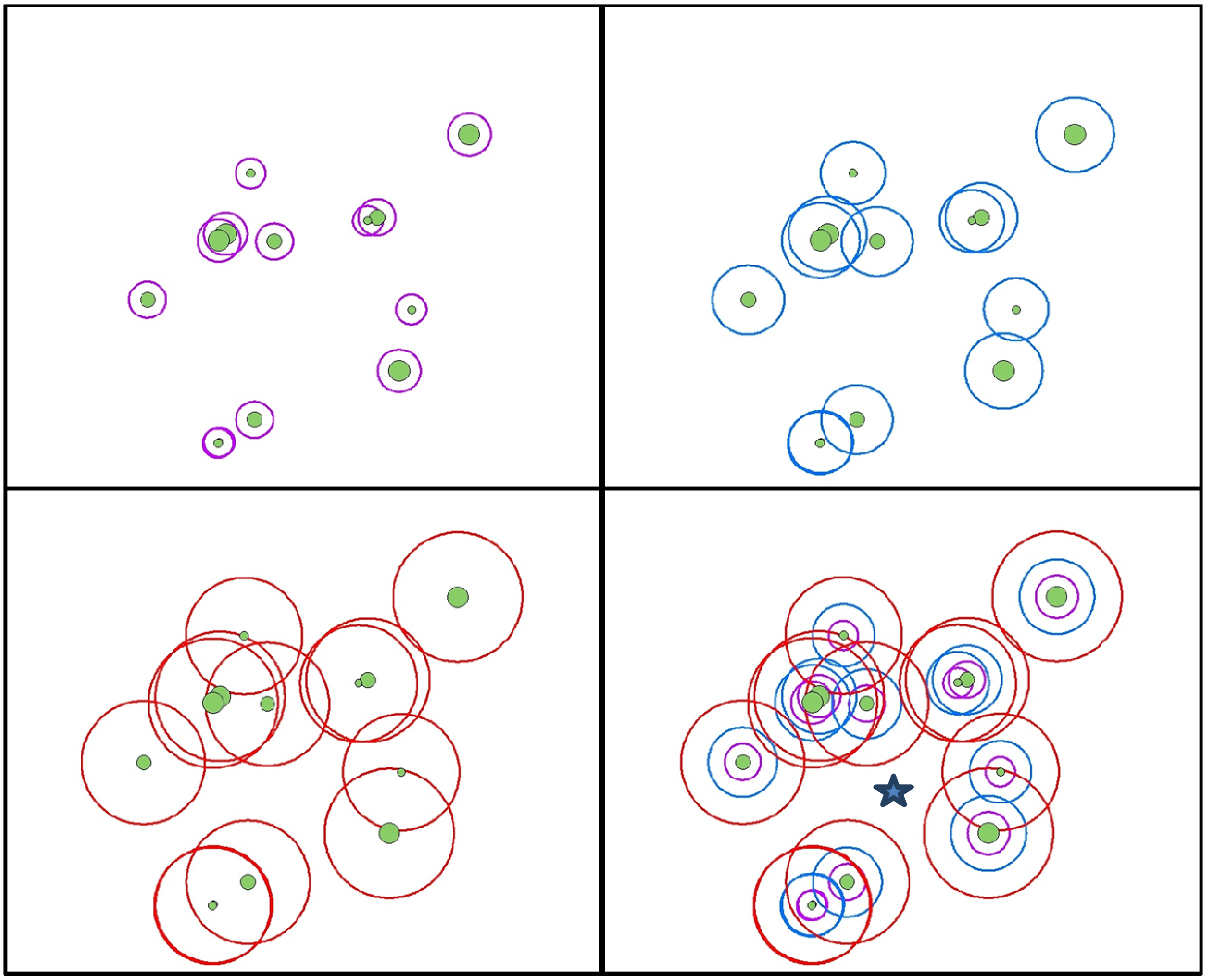

Figure 4.8. *Functional connectivity of research wetlands in Langdon Bend*. The wetlands are represented by the green circles. Each ring represents 0.5 x the dispersal distance being assessed. Thus, if two rings overlap the wetlands are functionally connected. Functional connectivity at 200m (purple, upper left), 500m (blue, upper right), 1000m (red, lower left), and all three distances (lower right). The star indicates an ideal location for a new wetland restoration that would increase connectivity of the bend.

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CHAPTER 5: CONCLUSION

Wetlands provide ecosystem services like water filtration, erosion control, and nutrient retention that can improve water quality in rivers and groundwater. They often increase regional biodiversity and can provide important habitat to many species. A decline in floodplain wetlands could pose conservation concerns for many taxa. Amphibians, which depend on wetlands for most or all of their life, are declining worldwide. Local populations of Smallmouth Salamanders and Northern Cricket Frogs may also be in decline. Sensitivity to water quality and bi-phasic life cycles requiring both aquatic and terrestrial habitat may make amphibians more vulnerable to habitat loss and degradation. These same qualities make amphibians excellent indicators of wetland quality. Programs like the Missouri River Recovery Program are implemented by the U.S. Army Corps of Engineers to create restorations with a goal of providing wildlife habitat. Ambitious in both goals and extent, monitoring is crucial to the success of such programs. Monitoring amphibians allows managers and agencies to assess whether restorations are meeting the habitat needs of this important and unfortunately, declining, taxa. Additionally, information about amphibian occupancy and habitat covariates may also provide an index of how well the wetland is functioning for a wider variety of species.

In chapter 2, I examined two methods currently used to assess anuran occupancy in wetlands, aural anuran surveys and tadpole dip-netting. I assessed survey and site-specific factors that may influence detection success of anuran species using these two methods and found that water temperature appears to play a role in aural detection of several species during call surveys. Water temperature can affect the calling behavior of amphibians by inhibiting calling when it is too cold, or driving early callers out of the wetland when it is too warm. Slope appeared to impact detection of tadpoles. This could indicate a sampling bias (steep wetlands are more difficult to sweep) or a micro-habitat choice (if present in the wetland tadpoles may seek shallower waters). The *global* and *null* models were selected frequently and little inference could be drawn about many of the other covariates assessed.

In chapter 3 I incorporated the top detection models for each species and assessed occupancy of amphibians in restored wetlands in the Missouri River. Although the null was selected often, occasionally as the top model, it was clear from my results that the slope of a wetland is driving occupancy of many species at the research sites. In most cases slope had a negative impact on occupancy. This indicates that future site selection and current site maintenance should focus on shallow, gently sloping wetlands if wildlife habitat continues to be a management goal of the U.S. Army Corps of Engineers' Missouri River Recovery Program.

In chapter 4 I assessed the connectivity of existing wetlands in three Missouri River bend wetland complexes, examined the impact of wetland loss on connectivity of the complexes, and made suggestions for improving connectivity with future site selection. I found that average connectivity of a bend may not be the best indicator of functional connectivity. Isolated wetlands near the edges of a complex generally do not improve connectedness and may be lost with relative impunity. All of the research bends had clusters of wetlands that were highly connected to one another but relatively unconnected to the rest of the complex. A few well-placed restorations could increase functional connectivity of the complex and improve the resilience of amphibian populations to droughts, floods, and localized disturbances like land-use changes.

Future Research

This project was part of a larger cooperative effort between agency personnel and university staff and students across four states: Iowa, Missouri, Kansas, and Nebraska. After the conclusion of my work in June of 2011, two more years of field work were slated to be conducted. The 2012 field season has been completed successfully but sample sizes were reduced by severe drought. The last year of the study will begin in April 2013 and be completed by August of 2013. At the conclusion of this study the group will have four years of complete data and at least one year of pilot data that will be pooled to answer the question of what factors influence detection and occupancy of amphibians in restored Missouri River bends across a larger scale. Their conclusions will be presented to the U.S. Army Corps of Engineers to aid in ongoing restorations and in the implementation of new restorations. The scope of the data, both spatially and temporally, is intriguing and may provide powerful answers to the questions I began to answer here.

Appendix A: April, 2010

Table A.1. *April 2010 Call Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) as a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Treefrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	0	0	0	0
H11	0	0	0	0	0	0	0	0	0	0
H12	1	0	0	0	0	0	0	0	0	0
H14	1	0	0	0	1	0	0	0	1	0
H15F	1	0	0	0	0	0	0	0	0	0
H15S	0	0	0	0	0	0	0	1	0	0
H34	1	0	0	1	0	0	1	1	0	0
H59	1	0	0	0	1	0	0	1	0	0
H64	1	0	0	0	0	0	1	0	0	0
H65N	.	0	.	1	.	1	.	1	.	0
H65S	1	0	0	0	1	1	1	1	0	0
K02	0	1	0	0	0	1	0	1	0	0
K06	0	0	0	0	0	0	1	1	0	0
K07	1	1	0	0	1	1	1	0	0	0
K10	0	0	1	1	0	1	1	1	0	0
K23	0	0	0	0	0	0	0	0	0	0
K24	0	0	0	0	0	0	0	0	0	0
K25	1	0	1	1	1	1	1	1	1	1
K27	1	0	1	1	1	1	1	1	0	0
K32	0	0	0	0	0	0	1	1	1	1
K56I	1	1	0	1	1	1	1	1	1	0
K56O	1	0	0	1	1	0	0	1	0	0
K57N	0	0	0	0	0	0	0	0	0	0
K57S	1	0	0	1	1	1	1	1	0	0
K66	1	0	1	1	1	1	0	0	1	0
K67F	1	0	1	1	1	1	1	1	1	0
K67S	0	0	0	0	0	0	0	0	0	0
K68	0	0	0	0	0	0	0	0	0	0
K69	1	0	1	0	1	1	1	0	0	0
K71	0	0	0	0	0	0	0	0	0	0

Table A.1. *April 2010 Call Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Treefrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	1	1	0	1	1	1	1	1	1	0
L39	1	0	0	0	1	1	1	0	1	0
L43	1	1	0	1	1	1	0	1	1	1
L44	1	1	0	0	0	1	0	0	0	0
L46	0	0	0	1	0	1	0	0	0	0
L51N	1	0	0	0	1	0	1	1	1	0
L51S	0	0	0	0	1	0	1	0	1	0
L53	0	0	0	1	0	0	0	0	0	0
L54E	1	1	0	0	1	1	0	1	1	1
L54W	0	0	0	0	0	0	1	0	0	0
L55E	0	0	0	0	0	0	0	1	0	0
L55W	1	0	0	0	0	0	0	0	1	0

Table A.2. *April 2010 Tadpole Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) as a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	0	0	0	0	0	0
H11	0	0	0	0	0	0	1	0	0	0	0	0
H12	0	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15F	1	1	0	0	0	0	0	0	0	0	0	1
H15S	0	0	0	0	0	0	0	0	0	1	0	0
H34	1	1	0	0	0	0	1	1	0	0	1	1
H59	1	1	0	0	0	0	0	1	0	0	0	0
H64	0	1	0	0	0	0	0	0	0	0	0	0
H65N	1	1	0	0	0	0	1	0	0	0	0	0
H65S	1	1	0	0	0	0	0	0	0	0	0	0
K02	0	0	0	0	0	0	0	0	0	0	0	0
K06	0	0	0	0	0	0	0	0	0	0	0	0
K07	1	1	0	0	0	0	0	0	0	0	0	1
K10	0	0	0	0	0	0	0	1	0	0	0	0
K23	0	0	0	0	0	0	0	0	0	0	0	0
K24	0	0	0	0	0	0	0	0	0	0	0	0
K25	1	1	0	0	0	0	1	1	0	0	1	1
K27	1	1	0	0	0	0	1	1	0	0	0	0
K32	0	0	0	0	0	0	0	1	0	0	0	1
K56I	1	1	0	0	0	0	1	1	0	0	0	1
K56O	1	1	0	0	0	0	1	1	0	0	0	0
K57N	0	0	0	0	0	0	0	0	0	0	0	0
K57S	0	1	0	0	0	0	0	0	0	0	1	1
K66	1	1	0	0	0	0	1	1	0	0	0	0
K67F	1	1	0	0	0	0	1	0	0	0	0	0
K67S	0	0	0	0	0	0	1	1	0	0	0	0
K68	0	0	0	0	0	0	0	0	0	0	0	0
K69	1	1	0	0	0	0	0	0	0	0	0	0
K71	0	0	0	0	0	0	1	0	0	0	0	0

Table A.2. *April 2010 Tadpole Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	0	1	0	0	0	0	1	1	0	0	0	1
L39	0	0	0	0	0	0	1	1	0	0	1	1
L43	1	0	0	0	0	0	1	0	0	0	1	0
L44	1	1	0	0	0	0	0	0	0	0	0	0
L46	0	0	0	0	0	0	0	0	0	0	0	0
L51N	0	0	0	1	0	0	1	1	0	0	0	0
L51S	0	0	0	0	0	0	0	0	0	0	0	0
L53	0	0	0	0	0	0	0	0	0	0	0	0
L54E	1	1	0	0	0	0	1	1	0	0	0	0
L54W	0	0	0	0	0	0	0	0	0	0	0	0
L55E	0	0	0	0	0	0	0	0	0	1	0	0
L55W	0	0	1	0	0	0	1	0	1	0	0	0

Table A.3. *Call Survey Specific Covariates for April 2010*. Covariates include: Julian date (Year, Day of Year), time, water temperature, and moonshine and were recorded during each survey conducted. Each site was visited twice during the month.

	Julian Date		Time		Water Temperature		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2
H09	10108	10123	21:21	21:04	13.3	17.3	0.15	0.48
H11	10108	10123	21:45	21:20	17.6	20.2	0.15	0.48
H12	10104	10123	20:28	22:01	18.0	18.5	0.00	0.48
H14	10104	10123	20:58	22:28	*16.5	13.3	0.00	0.48
H15F	10104	10123	21:17	23:02	17.3	13.3	0.00	0.48
H15S	10104	10123	21:32	23:02	17.4	13.8	0.00	0.48
H34	10108	10123	23:28	20:49	15.9	21.5	0.14	0.65
H59	10104	10123	21:53	22:46	17.2	14.2	0.00	0.48
H64	10108	10123	22:59	21:46	15.7	18.2	0.12	0.48
H65N	.	10123	.	21:11	.	19.4	.	0.48
H65S	10108	10123	23:04	21:11	16.7	21.1	0.14	0.48
K02	10109	10121	21:26	20:33	14.9	19.1	0.21	0.37
K06	10109	10121	21:59	20:56	14.4	18.5	0.21	0.37
K07	10109	10121	22:22	21:15	16.3	19.3	0.21	0.36
K10	10111	10121	20:34	22:20	17.6	19.4	0.28	0.61
K23	10109	10121	22:29	21:33	17.7	19.6	0.21	0.36
K24	10109	10121	22:47	21:51	18.3	19.4	0.21	0.36
K25	10111	10121	21:20	22:12	17.2	18.5	0.18	0.61
K27	10111	10121	21:27	22:15	19.5	20.6	0.18	0.61
K32	10111	10121	22:50	20:50	14.1	18.9	0.30	0.37
K56I	10111	10121	21:49	21:50	19.2	19.5	0.18	0.36
K56O	10111	10121	21:52	21:52	17.6	17.9	0.18	0.36
K57N	10111	10121	22:33	21:11	16.2	17.0	0.30	0.36
K57S	10111	10121	22:34	21:14	15.6	20.2	0.30	0.36
K66	10109	10120	20:34	22:47	18.3	17.3	0.16	0.96
K67F	10109	10120	20:50	22:59	20.2	14.8	0.16	0.96
K67S	10109	10120	21:02	23:11	*19.5	*16.6	0.21	0.96
K68	10111	10121	20:50	22:36	17.6	*16.6	0.28	0.96
K69	10109	10120	20:58	22:48	20.2	17.7	0.16	0.96
K71	10109	10120	20:48	22:57	*19.5	*16.6	0.16	0.96

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table A.3. *Call Survey Specific Covariates for April 2010, continued.*

	Julian Date		Time		Water Temperature		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2
L37	10103	10117	21:21	21:07	19.4	18.2	0.01	0.77
L39	10103	10120	22:05	21:13	17.3	18.4	0.02	0.96
L43	10103	10120	23:05	21:50	16.4	15.9	0.02	0.96
L44	10103	10113	23:38	20:55	16.1	19.1	0.02	0.51
L46	10103	10120	23:54	22:06	19.7	17.1	0.02	0.96
L51N	10103	10117	20:55	20:50	20.2	16.7	0.01	0.77
L51S	10103	10117	20:56	20:50	18.8	19.1	0.01	0.89
L53	10103	10120	20:30	20:38	*18.5	17.3	0.01	0.87
L54E	10103	10120	22:45	21:30	17.7	19.6	0.02	0.96
L54W	10103	10120	22:47	21:33	18.8	16.9	0.02	0.96
L55E	10103	10113	23:20	20:39	19.8	19.9	0.02	0.51
L55W	10103	10113	23:20	20:30	19.8	19.1	0.02	0.50

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table A.4. *Tadpole Survey Specific Covariates for April 2010.* In April 2010 the Julian date (Year, Day of Year) was the only survey specific covariate recorded during tadpole sampling.

	Julian Date	
SITE	S1	S2
H09	10133	10133
H11	10133	10133
H12	10133	10133
H14	10133	10133
H15F	10133	10133
H15S	10133	10133
H34	10131	10131
H59	10133	10133
H64	10131	10131
H65N	10131	10131
H65S	10131	10131
K02	10127	10127
K06	10127	10127
K07	10127	10127
K10	10126	10126
K23	10127	10127
K24	10127	10127
K25	10126	10126
K27	10134	10134
K32	10134	10134
K56I	10134	10134
K56O	10134	10134
K57N	10126	10126
K57S	10126	10126
K66	10129	10129
K67F	10129	10129
K67S	10129	10129
K68	10126	10126
K69	10129	10129
K71	10129	10129

Table A.4. *Tadpole Survey Specific Covariates for April 2010, continued.*

	Julian Date	
SITE	S1	S2
L37	10124	10124
L39	10124	10124
L43	10125	10125
L44	10123	10123
L46	10125	10125
L51N	10124	10124
L51S	10124	10124
L53	10124	10124
L54E	10125	10125
L54W	10125	10125
L55E	10123	10123
L55W	10123	10123

Table A.5. *Site Specific Wetland Characteristics April 2010.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include: wetland size and type, bend, distance to nearest wetland, slope, and presence of emergent vegetation.

SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland (m)	Slope (0-1m)	Emergent Vegetation
H09	Large	Tributary	Hamburg	737.35	*0.37	1
H11	Small	Scour Hole	Hamburg	737.35	0.32	1
H12	Medium	Tributary	Hamburg	1770.79	0.62	0
H14	Medium	Tributary	Hamburg	146.14	0.07	0
H15F	Medium	Ephemeral, unfarmed	Hamburg	132.00	0.09	1
H15S	Small	Tributary	Hamburg	132.00	0.19	1
H34	Small	Ephemeral, farmed	Hamburg	363.33	0.12	1
H59	Small	Ground Fed Permanent	Hamburg	325.08	0.16	1
H64	Small	Ditch	Hamburg	430.53	0.28	1
H65N	Small	Ditch	Hamburg	5.62	0.32	1
H65S	Small	Ditch	Hamburg	5.62	0.26	1
K02	Small	Ephemeral, unfarmed	Kansas	332.86	0.13	0
K06	Medium	Ephemeral, unfarmed	Kansas	364.68	0.26	1
K07	Small	Ground Fed Permanent	Kansas	367.12	0.09	1
K10	Large	Ground Fed Permanent	Kansas	332.86	0.16	1
K23	Medium	Tributary	Kansas	171.23	*0.78	0
K24	Medium	Tributary	Kansas	657.94	*0.33	0
K25	Small	Impoundment	Kansas	680.94	0.08	1
K27	Large	Impoundment	Kansas	171.23	0.14	1
K32	Small	Ground Fed Permanent	Kansas	730.00	0.04	1
K56I	Small	Ditch	Kansas	95.62	0.24	1
K56O	Small	Ephemeral, unfarmed	Kansas	95.62	0.12	1
K57N	Small	Ditch	Kansas	53.54	0.26	1
K57S	Small	Ephemeral, unfarmed	Kansas	53.54	0.08	1
K66	Small	Impoundment	Kansas	93.65	0.09	1
K67F	Large	Impoundment	Kansas	43.22	0.11	1
K67S	Medium	Tributary	Kansas	37.92	*0.33	1
K68	Large	Tributary	Kansas	443.77	0.40	0
K69	Medium	Impoundment	Kansas	31.00	0.24	1
K71	Large	Tributary	Kansas	31.00	0.47	0

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table A.5. *Site Specific Wetland Characteristics April 2010, continued.*

SITE	Wetland Size (ha)	Wetland Type	Bend	Distance to Nearest Wetland (m)	Slope (0-1m)	Emergent Vegetation
L37	Medium	Ground Fed Permanent	Langdon	379.09	0.18	1
L39	Small	Ephemeral, farmed	Langdon	573.96	0.05	0
L43	Medium	Ground Fed Permanent	Langdon	442.18	0.07	1
L44	Small	Ditch	Langdon	599.78	0.09	0
L46	Medium	Ditch	Langdon	843.15	0.32	0
L51N	Small	Ephemeral, unfarmed	Langdon	14.28	0.11	1
L51S	Small	Ephemeral, farmed	Langdon	14.28	0.07	0
L53	Large	Backwater	Langdon	573.96	0.15	1
L54E	Medium	Ephemeral, unfarmed	Langdon	89.70	0.14	0
L54W	Small	Ground Fed Permanent	Langdon	89.70	0.19	1
L55E	Large	Ditch	Langdon	86.07	0.37	0
L55W	Large	Ditch	Langdon	86.07	0.38	0

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table A.6. *Site Specific Landscape Characteristics April 2010.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include adjacent land cover and terrestrial vegetation.

	Adjacent Land Cover (1000m^2)			Average Terrestrial Vegetation (% of shoreline)			
SITE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
H09	0.00	0.00	0.03	0.35	0.35	0	0.3
H11	0.00	0.00	0.03	0.55	0.325	0.125	0
H12	0.45	0.03	0.41	0	0.475	0.175	0.35
H14	0.39	0.06	0.25	0.7	0.225	0.05	0
H15F	0.29	0.02	0.49	0.875	0.075	0.05	0
H15S	0.36	0.07	0.38	0.7	0.025	0.275	0
H34	0.08	0.00	0.66	0.8	0.05	0.025	0.1
H59	0.43	0.00	0.13	0.875	0.015	0.11	0
H64	0.27	0.00	0.17	0.4	0.1	0.5	0
H65N	0.16	0.00	0.43	0.4	0.2	0.225	0
H65S	0.16	0.00	0.43	0.5	0.225	0.275	0
K02	0.29	0.03	0.08	0.15	0.325	0.525	0
K06	0.37	0.06	0.07	0.45	0.125	0.425	0
K07	0.45	0.01	0.18	0.5	0.275	0.275	0
K10	0.10	0.00	0.20	0.8	0.15	0.05	0
K23	0.50	0.00	0.13	0.9	0.075	0.025	0
K24	0.38	0.04	0.03	0.85	0.075	0.075	0
K25	0.00	0.00	0.24	1	0	0	0
K27	0.38	0.00	0.12	0.225	0.175	0.175	0.425
K32	0.00	0.00	0.44	0.025	0	0	0.975
K56I	0.00	0.00	0.34	0.3	0.1	0.45	0.15
K56O	0.01	0.00	0.29	0.15	0.6	0.25	0
K57N	0.00	0.00	0.45	0.3	0.35	0.35	0
K57S	0.00	0.00	0.52	*0.303	*0.173	*0.234	*0.286
K66	0.01	0.00	0.58	0.6	0.25	0.15	0
K67F	0.01	0.00	0.60	0.875	0.06	0.065	0
K67S	0.01	0.00	0.58	0.6	0.225	0.175	0
K68	0.03	0.00	0.32	0.8	0.15	0.05	0
K69	0.01	0.00	0.59	0.625	0.2	0.175	0
K71	0.01	0.00	0.57	0.5	7.625	0.2	0

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for that wetland type.

Table A.6. *Site Specific Landscape Characteristics April 2010, continued.*

	Adjacent Land Cover (1000m)			Average Terrestrial Vegetation (% of shoreline)			
SITE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
L37	0.00	0.00	0.31	0.2	0	0.8	0
L39	0.00	0.00	0.43	0	0	0	1
L43	0.00	0.00	0.90	0.1	0.05	0.05	0.8
L44	0.21	0.10	0.49	*0.46	*0.14	*0.27	*0.13
L46	0.01	0.00	0.67	0.7	0.05	0.1	0
L51N	0.00	0.00	0.26	0	0.2	0.6	0.2
L51S	0.00	0.00	0.23	*0.303	*0.173	*0.234	*0.286
L53	0.02	0.00	0.13	0.3	0	0.7	0
L54E	0.00	0.00	0.94	0	0.01	0	0.99
L54W	0.00	0.00	0.97	*0.417	*0.082	*0.214	*0.296
L55E	0.05	0.01	0.79	0.8	0.05	0.15	0
L55W	0.04	0.00	0.82	*0.46	*0.14	*0.27	*0.13

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for that wetland type.

Appendix B: May, 2010

Table B.1. *May 2010 Call Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) as a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	0	0	0	0	0	0
H11	0	0	0	1	0	1	0	1	0	0	0	0
H12	0	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15F	0	1	0	0	0	1	0	0	0	0	0	0
H15S	1	0	0	0	0	0	0	0	0	0	0	0
H34	1	1	1	1	1	1	0	1	0	0	0	1
H59	0	0	0	0	0	1	0	1	0	0	0	0
H64	0	0	0	0	0	1	0	1	0	0	0	0
H65N	0	0	1	1	1	1	0	0	0	0	0	0
H65S	0	0	0	0	1	1	0	1	0	0	0	0
K02	0	1	0	0	0	1	0	1	0	0	0	0
K06	1	0	1	0	0	0	0	1	0	0	0	0
K07	0	0	1	1	1	1	1	1	0	0	1	1
K10	0	0	1	1	1	1	0	1	1	0	0	0
K23	0	0	0	0	0	0	0	0	0	0	0	0
K24	0	0	0	0	0	0	0	0	0	0	0	0
K25	0	0	1	1	1	1	0	1	0	0	0	1
K27	0	1	1	0	1	1	0	1	0	0	0	0
K32	0	1	0	0	0	0	1	1	0	0	1	1
K56I	0	0	1	1	1	1	0	1	0	0	0	0
K56O	1	0	1	1	1	1	0	1	0	0	0	0
K57N	0	0	0	0	0	0	0	0	0	0	0	0
K57S	0	0	1	1	1	1	0	1	0	0	0	0
K66	0	0	0	1	1	1	1	1	0	0	1	0
K67F	0	0	1	1	1	1	0	0	0	0	0	0
K67S	0	0	0	0	0	0	0	0	0	0	0	0
K69	0	0	0	1	1	1	0	1	0	0	0	0
K71	0	0	0	0	0	0	0	0	0	0	0	0
L37	0	0	0	1	0	1	0	0	0	0	0	0

Table B.1. *May 2010 Call Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L39	0	0	0	1	0	1	0	0	0	0	0	0
L43	0	0	1	1	1	1	1	1	0	0	1	1
L44	0	0	0	0	0	1	0	0	0	0	0	0
L46	0	0	1	1	1	1	0	0	0	0	0	0
L51N	0	0	0	0	0	0	0	0	0	0	0	1
L51S	0	0	0	1	0	0	1	0	0	0	1	0
L53	0	0	0	0	0	0	0	0	0	1	0	0
L54E	1	0	1	1	1	1	1	0	0	0	1	1
L54W	0	0	0	1	0	0	0	1	0	0	0	0
L55E	0	0	0	0	0	0	0	0	0	0	0	0
L55W	0	0	0	0	0	0	0	0	0	0	0	0
L70	0	0	0	0	0	0	0	0	0	0	0	0

Table B.2. *May 2010 Tadpole Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) as a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	0	0	0	0	0	0
H11	0	0	0	0	0	0	0	1	0	0	0	0
H12	0	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15F	1	0	0	0	0	0	0	0	0	0	0	0
H15S	0	0	0	0	0	0	0	0	1	0	0	0
H34	1	1	0	0	0	0	1	1	0	0	0	0
H59	1	1	0	0	0	0	1	1	1	0	0	0
H64	1	1	0	0	0	0	0	0	0	0	0	0
H65N	1	1	0	0	0	1	1	1	0	0	0	0
H65S	1	1	0	0	0	0	0	1	0	0	0	0
K02	0	0	0	0	0	0	0	0	0	0	0	0
K06	0	0	0	0	0	0	0	1	0	0	0	0
K07	1	1	0	0	1	0	1	1	0	0	0	0
K10	0	0	0	0	0	0	1	1	0	0	1	0
K23	0	0	0	0	0	0	0	0	0	0	0	0
K24	0	0	0	0	0	0	0	0	0	0	0	0
K25	1	1	0	0	0	1	1	1	0	1	1	0
K27	1	1	0	0	0	0	1	1	0	0	0	1
K32	0	0	0	0	0	0	1	0	0	0	0	0
K56I	1	1	0	0	1	1	1	1	0	0	0	0
K56O	1	1	0	0	1	1	1	1	0	0	0	0
K57N	1	0	0	0	0	0	1	0	0	0	0	0
K57S	0	1	0	0	1	0	0	0	0	0	0	0
K66	1	0	0	0	1	1	0	0	0	0	0	0
K67F	1	1	0	0	0	0	1	1	0	0	0	0
K67S	0	0	0	0	0	0	1	0	0	0	0	0
K69	0	1	0	0	0	0	0	1	0	0	0	0
K71	0	0	0	0	0	0	0	0	0	0	0	0
L37	1	0	0	0	0	0	1	1	0	0	1	0

Table B.2. *May 2010 Tadpole Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L39	0	0	0	0	0	0	1	0	0	0	0	0
L43	0	0	0	0	0	0	1	1	0	0	1	1
L44	1	0	0	0	0	0	1	0	0	0	0	0
L46	0	0	0	0	0	0	0	0	0	1	0	0
L51N	0	0	0	0	0	0	1	1	0	0	0	0
L51S	0	0	0	0	0	0	0	0	0	0	1	1
L53	0	0	0	0	0	0	0	0	1	1	0	0
L54E	1	1	0	0	1	1	1	1	0	0	1	1
L54W	0	0	0	0	0	0	1	1	0	0	0	0
L55E	1	0	0	0	0	0	1	1	1	0	0	0
L55W	0	0	0	0	0	0	0	0	0	0	0	0
L70	0	0	0	0	0	0	0	0	0	0	0	0

Table B.3. *Call Survey Specific Covariates for May 2010.* Covariates include: Julian date (Year, Day of Year), time, water temperature, and moonshine and were measured during each survey conducted. Each site was visited twice during the month.

	Julian Date		Time		Water Temperature		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2
H09	10133	10138	21:08	21:13	*14.2	*18.8	0.01	0.16
H11	10133	10138	21:08	21:17	16.7	21.6	0.01	0.16
H12	10133	10138	21:45	22:01	*14.2	19.4	0.01	0.16
H14	10133	10138	22:17	22:30	11.7	*18.8	0.01	0.16
H15F	10133	10138	22:36	22:48	12.1	15.1	0.01	0.16
H15S	10133	10138	22:32	22:46	12.4	15.1	0.01	0.16
H34	10133	10138	20:51	21:04	17.7	23.6	0.01	0.16
H59	10133	10138	22:22	22:30	11.8	15.6	0.01	0.16
H64	10133	10138	21:25	21:32	13.9	18.8	0.01	0.16
H65N	10133	10138	21:07	21:16	16.4	20.1	0.01	0.16
H65S	10133	10138	21:07	21:17	15.3	20.2	0.01	0.16
K02	10135	10141	23:57	0:40	13.1	15.7	0.01	0.53
K06	10135	10141	0:07	0:05	15.3	17.4	0.00	0.53
K07	10135	10141	23:52	23:51	14.8	17.3	0.01	0.53
K10	10135	10141	22:25	22:33	14.8	19.8	0.00	0.53
K23	10135	10141	22:21	23:38	15.7	*20.1	0.00	0.53
K24	10135	10141	22:04	23:44	14.5	17.6	0.00	0.53
K25	10135	10141	22:09	22:51	15.1	21.2	0.00	0.53
K27	10135	10141	22:10	22:51	18.3	20.4	0.00	0.53
K32	10135	10141	21:09	21:55	16.5	19.3	0.00	0.53
K56I	10135	10141	21:52	22:55	17.4	19.4	0.00	0.53
K56O	10135	10141	21:53	22:58	18.1	20.5	0.00	0.53
K57N	10135	10141	21:33	22:10	14.8	19.6	0.00	0.53
K57S	10135	10141	21:33	22:13	18.2	21.8	0.00	0.53
K66	10135	10141	21:06	21:45	18	21.5	0.00	0.53
K67F	10135	10141	21:20	21:54	10.9	22	0.00	0.53
K67S	10135	10141	21:33	22:33	*15.8	*20.1	0.00	0.53
K69	10135	10141	21:20	21:57	17.5	21.1	0.00	0.53
K71	10135	10141	21:04	22:04	*15.8	*20.1	0.00	0.53
L37	10134	10144	21:35	21:45	18.3	27.4	0.00	0.64

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table B.3. *Call Survey Specific Covariates for May 2010, continued.*

	Julian Date		Time		Water Temperature		Moonshine		Precipitation	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L39	10134	10144	21:17	21:25	18.4	24.9	0.00	0.64	0	0
L43	10134	10144	22:15	22:27	18.1	23.1	0.00	0.64	0	0
L44	10134	10144	22:35	22:48	14.6	23.6	0.00	0.64	0	0
L46	10134	10144	22:48	23:01	18.2	26.3	0.00	0.64	0	0
L51N	10134	10144	21:36	21:45	18.5	22.9	0.00	0.64	0	0
L51S	10134	10144	21:37	21:45	18.3	23.6	0.00	0.64	0	0
L53	10134	10144	21:01	21:01	18.3	25.7	0.00	0.64	0	0
L54E	10134	10144	22:02	22:15	19.6	23.3	0.00	0.64	0	0
L54W	10134	10144	22:01	22:13	18.9	25	0.00	0.64	0	0
L55E	10134	10144	22:17	22:33	19	27.1	0.00	0.64	0	0
L55W	10134	10144	22:18	22:30	19.1	27.1	0.00	0.64	0	0
L70	10134	10144	20:59	21:07	*18.3	25.5	0.00	0.64	0	0

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table B.4. *Tadpole Survey Specific Covariates for May 2010.* Julian date (Year, Day of Year) was the only survey specific covariate recorded during tadpole sampling.

	Julian Date	
SITE	S1	S2
H09	10144	10144
H11	10144	10144
H12	10144	10144
H14	10144	10144
H15F	10144	10144
H15S	10144	10144
H34	10145	10145
H59	10144	10144
H64	10145	10145
H65N	10145	10145
H65S	10145	10145
K02	10146	10146
K06	10146	10146
K07	10146	10146
K10	10146	10146
K23	10146	10146
K24	10146	10146
K25	10148	10148
K27	10148	10148
K32	10147	10147
K56I	10147	10147
K56O	10147	10147
K57N	10147	10147
K57S	10147	10147
K66	10148	10148
K67F	10148	10148
K67S	10148	10148
K69	10148	10148
K71	10148	10148
L37	10154	10154

B.4. *Tadpole Survey Specific Covariates for May 2010, continued.*

	Julian Date	
SITE	S1	S2
L39	10154	10154
L43	10155	10155
L44	10153	10153
L46	10153	10153
L51N	10154	10154
L51S	10154	10154
L53	10154	10154
L54E	10155	10155
L54W	10155	10155
L55E	10153	10153
L55W	10153	10153
L70	10154	10154

Table B.5. *Site Specific Wetland Characteristics May 2010.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include: wetland size and type, bend, distance to nearest wetland, slope, and presence of emergent vegetation.

SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland (m)	Slope (0-1m)	Emergent Vegetation
H09	Large	Tributary	Hamburg	737.35	0.48	0
H11	Small	Scour Hole	Hamburg	737.35	0.50	1
H12	Medium	Tributary	Hamburg	1770.79	0.51	1
H14	Medium	Tributary	Hamburg	146.14	0.15	1
H15F	Medium	Ephemeral, unfarmed	Hamburg	132.00	0.12	1
H15S	Small	Tributary	Hamburg	132.00	0.14	1
H34	Small	Ephemeral, farmed	Hamburg	363.33	0.06	1
H59	Small	Ground Fed Permanent	Hamburg	325.08	0.10	1
H64	Small	Ditch	Hamburg	430.53	0.21	1
H65N	Small	Ditch	Hamburg	5.62	0.38	1
H65S	Small	Ditch	Hamburg	5.62	0.29	1
K02	Small	Ephemeral, unfarmed	Kansas	332.86	0.08	1
K06	Medium	Ephemeral, unfarmed	Kansas	364.68	0.30	1
K07	Small	Ground Fed Permanent	Kansas	367.12	0.11	1
K10	Large	Ground Fed Permanent	Kansas	332.86	0.12	1
K23	Medium	Tributary	Kansas	171.23	*0.78	0
K24	Medium	Tributary	Kansas	657.94	0.39	0
K25	Small	Impoundment	Kansas	680.94	0.21	1
K27	Large	Impoundment	Kansas	171.23	0.26	0
K32	Small	Ground Fed Permanent	Kansas	730.00	0.04	0
K56I	Small	Ditch	Kansas	95.62	0.16	1
K56O	Small	Ephemeral, unfarmed	Kansas	95.62	0.13	1
K57N	Small	Ditch	Kansas	53.54	0.27	1
K57S	Small	Ephemeral, unfarmed	Kansas	53.54	0.04	1
K66	Small	Impoundment	Kansas	93.65	0.09	1
K67F	Large	Impoundment	Kansas	43.22	0.11	1
K67S	Medium	Tributary	Kansas	37.92	*0.33	1
K69	Medium	Impoundment	Kansas	31.00	0.10	1
K71	Large	Tributary	Kansas	31.00	*0.44	1

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table B.5. *Site Specific Wetland Characteristics May 2010, continued.*

SIZE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland (m)	Slope (0-1m)	Emergent Vegetation
L37	Medium	Ground Fed Permanent	Langdon	379.09	0.15	1
L39	Small	Ephemeral, farmed	Langdon	573.96	0.03	0
L43	Medium	Ground Fed Permanent	Langdon	442.18	0.04	1
L44	Small	Ditch	Langdon	599.78	0.09	1
L46	Medium	Ditch	Langdon	843.15	0.28	1
L51N	Small	Ephemeral, unfarmed	Langdon	14.28	0.05	1
L51S	Small	Ephemeral, farmed	Langdon	14.28	0.05	0
L53	Large	Backwater	Langdon	573.96	0.27	1
L54E	Medium	Ephemeral, unfarmed	Langdon	89.70	0.11	1
L54W	Small	Ground Fed Permanent	Langdon	89.70	0.17	1
L55E	Large	Ditch	Langdon	86.07	0.34	1
L55W	Large	Ditch	Langdon	86.07	0.48	0
L70	Large	Backwater	Langdon	1124.55	*0.25	1

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table B.6. *Site Specific Landscape Characteristics May 2010.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include adjacent land cover and terrestrial vegetation.

	Adjacent Land Cover (1000m)			Average Terrestrial Vegetation (% of shoreline)			
SIZE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
H09	0.00	0.00	0.03	0.325	0.2	0.375	0.1
H11	0.00	0.00	0.03	0.25	0.45	0.3	0
H12	0.45	0.03	0.41	0.3	0.15	0.35	0.2
H14	0.39	0.06	0.25	0.6	0.35	0.05	0
H15F	0.29	0.02	0.49	0.975	0	0.025	0
H15S	0.36	0.07	0.38	0.55	0.4	0.05	0
H34	0.08	0.00	0.66	0.65	0.3	0.05	0
H59	0.43	0.00	0.13	0.7	0.25	0.05	0
H64	0.27	0.00	0.17	0.45	0.225	0.325	0
H65N	0.16	0.00	0.43	0.425	0.275	0.29	0
H65S	0.16	0.00	0.43	0.3	0.325	0.375	0
K02	0.29	0.03	0.08	0.525	0.1	0.375	0
K06	0.37	0.06	0.07	0.45	0.175	0.375	0
K07	0.45	0.01	0.18	0.5	0.075	0.425	0
K10	0.10	0.00	0.20	0.5	0.225	0.275	0
K23	0.50	0.00	0.13	0.55	0.225	0.225	0
K24	0.38	0.04	0.03	0.65	0.125	0.225	0
K25	0.00	0.00	0.24	0.575	0.25	0.175	0
K27	0.38	0.00	0.12	0.5	0.35	0.15	0
K32	0.00	0.00	0.44	0.075	0.075	0	0.85
K56I	0.00	0.00	0.34	0.375	0.3	0.375	0
K56O	0.01	0.00	0.29	0.125	0.65	0.225	0
K57N	0.00	0.00	0.45	0.15	0.35	0.5	0
K57S	0.00	0.00	0.52	0.525	0.35	0.125	0
K66	0.01	0.00	0.58	0.6	0.25	0.1	0
K67F	0.01	0.00	0.60	0.45	0.49	0.06	0
K67S	0.01	0.00	0.58	0.4	0.5	0.15	0
K69	0.01	0.00	0.59	0.5	0.465	0.035	0
K71	0.01	0.00	0.57	0.35	0.125	0.525	0

Table B.6. *Site Specific Landscape Characteristics May 2010, continued.*

	Adjacent Land Cover ($1000m^2$)			Average Terrestrial Vegetation (% of shoreline)			
SIZE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
L37	0.00	0.00	0.31	0.1	0.25	0.65	0
L39	0.00	0.00	0.43	0	0.02	0.255	0.725
L43	0.00	0.00	0.90	0.25	0.6	0.05	0.1
L44	0.21	0.10	0.49	0.4	0.125	0.475	0
L46	0.01	0.00	0.67	0.5	0.15	0.35	0
L51N	0.00	0.00	0.26	0.4	0.2	0.4	0
L51S	0.00	0.00	0.23	0.05	0.225	0.025	0.7
L53	0.02	0.00	0.13	0.075	0.05	0.875	0
L54E	0.00	0.00	0.94	0.375	0.3	0.15	0.175
L54W	0.00	0.00	0.97	0.6	0.35	0.05	0
L55E	0.05	0.01	0.79	0.65	0.2	0.15	0
L55W	0.04	0.00	0.82	0.6	0.2	0.2	0
L70	0.01	0.00	0.26	0.75	0.075	0.175	0

Appendix C: June, 2010

Table C.1. *June 2010 Call Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) as a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	0	0	0	0	0	0
H11	0	0	1	0	1	0	1	0	0	0	1	0
H12	0	0	0	0	0	0	1	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15S	0	0	0	0	0	0	0	0	0	0	0	0
H34	0	0	1	1	0	1	0	1	0	1	0	0
H59	0	0	1	0	1	1	0	0	0	0	0	0
H63	0	0	0	0	0	0	0	0	0	0	0	0
K02	0	0	0	0	0	0	0	0	0	0	0	0
K06	0	0	1	1	0	0	1	0	1	1	0	0
K07	0	0	0	0	1	1	0	0	0	0	0	1
K10	0	0	1	1	1	1	0	0	0	0	0	0
K25	0	0	1	1	1	1	1	1	0	0	0	1
K27	0	0	1	0	1	1	1	0	0	0	0	0
K30	0	0	0	1	1	1	1	1	0	0	0	0
K56I	0	0	1	1	1	1	1	1	0	0	0	0
K57N	0	0	0	0	0	0	0	0	0	0	0	0
K57S	0	0	0	1	1	1	0	1	0	0	0	0
K66	0	0	1	1	1	1	1	1	0	0	0	0
K67F	0	0	1	1	1	1	1	0	0	1	0	0
K67S	0	0	0	0	0	0	0	0	1	1	0	0
K68	0	0	0	0	0	0	1	0	0	0	0	0
K69	0	0	1	0	1	1	0	0	1	0	0	0
K71	0	0	0	0	0	0	0	0	0	1	0	0

Table C.1. *June 2010 Call Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	0	0	1	0	1	0	0	0	1	0	0	0
L39	0	0	0	0	0	0	0	0	0	0	0	0
L43	0	0	1	1	0	1	0	0	0	1	0	0
L44	0	0	0	0	0	0	0	0	0	0	0	0
L46	0	0	1	1	0	1	0	0	0	1	0	1
L51N	0	0	0	0	0	0	0	0	0	1	0	0
L53	0	0	0	1	0	1	0	1	1	0	0	0
L54E	0	0	1	1	0	1	0	1	0	0	0	1
L54W	0	0	1	1	0	1	0	1	0	1	0	0
L55E	0	0	1	1	1	1	0	1	0	1	0	0
L55W	0	0	1	1	1	1	0	1	0	1	0	1
L70	0	0	1	0	0	1	0	1	1	0	0	0

Table C.2. *June 2010 Tadpole Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) as a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	0	0	0	0	0	0
H11	0	0	0	0	0	0	0	0	0	0	0	0
H12	0	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15S,F	0	0	0	0	1	0	0	0	0	0	0	0
H34	0	0	0	0	1	0	1	0	0	0	0	0
H59	0	0	0	0	1	1	1	0	0	0	0	0
H63	0	0	0	0	0	0	0	0	0	0	0	0
K02	0	0	0	0	0	1	0	0	0	0	0	0
K06	0	0	0	0	1	0	0	0	0	0	0	0
K07	0	0	0	0	0	1	0	0	0	0	0	0
K10	0	0	0	0	0	1	0	0	0	0	0	0
K25	0	0	0	0	0	0	1	0	0	0	0	0
K27	0	0	0	0	1	1	1	1	0	0	0	1
K30	0	0	0	0	1	0	1	0	0	0	0	0
K56I	0	0	0	0	1	0	1	0	0	0	0	0
K57N	0	0	0	0	1	1	1	0	0	0	0	0
K57S	0	0	0	0	0	0	0	0	0	0	0	0
K66	0	0	0	0	1	1	0	0	0	0	0	0
K67F	0	0	1	1	1	1	1	0	0	0	0	0
K67S	0	0	0	1	1	1	1	1	0	0	0	0
K68	0	0	0	0	0	0	0	0	0	0	0	0
K69	0	0	0	0	1	0	1	0	0	0	0	0
K71	0	0	0	0	0	1	0	0	0	0	0	0

Table C.2. *June 2010 Tadpole Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	0	0	0	0	0	0	0	1	0	0	0	0
L39	0	0	0	0	0	0	1	1	0	0	0	0
L43	0	0	1	0	1	0	1	1	0	0	1	1
L44	0	0	0	0	0	0	0	0	0	0	0	0
L46	0	0	0	0	1	1	0	0	0	0	0	0
L51S,N	0	0	0	0	0	0	0	0	0	0	0	0
L53	0	0	0	0	0	0	0	0	0	0	0	0
L54E	0	0	0	0	1	0	1	1	0	0	0	0
L54W	0	0	0	0	0	0	1	1	0	0	0	0
L55E	0	0	0	0	0	0	0	1	0	0	0	0
L55W	0	0	0	1	1	1	1	1	0	0	0	0
L70	0	0	0	0	1	0	0	0	0	0	0	0

Table C.3. *Call Survey Specific Covariates for June 2010.* Covariates recorded during call surveys include: Julian date (Year, Day of Year), time, water temperature, and moonshine. Each site was visited twice during the month.

	Julian Date		Time		Water Temperature		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2
H09	10161	10174	21:42	21:50	*24.3	*26.4	0.05	0.10
H11	10161	10174	21:44	21:52	27.2	*26.4	0.05	0.10
H12	10161	10174	22:28	23:05	*24.3	28	0.04	0.10
H14	10161	10174	22:54	21:31	21.6	24.6	0.04	0.10
H15S	10161	10174	23:08	21:50	21.9	26.1	0.04	0.10
H34	10161	10174	21:28	0:05	27.1	27	0.05	0.10
H59	10161	10174	23:00	22:08	22.5	26.1	0.04	0.10
H63	10161	10174	22:00	22:08	25.5	*26.4	0.04	0.09
K02	10159	10166	23:28	23:08	19.4	18.4	0.08	0.09
K06	10159	10166	23:45	23:22	24.1	24.7	0.08	0.09
K07	10159	10166	23:49	23:07	21.6	23.3	0.08	0.09
K10	10159	10166	22:27	22:43	26.3	25.6	0.06	0.09
K25	10159	10166	22:51	22:27	28.2	23.4	0.06	0.09
K27	10159	10166	22:55	22:30	*24.9	29.5	0.06	0.08
K30	10159	10166	22:23	22:09	*24.9	27.2	0.06	0.81
K56I	10159	10166	22:36	21:40	*24.9	25	0.06	0.81
K57N	10159	10166	21:24	21:46	*24.9	27.7	0.14	0.81
K57S	10159	10166	21:25	21:50	*24.9	28.9	0.14	0.81
K66	10159	10166	21:36	23:47	25.7	24.4	0.14	0.81
K67F	10159	10166	22:00	23:47	26.3	24.4	0.06	0.81
K67S	10159	10166	21:46	0:00	*24.9	*25.4	0.14	0.81
K68	10159	10166	22:30	22:45	*24.9	*25.4	0.06	0.81
K69	10159	10166	21:48	23:47	27.4	27.6	0.14	0.81
K71	10159	10166	21:35	0:02	*24.9	*25.4	0.14	0.81

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table C.3. *Call Survey Specific Covariates for June 2010, continued.*

	Julian Date		Time		Water Temperature		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2
L37	10160	10175	22:09	21:30	30.8	*28.6	0.02	0.86
L39	10160	10175	21:50	21:30	28.1	*28.6	0.09	0.86
L43	10160	10175	22:55	22:21	27.5	28	0.02	0.86
L44	10160	10175	23:18	22:40	23.4	22.9	0.02	0.86
L46	10160	10175	23:31	22:49	29	31	0.02	0.86
L51N	10160	10175	22:09	21:32	27.2	*28.6	0.02	0.95
L53	10160	10175	21:37	21:30	26	*28.6	0.09	0.95
L54E	10160	10175	22:39	22:08	31	31.4	0.02	0.95
L54W	10160	10175	22:40	22:07	27.6	27.9	0.02	0.95
L55E	10160	10175	22:57	22:23	28.8	31.4	0.02	0.95
L55W	10160	10175	22:57	22:25	28.4	27	0.02	0.95
L70	10160	10175	21:36	21:53	*27.9	29	0.09	0.95

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table C.4. *Tadpole Survey Specific Covariates for June 2010.* Julian date (Year, Day of Year) was the only survey specific covariate recorded during tadpole sampling.

	Julian Date	
SITE	S1	S2
H09	10182	10182
H11	10182	10182
H12	10182	10182
H14	10187	10187
H15S,F	10187	10187
H34	10181	10181
H59	10187	10187
H63	10182	10182
K02	10180	10180
K06	10180	10180
K07	10180	10180
K10	10180	10180
K25	10179	10179
K27	10179	10179
K30	10179	10179
K56I	10179	10179
K57N	10179	10179
K57S	10179	10179
K66	10190	10190
K67F	10190	10190
K67S	10190	10190
K68	10179	10179
K69	10190	10190
K71	10190	10190

Table C.4. *Tadpole Survey Specific Covariates for June 2010, continued*.

	Julian Date	
SITE	S1	S2
L37	10189	10189
L39	10189	10189
L43	10189	10189
L44	10188	10188
L46	10188	10188
L51S,N	10189	10189
L53	10189	10189
L54E	10188	10188
L54W	10188	10188
L55E	10188	10188
L55W	10188	10188
L70	10189	10189

Table C.5. *Site Specific Wetland Characteristics June 2010.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include: wetland size and type, bend, distance to nearest wetland, slope, and presence of emergent vegetation.

SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland (m)	Slope (0-1m)	Emergent Vegetation
H09	Large	Tributary	Hamburg	737.35	0.21	1
H11	Small	Scour Hole	Hamburg	737.35	0.26	1
H12	Medium	Tributary	Hamburg	1770.79	*0.27	1
H14	Medium	Tributary	Hamburg	146.14	*0.27	0
H15S	Small	Tributary	Hamburg	132.00	0.33	0
H34	Small	Ephemeral, farmed	Hamburg	363.33	*0.20	1
H59	Small	Ground Fed Permanent	Hamburg	325.08	*0.25	0
H63	Medium	Ephemeral, unfarmed	Hamburg	1239.62	*0.20	1
K02	Small	Ephemeral, unfarmed	Kansas	332.86	0.16	1
K06	Medium	Ephemeral, unfarmed	Kansas	364.68	0.29	0
K07	Small	Ground Fed Permanent	Kansas	367.12	0.25	1
K10	Large	Ground Fed Permanent	Kansas	332.86	0.35	1
K25	Small	Impoundment	Kansas	680.94	0.54	1
K27	Large	Impoundment	Kansas	171.23	0.22	1
K30	Medium	Ephemeral, unfarmed	Kansas	872.41	0.29	1
K56I	Small	Ditch	Kansas	95.62	0.21	1
K57N	Small	Ditch	Kansas	53.54	0.26	1
K57S	Small	Ephemeral, unfarmed	Kansas	53.54	0.22	1
K66	Small	Impoundment	Kansas	93.65	0.22	1
K67F	Large	Impoundment	Kansas	43.22	0.12	1
K67S	Medium	Tributary	Kansas	37.92	*0.27	1
K68	Large	Tributary	Kansas	443.77	*0.27	0
K69	Medium	Impoundment	Kansas	31.00	0.17	1
K71	Large	Tributary	Kansas	31.00	*0.27	1

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table C.5. *Site Specific Wetland Characteristics June 2010, continued.*

SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland (m)	Slope (0-1m)	Emergent Vegetation
L37	Medium	Ground Fed Permanent	Langdon	379.09	*0.25	0
L39	Small	Ephemeral, farmed	Langdon	573.96	*0.20	0
L43	Medium	Ground Fed Permanent	Langdon	442.18	0.12	1
L44	Small	Ditch	Langdon	599.78	0.21	0
L46	Medium	Ditch	Langdon	843.15	*0.23	1
L51N, S	Small	Ephemeral, unfarmed	Langdon	14.28	*0.20	0
L53	Large	Backwater	Langdon	573.96	*0.27	0
L54E	Medium	Ephemeral, unfarmed	Langdon	89.70	0.14	1
L54W	Small	Ground Fed Permanent	Langdon	89.70	0.16	1
L55E	Large	Ditch	Langdon	86.07	0.15	1
L55W	Large	Ditch	Langdon	86.07	0.20	1
L70	Large	Backwater	Langdon	1124.55	*0.27	0

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table C.6. *Site Specific Landscape Characteristics June 2010.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include: adjacent land cover and terrestrial vegetation.

	Adjacent Land Cover (1000m^2)			Average Terrestrial Vegetation (% of shoreline)			
SITE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
H09	0.00	0.00	0.03	0.1	0.3	0.325	0
H11	0.00	0.00	0.03	0.125	0.06	0.315	0
H12	0.45	0.03	0.41	0.175	0.175	0.65	0
H14	0.39	0.06	0.25	0.475	0.275	0.25	0
H15S	0.36	0.07	0.38	0.325	0.15	0.45	0
H34	0.08	0.00	0.66	0.15	0.05	0.05	0.25
H59	0.43	0.00	0.13	0.15	0.1	2.975	0
H63	0.01	0.00	0.50	0.425	0.25	0.075	0
K02	0.29	0.03	0.08	0.05	0.15	0.8	0
K06	0.37	0.06	0.07	0.075	0.2	0.725	0
K07	0.45	0.01	0.18	0.1	0.1	0.3	0
K10	0.10	0.00	0.20	0.175	0.1	0.675	0
K25	0.00	0.00	0.24	0.45	0.25	0.3	0
K27	0.38	0.00	0.12	0.35	0.5	0.15	0
K30	0.00	0.00	0.35	0.35	0.35	0.2	0.1
K56I	0.00	0.00	0.34	0.45	0.225	0.325	0
K57N	0.00	0.00	0.45	0.125	0.275	0.6	0
K57S	0.00	0.00	0.52	0.55	0.375	0.05	0
K66	0.01	0.00	0.58	0.75	0.0775	0.17	0
K67F	0.01	0.00	0.60	0.65	0.35	0	0
K67S	0.01	0.00	0.58	0.75	0.175	0.075	0
K68	0.03	0.00	0.32	0.6	0.35	0.05	0
K69	0.01	0.00	0.59	0.65	0.325	0.025	0
K71	0.01	0.00	0.57	0.4	0.2	0.4	0

Table C.6. *Site Specific Landscape Characteristics June 2010, continued.*

	Adjacent Land Cover (1000m)			Average Terrestrial Vegetation (% of shoreline)			
SITE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
L37	0.00	0.00	0.31	0.45	0.1	0.45	0
L39	0.00	0.00	0.43	0.6	0.1	0.3	0
L43	0.00	0.00	0.90	0.15	0.8	0	0.05
L44	0.21	0.10	0.49	0.2	0.025	0.775	0
L46	0.01	0.00	0.67	0.1	0.5	0.4	0
L51N, S	0.00	0.00	0.26	0.55	0.125	0.325	0
L53	0.02	0.00	0.13	0.75	0.25	0	0
L54E	0.00	0.00	0.94	0.05	0.45	0	0.5
L54W	0.00	0.00	0.97	0.1	0.75	0	0.15
L55E	0.05	0.01	0.79	0.4	0.45	0.15	0
L55W	0.04	0.00	0.82	0.45	0.3	0.05	0.2
L70	0.01	0.00	0.26	0.65	0.35	0	0

Appendix D: April, 2011

Table D.1. *April 2011 Call Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) by a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	0	0	0	0	0	0
H11	0	1	0	0	0	0	1	1	0	0	0	0
H12	0	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15F	1	1	0	0	0	0	1	0	0	0	0	0
H15S	0	0	0	0	0	0	0	0	0	0	0	0
H34	1	1	0	0	0	0	1	0	0	0	0	0
H59	0	1	0	0	1	0	1	0	0	0	0	0
H64	1	1	0	0	0	0	1	0	0	0	0	0
H65N	1	1	0	0	0	0	1	0	0	0	0	0
H65S	1	1	0	0	0	0	1	0	0	0	0	0
K02	1	1	0	0	0	0	1	1	0	0	0	0
K06	0	0	0	0	0	0	1	1	0	0	0	0
K07	1	1	0	0	0	0	1	1	0	0	0	0
K10	1	1	0	0	0	0	1	1	0	0	0	0
K23	1	0	0	0	0	0	0	0	0	0	0	0
K24	1	0	0	0	0	0	1	1	0	0	1	0
K25	1	1	0	0	0	0	1	1	0	0	0	0
K27	1	1	0	0	0	0	1	1	0	0	0	0
K30	1	1	0	0	0	0	1	1	0	0	0	0
K32	1	0	0	0	0	0	0	0	0	0	0	0
K56I	1	1	0	0	0	0	0	1	0	0	0	0
K56O	1	1	0	0	0	0	1	1	0	0	0	0
K57N	1	1	0	0	0	0	1	0	0	0	0	0
K57S	1	1	0	0	0	0	1	1	0	0	0	0
K66	1	0	0	0	0	0	1	0	0	0	0	0
K67F	1	1	0	0	0	0	1	1	0	0	0	0
K67S	0	0	0	0	0	0	0	0	0	0	0	0
K68	0	0	0	0	0	0	0	1	0	0	0	0
K69	1	0	0	0	0	0	1	0	0	0	0	0
K71	0	1	0	0	0	0	0	1	0	0	0	0

Table D.1. *April 2011 Call Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	1	1	0	0	0	0	1	1	0	0	0	0
L39	1	1	0	0	0	0	0	1	0	0	0	0
L43	1	1	0	0	0	0	1	0	0	0	0	0
L44	1	1	0	0	0	0	1	0	0	0	0	0
L46	1	1	0	0	0	0	1	1	0	0	0	0
L51	1	1	0	0	0	0	1	1	0	0	0	0
L54E	1	1	0	0	0	0	1	0	0	0	0	0
L54W	0	0	0	0	0	0	1	0	0	0	0	0
L55E	1	0	0	0	0	0	1	0	0	0	0	0
L55W	1	1	0	0	0	0	1	0	0	0	0	0
L70	0	0	0	0	0	0	0	0	0	0	0	0

Table D.2. *April 2011 Tadpole Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) as a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	0	0	0	0	0	0
H11	0	0	0	0	0	0	0	0	0	0	0	0
H12	0	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15F	0	0	0	0	0	0	0	0	0	0	0	0
H15S	0	0	0	0	0	0	0	0	0	0	0	0
H34	1	1	0	0	0	0	0	0	0	0	0	0
H59	0	0	0	0	0	0	0	0	0	0	0	0
H64	0	1	0	0	0	0	0	0	0	0	0	0
H65N	0	0	0	0	0	0	0	0	0	0	0	0
H65S	0	0	0	0	0	0	0	0	0	0	0	0
K02	0	0	0	0	0	0	0	0	0	0	0	0
K06	0	0	0	0	0	0	0	0	0	0	0	0
K07	0	1	0	0	0	0	0	0	0	0	0	0
K10	0	0	0	0	0	0	0	0	0	0	0	0
K23	0	0	0	0	0	0	0	0	0	0	0	0
K24	0	0	0	0	0	0	0	0	0	0	0	0
K25	0	1	0	0	0	0	0	0	0	0	0	0
K27	0	0	0	0	0	0	0	0	0	0	0	0
K30	0	0	0	0	0	0	0	0	0	0	0	0
K32	0	0	0	0	0	0	0	0	0	0	0	0
K56I	1	0	0	0	0	1	0	0	0	0	0	0
K56O	0	0	0	0	0	0	0	0	0	0	0	0
K57N	0	0	0	0	0	0	0	0	0	0	0	0
K57S	0	0	0	0	0	0	0	0	0	0	0	0
K66	0	0	0	0	0	0	0	0	0	0	0	0
K67F	0	0	0	0	0	0	0	0	0	0	0	0
K67S	0	0	0	0	0	0	0	0	1	1	0	0
K68	0	0	0	0	0	0	0	0	1	0	0	0
K69	0	0	0	0	0	0	0	0	0	0	0	0
K71	0	0	0	0	0	0	0	0	1	1	0	0

Table D.2. *April 2011 Tadpole Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	0	0	0	0	0	0	0	0	0	0	0	0
L39	0	0	0	0	0	0	0	0	0	0	0	0
L43	0	0	0	0	0	0	0	0	0	0	0	0
L44	0	0	0	0	0	0	0	0	0	0	0	0
L46	0	0	0	0	0	0	0	0	1	1	0	0
L51	0	0	0	0	0	0	0	0	0	0	0	0
L54E	1	1	0	0	0	0	1	1	0	0	0	0
L54W	0	0	0	0	0	0	0	0	0	0	0	0
L55E	0	1	0	0	0	0	0	0	0	0	0	0
L55W	0	0	0	0	0	0	0	0	0	0	0	0
L70	0	0	0	0	0	0	0	0	0	0	0	0

Table D.3. *Call Survey Specific Covariates for April 2011.* Covariates recorded during call surveys include Julian date (Year, Day of Year), time, wind speed, air temperature, water temperature, and moonshine during each survey conducted. Each site was visited twice during the month.

	Julian Date		Time		Wind (kph)		Air Temperature (°C)		Water Temperature (°C)		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	11103	11110	23:01	23:35	2.4	1.0	21.9	9.7	15.8	9.3	0.23	0.58
H11	11103	11111	23:31	23:21	1.6	5.6	18.1	10.5	17.2	9.3	0.23	0.05
H12	11102	11111	20:36	23:49	0.0	2.7	20.2	13.4	18.0	65.5	0.41	0.05
H14	11102	11111	21:01	23:57	0.0	2.6	18.7	14.0	14.2	8.7	0.28	0.05
H15F	11102	11109	21:22	22:28	0.0	4.5	19.5	5.8	15.9	6.1	0.28	0.00
H15S	11102	11109	21:20	22:25	0.0	4.5	20.8	5.8	15.6	6.2	0.28	0.00
H34	11102	11109	23:23	20:51	1.4	1.8	18.0	1.4	13.4	7.5	0.28	0.00
H59	11102	11109	21:44	22:07	0.0	3.9	20.3	4.4	13.3	7.0	0.28	0.00
H64	11102	11109	22:47	21:07	0.0	2.9	20.8	3.1	17.7	8.3	0.35	0.00
H65N	11102	11109	23:02	21:09	0.0	2.9	18.8	3.1	16.7	8.1	0.28	0.00
H65S	11102	11109	23:05	21:09	1.3	2.9	18.8	3.1	18.7	9.1	0.28	0.00
K02	11107	11112	23:40	20:38	0.0	1.9	11.2	15.1	11.2	13.6	0.58	0.78
K06	11107	11112	23:21	20:58	1.3	0.0	11.2	15.8	12.9	13.4	0.58	0.78
K07	11107	11112	23:06	21:12	1.3	0.0	12.7	14.1	10.7	12.8	0.58	0.78
K10	11103	11112	21:51	22:23	1.3	2.9	17.4	16.9	17.0	13.7	0.04	0.78
K23	11107	11112	22:49	21:26	2.1	0.2	14.9	11.5	41.1	12.2	0.56	0.78
K24	11107	11112	22:52	21:32	5.6	0.0	11.5	15.2	12.7	11.0	0.56	0.78
K25	11103	11112	21:06	21:58	8.7	5.1	17.9	15.9	16.8	11.9	0.04	0.78
K27	11103	11112	21:18	22:00	1.8	2.4	18.8	15.0	18.8	13.7	0.04	0.78
K30	11107	11110	21:56	21:42	1.4	3.1	14.1	9.0	13.4	12.6	0.19	0.73
K32	11107	11110	20:46	20:48	4.8	1.0	14.6	9.8	13.4	12.0	0.50	0.73
K56I	11107	11110	22:23	22:11	8.4	1.4	13.6	9.5	12.7	12.0	0.56	0.58
K56O	11107	11110	22:24	22:10	7.1	1.0	13.2	9.1	13.2	9.7	0.56	0.58
K57N	11107	11110	21:04	21:06	2.3	1.0	14.4	9.8	13.6	11.5	0.19	0.73
K57S	11107	11110	21:05	21:06	3.5	1.4	14.6	10.9	14.0	14.0	0.19	0.73
K66	11103	11112	20:26	22:19	10.0	3.9	20.4	16.7	16.8	12.4	0.33	0.78
K67F	11103	11112	20:42	22:44	10.0	14.6	20.4	15.9	16.0	13.0	0.33	0.78
K67S	11103	11112	20:25	22:45	10.0	14.6	20.4	15.9	18.6	12.2	0.33	0.78
K68	11103	11110	21:51	21:57	1.9	0.0	17.1	8.8	16.8	11.0	0.04	0.73
K69	11103	11110	20:26	21:40	10.0	1.3	20.4	9.1	18.6	7.4	0.33	0.73
K71	11103	11110	20:26	21:24	10.0	1.9	20.4	10.9	17.8	7.7	0.33	0.73

Table D.3. *Call Survey Specific Covariates for April 2011, continued.*

	Julian Date		Time		Wind (kph)		Air Temperature (°C)		Water Temperature (°C)		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	11101	11111	21:43	20:49	0.0	5.1	11.2	11.1	15.5	10.4	0.47	0.05
L39	11101	11111	22:11	21:05	1.9	4.0	12.7	10.9	14.2	10.3	0.47	0.12
L43	11101	11111	23:06	21:54	5.1	7.2	10.1	10.1	10.8	9.9	0.47	0.12
L44	11101	11111	23:38	22:15	1.4	3.7	9.6	10.3	10.4	9.3	0.47	0.29
L46	11101	11111	23:52	22:20	3.9	8.0	8.7	10.1	17.2	11.1	0.47	0.29
L51	11101	11111	21:01	20:31	2.1	0.0	13.3	12.8	17.4	11.4	0.47	0.05
L54E	11101	11111	22:48	21:38	2.9	6.8	12.3	10.4	12.7	10.0	0.47	0.12
L54W	11101	11111	22:48	21:39	1.9	8.9	14.6	10.8	13.8	11.4	0.47	0.12
L55E	11101	11111	23:21	22:59	3.1	9.8	11.8	10.5	17.7	10.9	0.47	0.29
L55W	11101	11111	23:21	21:58	3.5	9.8	12.6	10.5	14.9	10.1	0.47	0.12
L70	11101	11111	22:30	21:22	1.3	1.9	15.1	10.6	15.9	10.3	0.47	0.12

Table D.4. *Tadpole Survey Specific Covariates for April 2011.* Covariates include: Julian date (Year, Day of Year), time, water temperature, air temperature, and wind speed.

	Julian Date		Time		Water Temperature (◦C)		Wind Speed (kph)		Air Temperature (◦C)	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	11125	11125	9:52	10:20	13.5	14.1	3.1	1.9	15.2	21.2
H11	11125	11125	10:31	9:36	16	15.4	2.6	2.3	18.3	18.6
H12	11117	11117	15:54	15:40	13.2	14.8	1.7	5.7	16.8	15.8
H14	11117	11117	14:18	15:40	15.8	14.8	3.5	5.7	16.7	15.8
H15F	11117	11117	12:23	13:06	*17.1	17.1	*7	5.7	*14.8	13.3
H15S	11117	11117	12:03	13:19	15.9	16	10.5	6.7	12.9	12.8
H34	11116	11116	12:11	14:50	12	13.2	5	1.8	12.9	16.0
H59	11117	11117	16:52	10:24	15.5	12	5.5	2.2	17.7	12.4
H64	11116	11116	13:27	14:20	12.3	14.7	2.3	0.2	14.3	17.3
H65N	11116	11116	13:11	14:17	12.9	12.7	2.8	1.4	14.0	17.8
H65S	11116	11116	13:37	12:31	12.7	12.1	3.9	4	14.7	12.3
K02	11118	11118	12:47	13:25	18.5	17.9	0	0.1	24.8	24.3
K06	11118	11117	12:38	11:52	13.8	13.5	1.5	2.8	23.9	21.9
K07	11118	11118	13:38	11:43	21.4	13.5	3.5	3.9	21.4	20.8
K10	11126	11126	12:27	12:55	20.3	23.6	3.9	5.1	25.3	27.2
K23	11118	11118	22:08	11:19	*12.9	12.9	1.1	4.1	17.3	20.3
K24	11118	11118	22:56	10:15	13.5	13.5	2.7	3.1	19.7	20.7
K25	11126	11126	23:40	11:04	15.6	15.4	9.3	3.7	23.2	25.8
K27	11126	11126	11:13	11:42	16.2	15.8	5.6	11.3	23.8	26.1
K30	11125	11125	14:59	14:31	17.6	17.6	3.7	0	23.5	24.3
K32	11125	11125	11:54	12:38	14.6	16.5	3.2	0.8	22.7	23.7
K56I	11126	11126	9:40	10:27	15.9	14.4	5	7.3	19.4	22.7
K56O	11126	11126	10:34	10:06	14.3	14.1	6.9	7.3	19.3	19.6
K57N	11125	11125	13:01	13:30	14.4	14.5	3.2	1.3	22.0	19.3
K57S	11125	11125	13:03	13:31	21.6	14.9	6.5	3.5	17.1	21.2
K66	11122	11123	11:55	14:18	20.2	21.9	0.8	4	18.7	16.8
K67F	11123	11123	14:34	11:55	25.9	22.3	1.6	0.9	19.0	19.6
K67S	11123	11123	13:49	10:52	17.9	16.5	0.2	3.2	20.5	19.4
K68	11126	11126	12:59	12:21	18.1	*18.1	5.7	2.6	25.3	28.1
K69	11123	11123	11:21	13:15	15.5	17.9	1	3.5	17.4	15.3
K71	11123	11123	15:16	13:15	17.4	18.2	2.5	0.8	19.2	20.4

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table D.4. *Tadpole Survey Specific Covariates for April 2011, continued.*

	Julian Date		Time		Water Temperature (◦C)		Wind Speed (kph)		Air Temperature (◦C)	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	11119	11119	11:48	12:36	17.6	18.9	6.8	3.7	24.2	27.5
L39	11119	11119	13:16	14:08	18.9	19.4	12.1	9.5	26.4	25.9
L43	11122	11122	11:59	12:46	18.6	20.2	5.7	3.6	16.9	20.7
L44	11122	11122	13:43	14:14	18.4	18.6	1.9	4.8	16.9	23.8
L46	11122	11122	14:11	13:35	17.9	18.1	3.4	4.1	17.0	23.7
L51	11119	11119	11:02	11:56	14.1	15.2	5.4	9	21.9	23.1
L54E	11122	11122	11:08	10:25	15.5	13.5	9.1	6.1	18.9	15.8
L54W	11122	11122	11:09	10:13	13.2	12.4	10.1	5.3	14.3	13.8
L55E	11122	11122	13:03	12:13	21.9	19.9	8.6	3.4	14.8	19.0
L55W	11122	11122	12:34	11:48	17.2	15.4	3.3	7.9	17.9	18.6
L70	11119	11119	14:13	13:30	14.6	14.7	13.6	10.2	26.8	25.1

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table D.5. *Site Specific Wetland Characteristics April 2011.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include: wetland size and type, bend, distance to nearest wetland, slope, and presence of emergent vegetation.

SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland (m)	Slope (0-1m)	Emergent Vegetation	Aquatic Vegetation % Woody	% Herby	% Open
H09	Large	Tributary	Hamburg	737.35	0.38	0	0.625	0.225	0.15
H11	Small	Scour Hole	Hamburg	737.35	0.33	0	0.625	0.35	0.025
H12	Medium	Tributary	Hamburg	1770.79	0.62	0	1	0	0
H14	Medium	Tributary	Hamburg	146.14	0.08	0	1	0	0
H15F	Medium	Ephemeral, unfarmed	Hamburg	132.00	0.08	1	0	0.6	0.4
H15S	Small	Tributary	Hamburg	132.00	0.14	1	0.925	0.025	0.05
H34	Small	Ephemeral, farmed	Hamburg	363.33	0.15	1	0.3	0.65	0.025
H59	Small	Ground Fed Permanent	Hamburg	325.08	0.44	0	0.875	0.05	0.075
H64	Small	Ditch	Hamburg	430.53	0.28	1	0.45	0.075	0.475
H65N	Small	Ditch	Hamburg	5.62	0.14	1	0.425	0.35	0.225
H65S	Small	Ditch	Hamburg	5.62	0.47	1	0.825	0.025	0.15
K02	Small	Ephemeral, unfarmed	Kansas	332.86	0.14	1	0.225	0.675	0.1
K06	Medium	Ephemeral, unfarmed	Kansas	364.68	0.36	0	0.925	0.025	0.05
K07	Small	Ground Fed Permanent	Kansas	367.12	0.14	0	0.425	0.5	0.05
K10	Large	Ground Fed Permanent	Kansas	332.86	0.13	1	0.025	0.95	0.025
K23	Medium	Tributary	Kansas	171.23	*0.78	0	0.55	0	0
K24	Medium	Tributary	Kansas	657.94	0.40	0	0.95	0	0.05
K25	Small	Impoundment	Kansas	680.94	0.15	1	0.05	0.925	0.025
K27	Large	Impoundment	Kansas	171.23	0.19	1	0.45	0.425	0.075
K30	Medium	Ephemeral, unfarmed	Kansas	872.41	0.21	1	0.1	0.65	0.25
K32	Small	Ground Fed Permanent	Kansas	730.00	0.19	1	0.575	0.375	0.05
K56I	Small	Ditch	Kansas	95.62	0.24	0	0.25	0.425	0.275
K56O	Small	Ephemeral, unfarmed	Kansas	95.62	0.18	0	0.375	0.525	0.1
K57N	Small	Ditch	Kansas	53.54	0.28	0	0.5	0.175	0.325
K57S	Small	Ephemeral, unfarmed	Kansas	53.54	0.09	1	0	0.9	0.075
K66	Small	Impoundment	Kansas	93.65	0.14	1	0.425	0.9	0
K67F	Large	Impoundment	Kansas	43.22	0.11	1	0	1	0
K67S	Medium	Tributary	Kansas	37.92	0.30	0	1	0	0.125
K68	Large	Tributary	Kansas	443.77	*0.65	0	1	0	0
K69	Medium	Impoundment	Kansas	31.00	0.39	0	0.9	0.1	0.275
K71	Large	Tributary	Kansas	31.00	0.38	0	0.825	0	0.175

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table D.5. *Site Specific Wetland Characteristics April 2011, continued.*

SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland (m)	Slope (0-1m)	Emergent Vegetation	Aquatic Vegetation % Woody	% Herby	% Open
L37	Medium	Ground Fed Permanent	Langdon	379.09	0.16	1	1	0	0
L39	Small	Ephemeral, farmed	Langdon	573.96	0.11	0	0.525	0.475	0
L43	Medium	Ground Fed Permanent	Langdon	442.18	0.06	0	0.825	0.175	0
L44	Small	Ditch	Langdon	599.78	0.11	1	0.125	0.525	0.15
L46	Medium	Ditch	Langdon	843.15	0.50	0	0.525	0	0.475
L51	Small	Ephemeral, farmed	Langdon	14.28	0.13	1	0.125	0.875	0
L54E	Medium	Ephemeral, unfarmed	Langdon	89.70	0.12	1	0.075	0.925	0
L54W	Small	Ground Fed Permanent	Langdon	89.70	0.15	0	1	0	0
L55E	Large	Ditch	Langdon	86.07	0.19	0	0.2	0.6	0.075
L55W	Large	Ditch	Langdon	86.07	0.24	1	1	0	0
L70	Large	Backwater	Langdon	1124.55	0.25	0	0.4	0.55	0.05

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table D.6. *Site Specific Landscape Characteristics April 2011.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include adjacent land cover and terrestrial vegetation.

	Adjacent Land Cover (1000m2)			Terrestrial Vegetation			
SITE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
H09	0.00	0.00	0.03	0.5	0.25	0.25	0
H11	0.00	0.00	0.03	0.7	0.225	0.075	0
H12	0.45	0.03	0.41	0	0.55	0.475	0
H14	0.39	0.06	0.25	0.35	0.3	0.375	0
H15F	0.29	0.02	0.49	0.825	0.11	0.065	0
H15S	0.36	0.07	0.38	0.8	0.15	0.105	0
H34	0.08	0.00	0.66	0.65	0.175	0.15	0.025
H59	0.43	0.00	0.13	0.325	0.6	0.9	0
H64	0.27	0.00	0.17	0.1	0.525	0.35	0.025
H65N	0.16	0.00	0.43	0.1	0.575	0.3	0.025
H65S	0.16	0.00	0.43	0.15	0.6	0.25	0
K02	0.29	0.03	0.08	0.2	0.325	0.425	0.05
K06	0.37	0.06	0.07	0.15	0.35	0.5	0
K07	0.45	0.01	0.18	0.2	0.4	0.3	0.1
K10	0.10	0.00	0.20	0.55	0.175	0.275	0
K23	0.50	0.00	0.13	0.325	0.175	0.3	0.15
K24	0.38	0.04	0.03	0.25	0.25	0.5	0
K25	0.00	0.00	0.24	0.45	0.5	0.05	0
K27	0.38	0.00	0.12	0.45	0.325	0.075	0.15
K30	0.00	0.00	0.35	0.275	0.5	0.225	0
K32	0.00	0.00	0.44	0.7	0.2	0.1	0
K56I	0.00	0.00	0.34	0.5	0.225	0.275	0
K56O	0.01	0.00	0.29	0.425	0.425	0.075	0.05
K57N	0.00	0.00	0.45	0.025	0.35	0.625	0
K57S	0.00	0.00	0.52	0.4	0.6	0	0
K66	0.01	0.00	0.58	0.805	0.08	0.015	0.1
K67F	0.01	0.00	0.60	0.9	0.05	0	0.05
K67S	0.01	0.00	0.58	0.625	0.265	0.15	0
K68	0.03	0.00	0.32	0.8	0.1	0.1	0
K69	0.01	0.00	0.59	0.8	0.175	0.025	0
K71	0.01	0.00	0.57	0.6	0.2	0.2	0

Table D.6. *Site Specific Landscape Characteristics April 2011, continued.*

	Adjacent Land Cover (1000m2)			Terrestrial Vegetation			
SITE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
L37	0.00	0.00	0.31	0.475	0.2	0.2	0
L39	0.00	0.00	0.43	0.4	0.175	0.425	0
L43	0.00	0.00	0.90	0.2	0.225	0.025	0.55
L44	0.21	0.10	0.49	0.35	0.3	0.35	0
L46	0.01	0.00	0.67	0.5	0.15	0.325	0.025
L51	0.00	0.00	0.23	0.3	0.3	0.4	0
L54E	0.00	0.00	0.94	0.275	0.175	0.1	0.45
L54W	0.00	0.00	0.97	0.3	0.1	0.05	0.55
L55E	0.05	0.01	0.79	0.725	0.25	0.025	0
L55W	0.04	0.00	0.82	0.175	0.05	0.075	0.7
L70	0.01	0.00	0.26	0.6	0	0.4	0

Appendix E: May, 2011

Table E.1. *May 2011 Call Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) by a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	1	0	1	0	0	0	1	0
H11	0	0	0	0	1	0	1	1	0	0	1	0
H12	0	0	0	0	1	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15S	0	0	0	0	0	0	0	0	0	0	0	0
H18	1	1	1	1	1	1	1	1	0	0	1	0
H34	0	1	1	0	1	0	0	0	0	0	0	0
H59	0	1	1	1	1	1	1	1	0	0	1	0
H61	0	1	0	1	0	1	0	1	0	0	0	1
H63	0	1	0	0	0	1	1	1	0	0	1	1
H64	0	0	0	0	1	0	0	0	0	0	0	0
H65N	0	0	1	0	1	0	0	0	0	0	0	0
H65S	0	0	1	1	1	1	1	1	0	0	0	1
K07	1	1	0	1	0	1	0	1	0	0	0	1
K10	0	0	0	1	0	0	0	0	0	0	0	0
K23	0	0	0	0	0	0	0	0	0	0	0	0
K24	0	0	0	1	0	1	0	1	0	0	0	0
K25	0	0	0	1	0	1	0	1	0	0	0	0
K27	1	0	0	1	0	1	0	1	0	0	0	0
K30	1	1	1	1	0	1	1	1	0	0	0	0
K32	1	0	1	0	0	0	0	1	0	0	0	0
K56I	0	0	1	1	0	1	0	1	0	0	0	0
K56O	0	0	0	0	0	0	0	1	0	0	0	0
K57N	0	0	0	0	0	0	0	1	0	0	0	0
K57S	0	0	0	1	0	1	1	1	0	0	0	0
K66	0	0	0	1	0	1	0	1	0	0	0	0
K67F	0	0	0	1	0	1	0	1	0	0	0	0
K67S	0	1	0	0	0	0	0	0	0	0	0	0
K68	0	0	0	0	0	0	0	0	0	0	0	0
K69	1	0	0	1	0	1	0	1	0	0	0	0
K71	0	0	0	0	0	0	0	0	0	0	0	0

Table E.1. *May 2011 Call Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L39	0	1	1	0	1	0	1	1	0	0	1	0
L43	0	0	1	0	1	0	0	0	0	0	0	0
L46	1	0	1	1	1	0	1	0	0	0	0	0
L51	0	1	1	0	1	0	0	1	0	0	1	0
L54E	0	0	1	0	1	0	1	0	0	0	0	0
L54W	0	0	1	0	0	0	1	1	0	0	0	0
L55E	0	1	1	0	0	0	0	1	0	0	0	0
L55W	0	0	1	0	1	0	0	1	0	0	1	0

Table E.2. *May 2011 Tadpole Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) as a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	0	0	1	1	0	0	0	0
H11	0	0	0	0	0	0	1	1	0	1	0	0
H12	0	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15S	0	0	0	0	0	0	0	0	0	0	0	0
H18	0	0	0	0	0	0	0	1	0	0	0	0
H34	1	1	0	0	0	0	1	1	0	0	0	0
H59	0	0	0	0	0	0	0	0	0	0	0	0
H61	0	0	0	0	0	0	1	1	0	0	0	0
H63	0	1	0	0	0	0	1	1	0	0	0	0
H64	0	0	0	0	0	0	0	0	0	1	0	0
H65N	0	0	0	0	0	0	0	0	1	0	0	0
H65S	0	0	0	0	0	0	1	0	0	0	0	0
K07	1	1	0	0	0	0	1	0	0	0	0	0
K10	1	1	0	0	0	0	0	0	0	0	0	0
K23	0	0	0	0	0	0	0	0	0	0	0	0
K24	0	1	0	0	0	0	1	1	1	0	0	0
K25	1	1	0	0	0	0	1	1	0	0	0	0
K27	1	1	0	0	0	0	1	1	0	1	0	0
K30	0	1	0	0	0	0	1	0	0	0	0	0
K32	1	0	0	0	0	0	1	1	0	0	0	0
K56I	1	0	0	0	0	0	0	0	0	0	0	0
K56O	1	1	0	0	0	0	0	0	0	0	0	0
K57N	0	1	0	0	0	0	1	1	0	0	0	0
K57S	1	1	0	0	0	0	1	1	0	0	0	0
K66	0	0	0	0	0	0	1	1	0	0	0	0
K67F	0	0	0	0	0	0	0	0	0	0	0	0
K67S	0	0	0	0	0	0	0	0	1	1	0	0
K68	0	0	0	0	0	0	0	0	0	0	0	0
K69	0	0	0	0	0	0	1	1	0	0	0	0
K71	0	0	0	0	0	0	0	0	1	1	0	0

Table E.2. *May 2011 Tadpole Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	1	1	0	0	0	0	1	1	0	0	0	0
L39	0	1	0	0	0	0	1	1	0	0	0	0
L43	0	1	0	0	0	0	1	1	0	0	1	0
L46	1	0	0	0	0	0	0	0	0	0	0	0
L51	1	0	0	0	0	0	1	1	0	0	0	0
L54E	1	1	0	0	0	0	1	1	0	0	0	0
L54W	0	0	0	0	0	0	1	0	0	0	0	0
L55E	0	1	0	0	0	0	1	1	0	0	0	0
L55W	0	0	0	0	0	0	0	0	0	0	0	0

Table E.3. *Call Survey Specific Covariates for May 2011.* Covariates recorded during call surveys include Julian date (Year, Day of Year), time, wind speed, air temperature, water temperature, and moonshine. Each site was visited twice during the month.

	Julian Date		Time		Water Temperature (°C)		Wind Speed (kph)		Air Temperature (°C)		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	11130	11136	21:12	21:37	22.3	14.5	2.1	0.0	29.1	16.4	0.30	0.89
H11	11130	11136	21:27	21:50	26.8	16.3	4.8	0.0	28.0	16.1	0.30	0.89
H12	11130	11136	22:01	22:33	25.8	16.8	0.0	0.0	25.9	17.9	0.30	0.89
H14	11130	11136	22:28	22:58	21.8	12.0	0.0	1.1	27.3	13.9	0.30	0.89
H15S	11130	11136	22:56	22:47	22.9	12.8	0.0	0.0	26.8	14.5	0.30	0.89
H18	11130	11136	22:16	22:10	*24.4	*15.9	0.0	0.0	28.3	15.7	0.30	0.89
H34	11130	11136	20:55	21:05	24.4	19.3	2.4	1.9	28.2	18.4	0.30	0.89
H59	11130	11136	22:35	22:28	27.2	16.8	0.0	0.0	27.7	16.1	0.30	0.89
H61	11130	11136	21:54	21:55	24.3	15.7	1.1	0.0	27.5	15.7	0.30	0.89
H63	11130	11136	21:44	22:05	25.2	17.8	9.2	0.0	28.1	16.1	0.30	0.89
H64	11130	11136	21:36	21:39	23.6	14.7	1.3	0.0	28.9	14.8	0.30	0.89
H65N	11130	11136	21:17	21:21	24	16.0	1.8	1.9	29.2	18.3	0.30	0.89
H65S	11130	11136	21:15	21:20	24.9	18.2	6.8	1.9	28.6	18.3	0.30	0.89
K07	11133	11137	22:58	22:43	10.3	15.5	5.0	0.0	10.8	15.4	0.00	0.70
K10	11133	11137	23:54	23:31	12.3	15.2	4.7	2.3	11.4	14.6	0.13	0.70
K23	11133	11137	22:41	22:30	13.5	19.0	2.9	1.1	10.8	17.1	0.00	0.70
K24	11133	11137	22:17	22:08	16.8	17.6	2.1	0.0	11.9	16.3	0.00	0.70
K25	11133	11137	23:28	22:59	12.3	18.9	11.1	0.0	9.9	14.3	0.13	0.70
K27	11133	11137	23:12	23:09	11.6	17.6	8.9	0.0	10.1	14.3	0.13	0.70
K30	11133	11137	22:15	22:04	11.7	16.7	8.4	2.4	9.9	14.7	0.00	0.70
K32	11133	11137	21:07	21:05	15.1	16.0	20.4	5.6	10.1	18.9	0.26	0.63
K56I	11133	11137	22:46	22:39	12	17.8	8.5	1.8	9.7	16.2	0.00	0.70
K56O	11133	11137	22:44	22:38	13.4	16.7	8.5	1.8	9.7	16.2	0.00	0.70
K57N	11133	11137	21:29	21:26	13.2	16.1	7.6	4.7	10.5	15.8	0.26	0.63
K57S	11133	11137	21:32	21:28	14.2	19.0	7.6	4.7	10.5	15.8	0.26	0.63
K66	11133	11137	21:27	21:15	11.4	14.7	10.6	1.3	10.1	18.2	0.26	0.63
K67F	11133	11137	21:14	21:15	12.8	16.1	5.5	2.7	10.8	14.7	0.26	0.63
K67S	11133	11137	20:59	21:03	*13	18.5	10.1	1.3	10.3	18.2	0.17	0.63
K68	11133	11137	0:06	23:29	*13	18.6	14.0	4.8	10.0	13.6	0.10	0.70
K69	11133	11137	21:14	21:01	14.3	17.6	10.6	1.3	10.1	18.2	0.26	0.63
K71	11133	11137	21:27	21:28	*13	18.1	10.6	1.3	10.1	13.1	0.26	0.63

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table E.3. *Call Survey Specific Covariates for May 2011, continued.*

	Julian Date		Time		Water Temperature (°C)		Wind Speed (kph)		Air Temperature (°C)		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L39	11129	11135	21:24	21:24	22.7	13.6	16.9	0.0	29.1	15.4	0.30	0.93
L43	11129	11135	22:20	22:10	21.9	10.7	13.0	0.0	28.3	11.6	0.26	0.93
L46	11129	11135	23:03	22:34	24.1	12.6	3.9	0.0	27.6	12.2	0.26	0.93
L51	11129	11135	20:55	21:01	23.0	13.3	13.8	2.4	29.4	14.7	0.30	0.93
L54E	11129	11135	22:02	21:52	22.9	11.1	13.0	0.0	28.4	12.6	0.26	0.93
L54W	11129	11135	22:03	21:52	23.5	11.9	15.3	0.0	23.5	11.8	0.26	0.93
L55E	11129	11135	22:26	22:13	24.7	11.7	10.8	3.7	28.0	11.3	0.26	0.93
L55W	11129	11135	22:26	21:14	25.1	12.4	10.8	3.7	28.0	11.3	0.26	0.93

Table E.4. *Tadpole Survey Specific Covariates for May 2011*. Covariates include: Julian date (Year, Day of Year), time, water temperature, air temperature, and wind speed.

	Julian Date		Time		Water Temperature (°C)		Wind Speed (kph)		Air Temperature (°C)	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	11155	11155	11:43	12:15	*23	23	*1.0	2.4	.	29.1
H11	11155	11155	12:18	11:40	*22.9	22.9	*5.5	0.0	.	27.3
H12	11147	11147	14:08	13:21	16.8	17	0.0	0.0	21.7	18.4
H14	11147	11147	12:30	11:03	14.3	13.5	4.8	10.0	18.4	17.0
H15S	11147	11147	11:20	12:25	15.3	15.1	0.0	2.3	17.9	19.8
H18	11151	11151	11:25	11:57	19.2	19.4	3.2	3.4	25.8	27.1
H34	11146	11146	9:43	11:41	15.7	18.9	3.5	1.4	19.4	29.0
H59	11146	11146	13:22	12:50	17.8	17.2	3.4	2.6	21.7	21.7
H61	11151	11151	10:30	10:59	22.9	23.5	2.6	4.0	24.9	27.8
H63	11155	11155	11:04	12:51	22.7	*22.7	1.8	*7.1	26.9	.
H64	11146	11146	10:33	12:01	14.7	16.5	0.0	1.3	22.8	22.3
H65N	11146	11146	10:09	11:20	17.1	8.9	3.9	10.3	21.1	16.6
H65S	11146	11146	10:35	9:45	18.5	18.6	15.6	12.1	16.3	20.5
K07	11153	11153	11:45	10:42	27.6	27.8	7.7	2.7	28.2	28.4
K10	11154	11153	11:26	14:00	*29.4	29.4	*4.2	2.7	.	30.0
K23	11152	11152	14:12	13:37	21.7	21.6	0.0	1.8	29.5	29.4
K24	11155	11155	16:57	16:34	*23.7	23.7	*8.3	1.9	.	28.6
K25	11154	11154	11:19	12:05	22.3	23.7	4.2	2.1	32.6	34.7
K27	11154	11154	12:01	11:23	28.9	27.7	4.2	8.9	34.6	33.5
K30	11155	11155	15:50	15:14	*24.1	24.1	*8.3	1.4	.	32.6
K32	11155	11155	14:44	14:13	*25.3	25.3	*1.9	4.2	.	28.8
K56I	11154	11154	13:41	13:10	*26.1	26.1	12.9	14.2	32.7	32.7
K56O	11154	11154	13:49	13:11	*24.1	24.1	*14.2	12.9	.	32.6
K57N	11154	11154	14:23	15:07	24.6	*24.6	15.4	18.0	33.1	33.5
K57S	11154	11154	14:23	15:07	30.4	17.7	15.4	18.0	34.1	33.5
K66	11152	11151	14:30	14:58	30.5	29.6	7.7	4.2	30.2	29.7
K67F	11152	11152	12:18	10:13	25.8	22.4	6.0	6.3	27.1	25.9
K67S	11152	11152	11:34	10:45	22.6	21.8	2.4	3.5	32.2	26.4
K68	11153	11153	14:00	14:47	24.8	24.8	10.6	5.5	28.6	30.0
K69	11151	11151	13:35	14:03	26.8	25.6	3.5	0.0	28.2	29.4
K71	11152	11152	11:30	10:35	22.4	22.7	2.3	0.0	30.2	27.1

* Data were missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table E.4. *Tadpole Survey Specific Covariates for May 2011, continued.*

	Julian Date		Time		Water Temperature (°C)		Wind Speed (kph)		Air Temperature (°C)	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	11157	11157	18:45	18:08	26.2	*26.2	2.9	.	34.9	.
L39	11157	11157	19:18	18:21	25.9	26.3	4.8	10.1	33.8	34.3
L43	11154	11155	13:21	12:45	29.9	*29.9	5.3	*6.3	31.0	.
L46	11155	11155	11:44	12:23	26.1	*26.1	0.0	*2.6	29.9	.
L51	11157	11157	17:59	18:40	26.6	*26.6	13.7	.	34.3	.
L54E	11154	11155	14:47	15:19	29.1	*29.1	2.3	4.2	31.7	.
L54W	11154	11155	15:22	14:42	26.2	*26.2	2.9	.	31.3	.
L55E	11154	11155	12:17	13:19	25.8	*25.8	7.9	*7.6	26.9	.
L55W	11155	11154	13:35	12:48	*26.3	26.3	*3.5	5.8	.	30.7

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table E.5. *Site Specific Wetland Characteristics May 2011.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include: wetland size and type, bend, distance to nearest wetland, slope, and presence of emergent vegetation.

							Aquatic Vegetation		
SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland	Slope (0-1m)	Emergent Vegetation	% Wood	% Herb	% Open
H09	Large	Tributary	Hamburg	0.7373	0.25	0	0	1	0
H11	Small	Scour Hole	Hamburg	0.7373	0.28	0	0	1	0
H12	Medium	Tributary	Hamburg	1.7708	0.60	1	0.25	0.25	0.5
H14	Medium	Tributary	Hamburg	0.1461	0.06	0	0	0.2	0.8
H15S	Small	Tributary	Hamburg	0.1320	0.30	1	0.125	0.875	0
H18	Small	Ground Fed Permanent	Hamburg	1.0730	0.59	0	0.175	0.125	0.7
H34	Small	Ephemeral, farmed	Hamburg	0.3633	0.12	1	0.05	0.75	0.2
H59	Small	Ground Fed Permanent	Hamburg	0.3251	0.37	0	0.275	0.325	0.4
H61	Medium	Ephemeral, unfarmed	Hamburg	0.9904	0.10	0	0	1	0
H63	Medium	Ephemeral, unfarmed	Hamburg	1.2396	0.33	0	0	1	0
H64	Small	Ditch	Hamburg	0.4305	0.21	1	0.825	0.1	0.075
H65N	Small	Ditch	Hamburg	0.0056	0.22	1	0.125	0.85	0.025
H65S	Small	Ditch	Hamburg	0.0056	0.24	1	0.2	0.775	0.025
K07	Small	Ground Fed Permanent	Kansas	0.3671	0.13	1	0.05	0.5	0.45
K10	Large	Ground Fed Permanent	Kansas	0.3329	0.14	1	0	0.9	0.1
K23	Medium	Tributary	Kansas	0.1712	0.78	0	0.05	0.1	0.85
K24	Medium	Tributary	Kansas	0.6579	0.20	0	0	0.27	0.73
K25	Small	Impoundment	Kansas	0.6809	0.18	1	0	1	0
K27	Large	Impoundment	Kansas	0.1712	0.26	1	0	0.875	0.125
K30	Medium	Ephemeral, unfarmed	Kansas	0.8724	0.25	1	0	0.975	0.025
K32	Small	Ground Fed Permanent	Kansas	0.7300	0.35	0	0	1	0
K56I	Small	Ditch	Kansas	0.0956	0.26	1	0.075	0.7	0.225
K56O	Small	Ephemeral, unfarmed	Kansas	0.0956	0.30	0	0	1	0
K57N	Small	Ditch	Kansas	0.0535	0.45	0	0.6	0.35	0.05
K57S	Small	Ephemeral, unfarmed	Kansas	0.0535	0.10	1	0.075	0.925	0
K66	Small	Impoundment	Kansas	0.0937	0.09	1	0.125	0.875	0
K67F	Large	Impoundment	Kansas	0.0432	0.10	1	0	1	0
K67S	Medium	Tributary	Kansas	0.0379	0.35	0	0.025	0.975	0
K68	Large	Tributary	Kansas	0.4438	0.90	0	0	1	0
K69	Medium	Impoundment	Kansas	0.0310	0.84	1	0	1	0
K71	Large	Tributary	Kansas	0.0310	0.46	0	0.1	0.9	0

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table E.5. *Site Specific Wetland Characteristics May 2011, continued.*

SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland	Slope (0-1m)	Emergent Vegetation	Aquatic Vegetation % Wood	 % Herb	 % Open
L37	Medium	Ground Fed Permanent	Langdon	0.3791	0.29	0	0	1	0
L39	Small	Ephemeral, farmed	Langdon	0.5740	0.32	0	0	0.95	0.05
L43	Medium	Ground Fed Permanent	Langdon	0.4422	0.07	1	0	0.275	0.725
L46	Medium	Ditch	Langdon	0.8431	*0.37	1	0.175	0.7	0.125
L51N	Small	Ephemeral, unfarmed	Langdon	0.0143	0.30	0	0	1	0
L54E	Medium	Ephemeral, unfarmed	Langdon	0.0897	0.12	1	0	0.95	0.05
L54W	Small	Ground Fed Permanent	Langdon	0.0897	0.11	1	0	0.8	0.2
L55E	Large	Ditch	Langdon	0.0861	0.41	1	0	0.55	0.45
L55W	Large	Ditch	Langdon	0.0861	0.29	1	0.025	0.375	0.6

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table E.6. *Site Specific Landscape Characteristics May 2011.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include adjacent land cover and terrestrial vegetation.

	Adjacent Land Cover			Terrestrial Vegetation			
SITE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
H09	0.00	0.00	0.03	0.55	0.3	0.15	0
H11	0.00	0.00	0.03	0.375	0.375	0.25	0
H12	0.45	0.03	0.41	0.3	0.075	0.625	0
H14	0.39	0.06	0.25	0.3	0.5	0.15	0.05
H15S	0.36	0.07	0.38	0.8	0.075	0.125	0
H18	0.28	0.02	0.24	0.05	0.25	0.65	0.05
H34	0.08	0.00	0.66	0.4	0.425	0.05	0.125
H59	0.43	0.00	0.13	0.125	0.525	0.35	0
H61	0.29	0.08	0.20	0.1	0.15	0.25	0.5
H63	0.01	0.00	0.50	0.6	0.275	0.125	0
H64	0.27	0.00	0.17	0.025	0.225	0.885	0
H65N	0.16	0.00	0.43	0.0625	0.4875	0.475	0
H65S	0.16	0.00	0.43	0.1	0.65	0.25	0
K07	0.45	0.01	0.18	0.2	0.35	0.35	0.1
K10	0.10	0.00	0.20	0.2	0.6	0.2	0
K23	0.50	0.00	0.13	0.4	0.4	0.2	0
K24	0.38	0.04	0.03	0.1	0.2	0	0.1
K25	0.00	0.00	0.24	0.7	0.15	0.15	0
K27	0.38	0.00	0.12	0.725	0.175	0.075	0.025
K30	0.00	0.00	0.35	0.175	0.7	0.125	0
K32	0.00	0.00	0.44	0.3	0.7	0	0
K56I	0.00	0.00	0.34	0.325	0.6	0.075	0
K56O	0.01	0.00	0.29	0.325	0.375	0.2	0
K57N	0.00	0.00	0.45	0.15	0.325	0.45	0.075
K57S	0.00	0.00	0.52	0.275	0.6375	0.0875	0
K66	0.01	0.00	0.58	0.775	0.125	0.1	0
K67F	0.01	0.00	0.60	0.6	0.2625	0.0875	0.05
K67S	0.01	0.00	0.58	0.475	0.425	0.075	0.025
K68	0.03	0.00	0.32	0.675	0.225	0.075	0.025
K69	0.01	0.00	0.59	0.8	0.145	0.055	0
K71	0.01	0.00	0.57	0.3	0.25	0.45	0

Table E.6. *Site Specific Landscape Characteristics May 2011, continued.*

	Adjacent Land Cover			Terrestrial Vegetation			
SITE	%forest	%field	%agriculture	Grasses	Herbs/ Forbs	Shrubs/ Trees	Crops/ Bare
L37	0.00	0.00	0.31	0.6	0.4	0	0
L39	0.00	0.00	0.43	0.625	0.375	0	0
L43	0.00	0.00	0.90	0.25	0.425	0	0.325
L46	0.01	0.00	0.67	0.125	0.45	0.35	0.075
L51N	0.00	0.00	0.26	0.375	0.425	0.2	0
L54E	0.00	0.00	0.94	0.3	0.55	0.05	0.1
L54W	0.00	0.00	0.97	0.4	0.525	0.025	0.05
L55E	0.05	0.01	0.79	0.35	0.5	0.03	0.12
L55W	0.04	0.00	0.82	0.475	0.365	0.01	0.35

Appendix F: June, 2011

Table F.1. *June 2011 Call Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) by a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	0	0	0	1	1	1	0	0	0	0	0
H11	0	0	0	1	1	1	0	0	0	0	0	0
H12	0	0	0	1	1	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15S	0	1	1	0	1	1	1	1	0	0	0	0
H18	0	0	1	1	1	0	0	0	0	0	0	0
H59	0	0	1	1	1	1	1	1	0	1	0	0
H63	0	0	0	1	0	1	0	1	0	1	0	0
K06	0	0	0	1	0	1	0	1	0	0	0	0
K07	0	0	1	1	1	1	0	0	1	0	0	0
K10	0	0	1	0	1	1	0	0	0	0	0	0
K23	0	0	1	0	1	0	0	0	0	0	0	0
K25	0	0	1	0	1	0	0	1	1	0	0	0
K27	0	0	1	0	1	0	0	0	1	0	0	0
K30	0	0	1	0	1	0	1	1	0	0	0	0
K56I	0	0	1	0	1	0	1	1	1	0	0	0
K57N	0	0	1	1	1	1	0	0	0	0	0	0
K57S	0	0	1	0	1	1	1	1	0	1	0	0
K66	0	0	1	1	1	0	0	0	0	0	0	0
K67F	0	0	1	1	1	1	1	1	0	0	0	0
K67S	0	0	0	1	0	1	0	1	0	1	0	0
K68	0	0	0	0	0	0	0	0	0	0	0	0
K69	0	0	1	0	1	1	0	0	1	1	0	0
K71	0	0	0	1	0	1	0	0	0	0	0	0

Table F.1. *June 2011 Call Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	0	0	0	0	1	0	0	0	0	0	0	0
L39	0	0	0	0	1	0	1	0	1	0	0	0
L43	0	0	0	1	0	1	0	1	0	1	0	0
L46	0	0	1	0	1	1	1	0	1	0	0	0
L51S	0	0	0	1	1	1	0	0	1	0	0	0
L54E	0	0	1	0	1	0	0	0	0	0	0	0
L54W	0	0	1	1	0	1	1	0	1	1	0	0
L55E	0	0	1	0	0	0	0	0	0	0	0	0
L55W	0	0	1	1	1	1	1	0	1	0	0	0
L70	0	0	0	0	1	0	1	1	0	0	0	0

Table F.2. *June 2011 Tadpole Survey Data.* Presence of a species is indicated by a 1 and absence (or failure to detect) by a 0. Each site was visited twice during the month.

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	0	1	0	0	0	0	1	1	0	0	0	0
H11	0	0	0	0	0	0	1	1	0	0	0	0
H12	0	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0	0
H15 F&S	1	1	0	0	0	0	1	1	0	0	0	0
H18	1	1	0	0	0	0	1	1	0	0	0	0
H59	0	1	0	0	0	0	0	0	0	0	0	0
H63	0	0	0	0	0	0	1	1	0	0	0	0
K06	0	0	0	0	0	0	0	0	1	0	0	0
K07	0	0	0	0	1	1	1	1	0	0	0	0
K10	0	0	0	0	0	0	1	0	0	0	0	0
K23	0	0	0	0	0	0	1	1	0	0	0	0
K25	0	0	0	0	0	0	1	1	0	0	0	0
K27	0	0	0	0	1	1	1	1	0	0	0	0
K30	0	0	0	1	0	1	1	1	0	0	0	0
K56I	0	0	0	0	1	1	1	0	0	0	0	0
K57N	0	0	0	0	0	0	1	1	0	0	0	0
K57S	0	1	0	0	1	1	1	1	0	0	0	0
K66	0	1	0	0	0	0	1	1	0	0	0	0
K67F	1	1	0	0	1	1	1	1	0	0	0	0
K67S	0	0	0	0	0	0	0	0	1	1	0	0
K68	0	0	0	0	0	0	0	0	0	1	0	0
K69	1	0	0	0	0	0	1	0	0	0	0	0
K71	0	0	0	0	0	0	0	0	1	1	0	0

Table F.2. *June 2011 Tadpole Survey Data, continued.*

	Western Chorus Frog		Northern Cricket Frog		Cope's Gray Treefrog		Plains Leopard Frog		American Bullfrog		Woodhouse's Toad	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	0	0	0	0	0	0	1	1	0	0	0	0
L39	0	0	0	0	0	0	1	1	0	0	0	0
L43	0	0	0	0	0	0	1	1	0	0	0	0
L46	0	0	0	0	0	0	0	0	1	1	0	0
L51 N&S	0	0	0	0	0	0	1	1	0	0	0	0
L54E	1	0	0	0	0	0	1	1	0	0	0	0
L54W	0	0	0	0	0	0	1	1	0	1	0	0
L55E	0	0	0	0	1	1	1	1	0	0	0	0
L55W	0	0	0	0	0	0	0	0	0	1	0	0
L70	0	0	0	0	0	0	1	1	0	1	0	0

Table F.3. *Call Survey Specific Covariates for June 2011.* Covariates recorded during call surveys include Julian date (Year, Day of Year), time, air temperature, water temperature, wind speed, and moonshine. Each site was visited twice during the month.

	Julian Date		Time		Wind Speed (kph)		Air Temperature (°C)		Water Temperature (°C)		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	11158	11161	22:32	21:25	10.3	2.9	29.7	18.5	24.0	21.7	0.27	0.58
H11	11158	11161	22:38	21:26	5.1	2.4	29.6	17.9	23.8	14.6	0.27	0.58
H12	11158	11161	23:36	21:29	0.0	0.0	28.5	19.0	27.5	22.2	0.27	0.58
H14	11158	11161	23:57	21:50	0.0	1.9	29.0	19.8	21.5	22.3	0.27	0.58
H15S	11158	11161	23:31	22:23	0.0	0.0	30.7	19.0	24.4	19.0	0.27	0.58
H18	11158	11161	22:51	22:23	0.0	3.1	28.9	19.3	24.6	18.0	0.27	0.57
H59	11158	11161	23:17	22:44	1.6	3.2	29.6	17.5	25.2	20.4	0.27	0.57
H63	11158	11162	23:00	21:32	3.7	0.0	29.4	23.1	23.9	25.3	0.27	0.58
K06	11159	11162	0:25	21:47	2.6	0.0	26.6	19.2	25.1	24.0	0.10	0.46
K07	11159	11162	23:51	21:50	2.9	1.8	26.4	20.2	23.3	22.3	0.17	0.46
K10	11159	11162	22:45	22:13	3.5	0.0	27.7	21.4	27.1	23.3	0.08	0.00
K23	11159	11162	23:52	22:15	3.2	0.0	25.5	20.5	25.6	20.7	0.17	0.46
K25	11159	11162	23:11	22:39	0.0	0.0	27.5	19.8	23.3	18.2	0.17	0.00
K27	11159	11162	23:30	22:43	0.0	0.0	26.2	20.6	24.8	20.5	0.17	0.00
K30	11159	11162	22:49	22:59	6.1	0.0	25.1	22.2	20.6	20.9	0.08	0.46
K56I	11159	11162	23:21	23:59	4.3	1.1	25.0	20.9	22.2	20.6	0.17	0.46
K57N	11159	11164	22:10	21:21	*4.0	9.0	*26.5	20.2	26.4	*20.5	0.08	0.46
K57S	11159	11164	22:07	21:22	1.9	9.0	25.8	20.2	25.6	*20.5	0.08	0.46
K66	11159	11164	21:54	21:25	4.0	3.9	27.2	21.9	25.8	19.9	0.19	0.46
K67F	11159	11164	22:10	21:25	4.0	3.9	27.2	21.9	25.5	*20.5	0.08	0.46
K67S	11159	11164	21:33	21:34	0.0	9.0	26.9	20.2	25.2	*20.5	0.19	0.46
K68	11159	11164	22:49	21:34	1.1	9.0	25.8	20.2	*24.8	*20.5	0.08	0.00
K69	11159	11164	21:39	21:44	0.0	2.1	26.9	21.4	27.2	20.6	0.19	0.46
K71	11159	11164	21:44	21:46	4.0	2.1	27.2	21.4	*24.8	20.2	0.19	0.46

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table F.3. *Call Survey Specific Covariates for June 2011, continued.*

	Julian Date		Time		Wind Speed (kph)		Air Temperature (°C)		Water Temperature (°C)		Moonshine	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	11157	11164	21:28	22:21	0.0	4.2	29.4	21.2	25.7	19.8	0.18	0.16
L39	11157	11164	21:50	22:23	3.4	1.1	29.3	22.0	25.2	*18.2	0.18	0.16
L43	11157	11164	22:35	22:43	7.2	0.0	28.8	22.1	23.2	*18.3	0.18	0.08
L46	11157	11164	23:03	22:43	7.6	16.6	28.3	21.1	27.4	20.0	0.18	0.13
L51S	11157	11164	21:27	22:58	3.7	10.9	29.5	20.2	25.4	17.3	0.18	0.16
L54E	11157	11164	22:16	22:59	7.4	10.9	28.8	20.2	25.4	20.2	0.18	0.08
L54W	11157	11164	22:18	23:17	4.5	4.8	29.6	21.3	25.6	18.9	0.18	0.08
L55E	11157	11164	22:36	23:24	8.4	5.1	28.9	20.7	27.1	*19.7	0.18	0.08
L55W	11157	11164	22:36	23:25	8.4	2.4	28.9	20.3	26.0	20.5	0.18	0.08
L70	11157	11164	21:55	23:43	5.1	1.0	28.9	20.3	25.0	20.3	0.18	0.08

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table F.4. *Tadpole Survey Specific Covariates for June 2011.* Covariates include: Julian date (Year, Day of Year), time, water temperature, wind speed, and air temperature.

	Julian Date		Time		Water Temperature (°C)		Wind Speed (kph)		Air Temperature (°C)	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
H09	11180	11180	11:46	11:13	23.9	23.8	4.2	10.5	30.0	25.9
H11	11180	11180	11:29	12:40	22.8	*22.8	5.5	*5.5	30.6	*30.1
H12	11172	11172	13:19	12:45	25.8	25.5	0.0	1.3	26.7	26.9
H14	11172	11172	12:16	11:34	22.6	22.9	3.5	1.8	26.6	24.7
H15 F&S	11172	11172	10:51	11:26	22.5	22.4	3.7	0.0	24.3	24.9
H18	11173	11173	12:12	11:40	21.6	21.5	1.8	0.0	22.0	21.0
H59	11173	11173	13:02	13:33	21.8	21.4	2.7	3.9	22.0	23.6
H63	11180	11180	13:09	12:11	22.6	25.4	5.0	6.0	32.3	27.9
K06	11171	11171	12:49	12:03	27.5	*27.5	2.3	*4.7	29.8	*31.6
K07	11171	11171	12:28	11:57	30.1	28.8	1.6	7.7	31.8	31.3
K10	11168	11168	14:11	13:21	31.8	31.3	0.0	1.6	34.6	32.8
K23	11171	11171	11:45	12:32	25.2	*25.2	5.3	*2.0	28.7	*30.8
K25	11171	11171	10:50	10:06	*23.1	23.1	*10.4	6.1	*27.2	26.3
K27	11171	11171	10:50	10:12	26.3	24.8	16.4	4.3	25.8	28.5
K30	11171	11171	14:05	14:37	23.6	28.4	15.6	10.1	30.1	32.2
K56I	11171	11171	14:38	13:45	23.5	24.0	8.5	8.2	32.1	31.4
K57N	11168	11168	11:46	10:51	23.4	22.8	4.0	0.0	27.5	26.2
K57S	11168	11168	10:58	11:54	24.0	27.5	2.1	2.7	29.4	31.5
K66	11169	11169	12:46	13:17	*24.8	24.8	*4.8	5.0	*26.9	29.2
K67F	11169	11169	11:26	12:07	25.3	*25.3	1.3	*4.4	25.2	*25.3
K67S	11169	11169	12:11	11:24	23.4	*23.4	4.8	*2.1	26.5	*25.0
K68	11168	11168	13:26	14:08	26.0	25.8	1.4	1.3	31.1	32.3
K69	11169	11169	12:42	12:05	25.6	24.4	8.0	4.0	26.3	24.0
K71	11169	11169	11:25	12:55	27.3	25.5	2.9	1.6	25.0	27.6

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table F.4. *Tadpole Survey Specific Covariates for June 2011, continued.*

	Julian Date		Time		Water Temperature (°C)		Wind Speed (kph)		Air Temperature (°C)	
SITE	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
L37	11179	11179	11:22	11:52	23.5	23.4	1.6	2.1	27.7	32.7
L39	11179	11179	12:37	13:00	24.0	25.6	1.3	3.9	31.4	28.1
L43	11166	11166	12:38	13:11	*28.0	28.0	*11.5	12.1	*28.6	29.3
L46	11166	11166	14:48	15:15	23.5	25.7	7.2	5.1	30.9	31.3
L51 N&S	11179	11179	11:15	12:02	24.5	25.9	3.4	1.1	24.2	30.5
L54E	11166	11166	11:45	12:34	*26.9	26.9	*11.5	10.3	*28.6	29.0
L54W	11166	11166	12:34	11:52	24.0	23.5	*11.5	10.9	*28.6	27.9
L55E	11166	11166	13:23	14:07	26.7	27.3	8.4	7.7	29.4	29.8
L55W	11166	11166	13:23	14:05	24.0	24.0	9.5	9.5	28.3	28.3
L70	11179	11179	13:56	13:24	25.7	25.0	3.4	2.7	26.1	26.7

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of nearest surveys conducted prior to and after survey with missing data.

Table F.5. *Site Specific Wetland Characteristics June 2011.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data. Covariates include: wetland size and type, bend, distance to nearest wetland, slope, and presence of emergent vegetation.

SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland	Slope (0-1m)	Emergent Vegetation	Aquatic Vegetation % Wood	% Herb	% Open
H09	Large	Tributary	Hamburg	737.35	0.29	0	0.075	0.275	0.65
H11	Small	Scour Hole	Hamburg	737.35	0.32	0	0.05	0.05	0.9
H12	Medium	Tributary	Hamburg	1770.79	0.20	1	0.05	0.925	0.025
H14	Medium	Tributary	Hamburg	146.14	0.47	1	0	0.965	0.035
H15S	Small	Tributary	Hamburg	132.00	0.24	0	0.05	0.125	0.825
H18	Small	Ground Fed Permanent	Hamburg	1073.05	0.29	0	0.1	0.15	0.75
H59	Small	Ground Fed Permanent	Hamburg	325.08	0.45	0	0	0	1
H63	Medium	Ephemeral, unfarmed	Hamburg	1239.62	0.32	0	0	0.275	0.725
K06	Medium	Ephemeral, unfarmed	Kansas	364.68	0.29	0	0.10	0.00	0.90
K07	Small	Ground Fed Permanent	Kansas	367.12	0.14	1	0	0.675	0.325
K10	Large	Ground Fed Permanent	Kansas	332.86	0.01	1	0	1	0
K23	Medium	Tributary	Kansas	171.23	*0.35	0	0.025	0.075	0.9
K25	Small	Impoundment	Kansas	680.94	0.30	1	0.05	0.9	0.05
K27	Large	Impoundment	Kansas	171.23	0.26	1	0.025	0.85	0.125
K30	Medium	Ephemeral, unfarmed	Kansas	872.41	0.21	1	0	0.925	0.075
K56I	Small	Ditch	Kansas	95.62	0.28	1	0.08	0.7	0.22
K57N	Small	Ditch	Kansas	53.54	0.22	1	0.355	0.475	0.17
K57S	Small	Ephemeral, unfarmed	Kansas	53.54	0.01	1	0	1	0
K66	Small	Impoundment	Kansas	93.65	0.22	1	0	1	0
K67F	Large	Impoundment	Kansas	43.22	0.15	1	0	1	0
K67S	Medium	Tributary	Kansas	37.92	0.47	0	0	0	1
K68	Large	Tributary	Kansas	443.77	0.40	0	0	0.2	0.8
K69	Medium	Impoundment	Kansas	31.00	0.25	1	0	1	0
K71	Large	Tributary	Kansas	31.00	0.39	0	0.125	0.175	0.7

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table F.5. *Site Specific Wetland Characteristics June 2011, continued.*

							Aquatic Vegetation		
SITE	Wetland Size	Wetland Type	Bend	Distance to Nearest Wetland	Slope (0-1m)	Emergent Vegetation	% Wood	% Herb	% Open
L37	Medium	Ground Fed Permanent	Langdon	379.09	0.39	0	0	1	0
L39	Small	Ephemeral, farmed	Langdon	573.96	0.32	0	0	0.225	0.775
L43	Medium	Ground Fed Permanent	Langdon	442.18	0.05	1	0	0.6	0.4
L46	Medium	Ditch	Langdon	843.15	0.51	1	0	0.7	0.3
L51N	Small	Ephemeral, unfarmed	Langdon	14.28	0.34	0	0	0	1
L54E	Medium	Ephemeral, unfarmed	Langdon	89.70	0.11	1	0	1	0
L54W	Small	Ground Fed Permanent	Langdon	89.70	0.16	1	0	0.975	0.025
L55E	Large	Ditch	Langdon	86.07	0.40	1	0	0.875	0.125
L55W	Large	Ditch	Langdon	86.07	0.38	1	0.025	0.525	0.45
L70	Large	Backwater	Langdon	1124.55	0.29	0	0	0.325	0.675

* Data was missing due to instrument failure, human error, or inability to measure safely. Value was estimated as an average of values for the wetland collected over the course of the study.

Table F.6. *Site Specific Landscape Characteristics June 2011.* Site specific characteristics were only measured or calculated once during the month and were used in analysis with both tadpole survey data and call survey data.

	Adjacent Land Cover			Terrestrial Vegetation			
SITE	%forest	%field	%ag	G	HF	ST	CB
H09	0.00	0.00	0.03	0.75	0.25	0	0
H11	0.00	0.00	0.03	0.95	0.05	0	0
H12	0.45	0.03	0.41	0.075	0.475	0.4	0.05
H14	0.39	0.06	0.25	0.45	0.425	0.125	0
H15S	0.36	0.07	0.38	0.025	0.2	0.425	0.35
H18	0.28	0.02	0.24	0	0.25	0.5	0.25
H63	0.01	0.00	0.50	0.85	0.15	0	0
K06	0.45	0.175	0.375	0.15	0.25	0.6	0
K07	0.45	0.01	0.18	0.52	0.265	0.215	0
K10	0.10	0.00	0.20	0.225	0.55	0.225	0
K23	0.50	0.00	0.13	0.2	0.4	0.25	0.15
K25	0.00	0.00	0.24	0.3	0.55	0.15	0
K27	0.38	0.00	0.12	0.5	0.375	0.125	0
K30	0.00	0.00	0.35	0.225	0.65	0.125	0
K56I	0.00	0.00	0.34	0.225	0.65	0.125	0
K57N	0.00	0.00	0.45	0.1	0.2	0.675	0.025
K57S	0.00	0.00	0.52	0.475	0.45	0.075	0
K66	0.01	0.00	0.58	0.375	0.4	0.225	0
K67F	0.01	0.00	0.60	0.3	0.7	0	0
K67S	0.01	0.00	0.58	0.515	0.215	0.12	0.15
K68	0.03	0.00	0.32	0.65	0.29	0.01	0.05
K69	0.01	0.00	0.59	0.5	0.5	0	0
K71	0.01	0.00	0.57	0.45	0.225	0.2	0.125

Table F.6. *Site Specific Landscape Characteristics June 2011, continued.*

	Adjacent Land Cover			Terrestrial Vegetation			
SITE	%forest	%field	%ag	G	HF	ST	CB
L37	0.00	0.00	0.31	0.325	0.625	0.05	0
L39	0.00	0.00	0.43	0.79	0.21	0	0
L43	0.00	0.00	0.90	0.525	0.225	0	0.25
L46	0.01	0.00	0.67	0.2875	0.5625	0.075	0.075
L51N	0.00	0.00	0.26	0.5	0.5	0	0
L54E	0.00	0.00	0.94	0.675	0.325	0	0
L54W	0.00	0.00	0.97	0.75	0.25	0	0
L55E	0.05	0.01	0.79	0.55	0.35	0.1	0
L55W	0.04	0.00	0.82	0.4	0.325	0.05	0.225
L70	0.75	0.075	0.175	0.7	0.3	0	0

Appendix G: Connectivity

Table G.1. *Connectivity of Hamburg bend sites.* The connectivity of Hamburg sites indicating which sites are connected and how many connections each wetland has. A period indicates that there were no connections for a given wetland at that scale.

	200m		500m		1000m	
	Sites	#	Sites	#	Sites	#
H08	.	0	H15F, H59	2	H15F, H15S, H59	3
H09	.	0	.	0	H11, H14, H62	3
H11	.	0	.	0	H09	1
H12	.	0	.	0	.	0
H14	H62	1	H62	1	H09, H15F, H15S, H62	4
H15F	H15S	1	H15S, H08, H62	3	H08, H14, H15S, H59, H62	5
H15S	H15F	1	H15F, H62	2	H08, H14, H15F, H59, H62	5
H18	.	0	.	0	H61	1
H34	.	0	H65N, H65S	2	H64, H65N, H65S	3
H59	.	0	H08	1	H08, H15F, H15S	3
H61	.	0	.	0	H18, H64	2
H62	H14	1	H14, H15F, H15S	3	H09, H14, H15F, H15S	4
H63	.	0	.	0	.	0
H64	.	0	H65N, H65S	2	H34, H61, H65N, H65S	4
H65N	H65S	1	H34, H64, H65S	3	H34, H64, H65S	3
H65S	H65N	1	H34, H64, H65N	3	H34, H64, H65N	3

Table G.2. *Connectivity of Kansas bend sites.* The connectivity of Kansas sites indicating which sites are connected and how many connections each wetland has. A period indicates that there were no connections for a given wetland at that scale.

	200m		500m		1000m	
	Sites	#	Sites	#	Sites	#
K02	.	0	K06, K10	2	K06, K07, K10, K68	4
K06	.	0	K02, K07, K10, K68	4	K02, K07, K10, K23, K25, K27, K68	7
K07	.	0	K06, K23, K27, K68	4	K02, K06, K10, K23, K25, K27, K68	7
K10	.	0	K02, K06, K68	3	K02, K06, K07, K23, K25, K68, K71	7
K23	K27	1	K07, K27	2	K06, K07, K10, K24, K25, K27, K68	7
K24	.	0	K27	1	K23, K27	2
K25	.	0	.	0	K06, K07, K10, K23, K27, K56I, K56O, K68	8
K27	K23	1	K07, K23, K24	3	K06, K07, K23, K24, K25, K68	6
K30	.	0	.	0	K57N, K57S, K56I, K56O	4
K32	.	0	.	0	K33	1
K33	.	0	.	0	K32	1
K57N	K57S	1	K57S	1	K30, K32, K57S	3
K57S	K57N	1	K57N	1	K30, K32, K57N	3
K56I	K56O	1	K56O	1	K25, K30, K56O	3
K56O	K56I	1	K56I	1	K25, K30, K56I	3
K66	K67F, K67S, K69, K71	4	K67F, K67S, K69, K71	4	K67F, K67S, K69, K71	4
K67F	K66,K67S, K69, K71	4	K66,K67S, K69, K71	4	K66,K67S, K69, K71	4
K67S	K66, K67F,K69, K71	4	K66, K67F,K69, K71	4	K66, K67F,K69, K71	4
K68	.	0	K06, K07, K10	3	K02, K06, K07, K10, K23, K25, K27	7
K69	K66, K67F, K67S,K71	4	K66, K67F, K67S,K71	4	K66, K67F, K67S,K71	4
K71	K66, K67F, K67S, K69	4	K66, K67F, K67S, K69	4	K10, K66, K67F, K67S, K69	5

Table G.3. *Connectivity of Langdon bend sites*. The connectivity of Langdon sites indicating which sites are connected and how many connections each wetland has. A period indicates that there were no connections for a given wetland at that scale.

	200m		500m		1000m	
	Sites	#	Sites	#	Sites	#
L37	.	0	L51N, L51S	2	L51N, L51S	2
L39	.	0	L53	1	L53	1
L43	.	0	L55E, L55W	2	L44, L46, L55W, L55E	4
L44	.	0	L55E	1	L43, L55W, L55E	3
L46	.	0	.	0	L55W, L55E	2
L53	.	0	L39	1	L39	1
L51N	L51S	1	L51S, L37	2	L51S, L37	2
L51S	L51N	1	L51N, L37	2	L51N, L37	2
L54E	L54W	1	L54W	1	L39, L43, L54W, L70	4
L54W	L54E	1	L54E	1	L39, L43, L54E	3
L55E	L55W	1	L55W, L43	2	L43, L44, L46, L55W	4
L55W	L55E	1	L55E, L43, L44	3	L43, L44, L46, L55E	4
L70	.	0		0		0

0