2011

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Recommended Citation

McIntyre, Catherine Anne, "Predicting Amphibian Occurrence Based on Wetland and Landscape Level Factors in Montana" (2011). *Graduate Student Theses, Dissertations, & Professional Papers*. 762.
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PREDICTING AMPHIBIAN OCCURRENCE BASED ON WETLAND AND LANDSCAPE LEVEL FACTORS IN MONTANA

By

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Thesis

presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Environmental Studies

The University of Montana
Missoula, MT

May, 2011

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McIntyre, Catherine, M.S., May, 2011 Environmental Studies

Predicting Amphibian Occurrence Based on Wetland and Landscape Level Factors in Montana.

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ABSTRACT

Amphibians have a complex life history that requires a mosaic of habitats, including breeding, foraging, and over-wintering areas. Historically, regulators have focused on wetland breeding habitat quality to explain amphibian presence. Recently, other habitat requirements including landscape level factors have been examined. Data collected from amphibian surveys in Montana were used to determine if wetland quality factors or landscape level factors were better determinants of amphibian occurrence at breeding sites. Twenty-six habitat models were constructed *a priori* for eight species of amphibians in Montana. This included five models containing parameters associated with wetland quality, ten landscape level models, and ten models that combined both local and landscape covariates. Logistic regression analysis with an information theoretic approach was used to select the best approximating model.

Results indicate that habitat models including only wetland variables were not good predictors of presence for most amphibians. The landscape scale at which habitat models were best supported varied among species and was consistent with differing life history traits. The presence of *Ambystoma macrodactylum*, the western population of *Ambystoma tigrinum*, *Bufo boreas*, and *Rana luteiventris* was best predicted by landscape covariates. Models with a combination of local and landscape covariates were best supported for *Rana pipiens*, *Bufo woodhousii*, *Pseudacris maculata*, and *Pseudacris regilla*. The probability of *Ambystoma macrodactylum* presence is highest at breeding sites that are surrounded by forested areas. The western population of *Ambystoma tigrinum* was positively associated with an increased distance to forest and a higher density of wetlands around a breeding site. The eastern population of *Ambystoma tigrinum* was negatively associated with higher elevations. *Bufo boreas* and *Rana luteiventris* were positively associated with increased forest within 1,000 m, and negatively associated with increased distance to forest and aquatic sites in an agricultural landscape. *Bufo woodhousii* and *Pseudacris maculata* were positively associated with open landscapes dominated by natural grasses. The presence of *Rana pipiens* was positively associated with open landscapes dominated by natural grasses. This project highlights the importance of maintaining intact landscapes around amphibian breeding ponds in order to meet the habitat requirements of amphibians during all stages of their life cycle.

ACKNOWLEDGEMENTS

This project would not have been successful without the help of many dedicated individuals including my committee members, Dr. Vicki Watson, Dr. Winsor Lowe, Dr. Linda Vance, and Dr. Len Broberg. Dr. Vicki Watson provided guidance, acted as a sounding board for ideas during the development of my thesis project, and was invaluable as an advisor. Dr. Winsor Lowe provided encouragement and advice throughout the project, especially at times when I found myself bogged down by all the statistical details. Dr. Linda Vance gave immense support and the opportunities to learn many of the skills needed to complete this project. Dr. Len Broberg always offered clear alternative explanations for the more complicated aspects of this project, and taught me the correct pronunciation of “Akaike”. I would also like to thank Dr. Jon Graham who assisted me with the statistical components of my thesis. Without his help, I might still be figuring out the intricacies of the Principal Component Analysis. Dr. Bryce Maxell, of the Montana Natural Heritage Program, graciously let me use his amphibian distribution data and trained me in the MTNHP amphibian survey protocol. Adam Sepulveda was an invaluable resource for both Akaike’s Information Criterion and statistics. Thanks also to Natalie Shapiro for helping format the final version for submittal. I would also like to acknowledge Karen Newlon, my good friend and colleague, who spent many hours explaining and philosophizing over Akaike’s Information Criterion with me, editing an early draft of my thesis, baking delicious cupcakes for my defense, and most of all for always knowing how to make me smile and feel a little less stressed. Finally, thanks to Matt Wegener, Thor, Mishka, the Lady, Gus, and Moose for their unconditional love.

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INTRODUCTION

Amphibian populations are experiencing global population declines. Nearly 1,900 known amphibian species are considered threatened. Between 1998 and 2009, the number of amphibians species considered critically endangered increased from 18 to 484, species considered endangered increased from 31 to 754, and species considered vulnerable increased from 75 to 657 (IUCN 2009). Although some declines in amphibian populations may result from natural population fluctuations (Pechmann and Wilbur 1994, Halley et al.1996, Hecnar and M'Closkey 1996), it is widely accepted that most population declines are attributable to habitat degradation and fragmentation (Lannoo et al.1994, Hecnar and M'Closkey 1996, Gibbs 1998, Rittenhouse and Semlitsch 2006).

Historically, researchers and regulators have focused on the quality of wetland breeding habitat to explain amphibian declines. Recent studies have examined other habitat requirements and landscape level factors that are important to the life history traits of amphibians (Pope et al. 2000, Semlitsch and Bodie 2003). Anthropogenic landscape-level factors including road density, agricultural uses, and urban development have been shown to affect the distribution and abundance of amphibians in wetlands (Fahrig et al. 1995, Gibbs 1998, Vos and Chardon 1998, Weyrauch and Grubb 2004, Mazerolle et al. 2005). Landscape factors unrelated to human disturbances may also affect amphibian distributions and populations. For example, distance from wetland habitat to the nearest woodland and steep slopes were found to be important determinants of amphibian diversity (Laan and Verboom1990). Therefore, it is critical that any assessment of landscape-level factors influencing amphibian populations consider both anthropogenic and environmental variables.

Although recent research has indicated that amphibian distribution is strongly associated with landscape characteristics, wetland level habitat factors also influence amphibian distribution (Hamer and Mahoney 2010). In fact, some studies have determined that wetland variables are better predictors of site occupancy than landscape factors (Weyrauch and Grubb 2004). Wetland parameters that have been found to correlate with amphibian distribution and abundance include wetland surface area (Vos and Chardon 1998, Laan and Verboom 1999, Hamer and Mahony 2010), water body depth (Laan and Verboom 1999, Knapp et al. 2003), elevation (Knapp et al. 2003), area of emergent vegetation (Vos and Chardon 1998), fish presence (Knapp et al. 2003), substrate (Suzuki et al. 2008) and hydroperiod (Kolozsvary and Swihart 1999, Snodgrass et al. 2000, Weyrauch and Grubb 2004). Van Buskirk (2005) found that complex models containing both wetland and landscape covariates were better suited to predict site occupancy than either wetland or landscape models illustrating the importance of considering both local wetland and landscape factors.

The objective of this study was to determine the local level wetland and landscape-level factors that influence amphibian distribution across western and central Montana. In addition, I identify the most effective spatial scale for management of eight amphibian species in Montana. To be effective, the scale at which management should occur will depend on each species habitat requirements during all stages of the life cycle. By correlating landscape-level factors to amphibian occurrence and identifying at what scales these relationships occur, adequate buffer zones can be implemented to protect areas of high quality habitat and connectivity. Similarly, identifying important wetland level habitat features will allow managers and planners to identify appropriate wetlands for protection or restoration.

There were three main research objectives to this project: 1) determine if there are important associations between wetland level and landscape level factors and the presence of amphibian species in Montana and 2) identify which associations are significant and at which scale of three broad landscape scales and 3) make recommendations for the most effective scale of amphibian habitat management based on predictive models.

LITERATURE REVIEW

Important Amphibian Habitat Components

Amphibians have a complex life history requiring a mosaic of habitats for rearing, foraging and over-wintering. For example, northern leopard frogs (*Rana pipiens*) require three distinct habitat types that include breeding ponds in the spring, grassy fields for foraging in the summer, and a stream or lake for over-wintering (Pope et al. 2000). Impacts on any one of these habitat types could lead to a decline or local extinction event (Maxell 2009). Landscape complexity and habitat patch distribution have also been demonstrated to be critical factors in amphibian species richness (Marsh and Trenham 2000, Guerry and Hunter 2002).

Dispersal rates are thought to be the primary driving forces structuring amphibian communities (Gibbs 1998, Marsh and Trenham 2000) by linking partially isolated breeding habitat patches and creating metapopulations (Hecnar and M'Closkey 1996, Smith and Green 2005). Dispersal between populations influences extinction and recolonization rates (Hecnar and M'Closkey 1996, Semlitsch 2008) where following an extinction event a population may be recolonized by individuals from another nearby population. Amphibian populations are only considered metapopulations if separate breeding populations are supported, no single population is large enough to ensure long term survival, patches are not too isolated to prevent recolonization, and each local population experiences independent extinction events (Hanski 1998). Not all amphibian populations meet these criteria because dispersal is often too frequent and breeding sites are too connected, so that local populations are more linked.

Regardless of whether or not amphibian populations act as metapopulations, it is apparent that adult seasonal migrations and juvenile dispersal are crucial to population dynamics. Dispersal links important breeding and rearing habitat, while seasonal migrations connect aquatic habitat to the terrestrial habitat that is crucial in the adult phase of almost all amphibians. Therefore, amphibians are particularly sensitive to landscape-level changes because they not only require different interconnected habitat patches but also the habitat corridors connecting habitat patches. In a study investigating the important landscape characteristics that contribute to efficient and successful dispersal of amphibians (Gibbs 1998), drift fences and pitfall traps were used to determine amphibian movements relative to forest habitat, edge habitat, streams and roads. It was determined that amphibian's dispersal between habitat areas is not independent of landscape features. Roads had the most significant effect on dispersal patterns where forest-road edges were used less of the time than forest-residential edges. Furthermore, forest edges adjacent to open areas were used more often to access breeding pools, even if this was a less efficient route than using a route next to a road. This demonstrates that amphibians are choosing routes away from roads despite having to travel greater distances.

In a similar study, amphibians, reptiles, and birds were all found to decrease in richness with increasing road density (Findlay and Houlahan 1997). Regression models predicted that a 2 km/ha increase in road density would contribute to a 19% reduction in herptile species richness and a 14% decline in bird species richness. This decline could be attributed to reduced recolonization following local extinction due to decreased dispersal. It was also determined that species richness would be greatly reduced with decreasing forest cover at all distance intervals used in the study (0-2000m). Specifically, a 20% decline in forest cover within 2 km of a wetland was predicted to cause a decline in herptile species richness by 17%. It was estimated that a 20% loss in forest cover had a similar impact to a 50% loss in actual wetland habitat. If this prediction is accurate, then wetland protection regulations that concentrate only on reducing wetland losses, and do not consider buffer areas to these ecosystems, are not adequately protecting amphibian populations. Furthermore, there is a species-area relationship where species richness increases with increased wetland area. This suggests that wetland size may be an important factor influencing site selection by amphibians.

Because amphibians need access to a mosaic of good quality habitats to complete various stages of their life cycle, they are significantly more affected by landscape-level impacts than are species with fewer habitat requirements. With obvious declines in amphibian populations, both aquatic and terrestrial habitat areas need to be protected. Semlitsch and Bodie (2003) estimated the biologically relevant size of "core habitats" necessary to support an amphibian population by considering local and landscape factors. They determined that core terrestrial habitat area for amphibians extends approximately 159 to 290 m and for reptiles approximately 127 to 289 m from the edge of aquatic habitat used for reproduction. These numbers were determined by using radio telemetry and other tracking methods to determine dispersal and migration rates. These numbers indicate that the 15-30 m buffer zones required under current regulations in some states are not even close to adequate in protecting amphibian populations.

Habitat Models

Wildlife habitat models are important tools that can be used to predict occupancy and density of a species based on habitat values (Beutel et al. 1999).We use models to understand relationships and make inferences about biological processes from scientific data (Burnham and Anderson 2002). The main assumption underlying habitat models is that there are associations between habitat factors and species distribution created by site specific and landscape processes (Van Buskirk 2005). The joint use of field surveys and GIS assessment has allowed for habitat models to be created for broader landscapes. Scientists and resource managers can take a broader view of how landscape-level factors impact ecosystems and species distribution by applying both GIS and remote sensing technologies (Klemas et al. 2000). By using these technologies, we can study ecological patterns and processes that occur along ecological boundaries (Vogt 1997).

In Iowa and Wisconsin, GIS was used to look at landscape variables that included forest cover, agriculture, urban areas, open water, emergent wetlands, and forested wetlands (Knutson et al.1999). These landscape variables were further grouped by land type, type of edge (i.e. edge density of emergent marsh) and percent of each patch type. Assemblages of amphibians were located in different breeding ponds based on calling by males during the breeding season and a 1000 m buffer area around breeding sites was examined. Correlations between landscape parameters and amphibian abundance and richness were determined. Consistent positive correlations were found between amphibian abundance and richness with both upland and wetland forests in Iowa and Wisconsin. Unlike similar studies, there was a positive correlation between amphibians and agricultural areas in Wisconsin but not in Iowa. The authors attribute this to small-forested areas that were not mowed that could have been acting as refuge areas in Wisconsin. Most significantly, closeness to urban areas was negatively correlated with the presence of all amphibian guilds. This is most likely because high road density can have serious effects on amphibian abundance. In addition, wetland loss and habitat fragmentation is increased in urban areas.

Several habitat models were used to determine the influence of wetland and landscape factors on the occurrence and abundance of amphibians in Switzerland wetlands (Van Buskirk 2005). There were three primary habitat models: a model that looked at combinations of local and landscape covariates, a model that looked at water permanence, and a competition model that dealt with interspecific and intraspecific effects on amphibian populations. Using regression models and a bias corrected version of Akaike's Information Criterion to weight and select the most appropriate model, the author found that the occurrence of most species was influenced by models that included both local and landscape factors. Habitat models that only included local biotic covariates like the hydroperiod and competition models were not well supported by the data, indicating that the landscape-level factors included in the models added support. Habitat models that included only landscape-level factors were not well supported by the data.

Habitat models were developed for the Siskiyou Mountains salamander (*Plethodon stormi*) to determine if there were significant habitat associations at fine (10 ha), medium

(40ha), and broad (202 ha) spatial scales (Suzuki et al. 2008). An information theoretic approach was used (Burnham and Anderson 2002) to determine that a combination of both local and landscape level factors best predict the occurrence of the Siskiyou Mountains salamander. Site occupancy by amphibians was positively associated with rocky soils and Pacific madrone (*Abutus menziessi*) and negatively associated with elevation and white fir (*Abies concolor*). The best supported model was consistent at all three spatial scales and included the variables rocky soils, white fir, and Oregon white oak (*Quercus garryana*). These results indicate that this salamander is more apt to be found in areas with rockier soils that are not dominated by white fir or Oregon white oak.

Landscape level factors were determined to be more important to site occupancy of the green and golden bell frog (*Litoria aurea*) in Australia (Bertrand et al. 2009). Based on habitat models, the probability that a site would be occupied increased with increasing wetland size and decreasing distance to the nearest known breeding site used by that species. The authors also determined that larger wetlands within close proximity to other breeding sites experienced fewer turnovers between years. They attribute this to immigration, recruitment, and the abundance of philopatric individuals. These results suggest that both patches of wetlands as well as the connectivity between those patches should be protected.

Landscape level factors were most important to the occurrence of the Idaho Giant Salamander (*Dicamptodon aterrimus*) in the Lochsa River basin in Montana (Sepulveda and Lowe 2009). The best supported models contained only landscape level variables. The habitat models indicate that the presence of the Idaho giant salamander was highest in watersheds that were not fragmented by roads and lowest in streams that were spatially isolated. Habitat models that included local scale variables were not well supported, indicating that for this species of salamander habitat quality is not as important as landscape quality and connectivity.

Amphibians in Montana

In Montana, six of the thirteen endemic amphibian species are listed on the Montana Natural Heritage Program (MTNHP) and Fish, Wildlife and Parks (FW&P) List of Montana Animal Species of Concern (2009). The northern leopard frog (*Rana pipiens*) has been extirpated from most of its range west of the continental divide, while the eastern population is considered a potential species of concern. The primary cause of the leopard frogs' decline in the western part of the state is attributed to the chytrid fungus (*Batrachochytrium dendrobatidis*) (Werner et al. 2004). The western toad (*Bufo boreas*) is still found in 17 percent of watersheds in western Montana. However this is a reduced distribution compared to historic records, and they were found breeding in only 2 percent of the standing water bodies included in the MTNHP survey (Maxell et al. 2009). The Great Plains toad (*Bufo cognatus*) is associated with glacial potholes in eastern Montana where much of the landscape has been altered by both grazing and agricultural uses. In addition, recent assessments of pothole wetlands in Montana indicate that hydroperiods have decreased due to prolonged drought conditions in the region (McIntyre et al. 2011). Both the Idaho Giant salamander (*Dicamptodon aterrimus*) and the Coeur d'Alene salamander (*Plethodon idahoensis*), found in the western part of the state, are considered at risk of a downward trend in population numbers (Maxell et al. 2009). The plains spadefoot (*Spea bombifrons*), found east of the continental divide, has only been observed in thirty locations over the past ten years (Werner et al. 2004). This species is considered a species of concern since little is known about its biology and habitat requirements.

Reasons for declining population numbers of amphibians at risk in Montana are primarily due to reduced range and habitat availability as well as disease and deformities (Maxell 2000, Werner et al. 2005). Habitats that threatened or endangered amphibians are associated with are also listed in the Montana Animal Species of Concern (2009). Lentic wetlands are identified as the primary habitat association, with 83% of Montana amphibian species of concern using this habitat type. Streams, rivers and lakes were determined to be used by 17% of Montana amphibian species of concern.

Seven other endemic species of amphibians occur in Montana. These include the long toed salamander (*Ambystoma macrodactylum*), Rocky Mountain tailed frog (*Ascaphus montanus*), pacific treefrog (*Pseudacris regilla*) and Columbia spotted frog (*Rana luteiventris*) found primarily in the western portion of the state and the tiger salamander (*Ambystoma tigrinum*), Woodhouse's toad (*Bufo Woodhousei*), and the boreal chorus frog (*Pseudacris maculata*) distributed throughout the central and eastern part of the state.

Several studies of amphibians in Montana suggest that some species are particularly sensitive to landscape level changes that may lead to habitat fragmentation (Funk et al. 2005, Sepulveda and Lowe 2009). For example, a study of Columbia spotted frogs illustrated that juveniles were able to migrate over great horizontal distances (maximum distance of 5,740 m) and overcome significant elevation gains (maximum of 700 m gain) to reach new territory. This illustrates that isolation of populations could lead to increased extinction events (Funk et al. 2004). Studies looking at genetic differentiation of Columbia spotted frogs in Montana were also able to illustrate that natural landscape features like mountain ridges and extreme elevation gains act as barriers to dispersal (Funk et al. 2005). Using genetic markers, it was also established that populations of Columbia spotted frog populations consist of not only one breeding aggregation, but of many groups of breeding ponds.

STUDY DESIGN

To develop habitat models for amphibian species in Montana, I selected both wetland-level and landscape-level parameters based on the biology of each species as well as through GIS analysis. Twenty-six habitat models were constructed *a priori*, including five wetland-level models that contain parameters associated with wetland quality, ten landscape-level models, and ten models that combine both wetland-level and landscape-level covariates. Goodness-of –fit of each candidate model was assessed using Akaike's Information Criterion (AIC). Candidate models that were found to be good predictors of amphibian presence were validated on sites that were not included in the initial calibration of the models.

Site Selection and Field Survey Methods

The data for this project were derived from over 2,000 amphibian distribution surveys conducted between 2000 and 2008. The Montana Natural Heritage Program developed a survey method by stratifying Montana into 11 geographic strata (Figure 1) based on level 3 ecoregions and 8-digit hydrologic unit code watersheds (Maxell et al. 2009). The 11 geographic strata were then further sub-divided into three categories by twelve-digit watersheds based on land ownership. Twelve-digit hydrologic unit code watersheds were randomly selected from the following three categories: 1) watersheds with greater than 40% public land; 2) watersheds with greater than 40% tribal land; and 3) watersheds with less than 40% public land.

Within each selected watershed, lentic sites were located using 7.5 minute (1:24,000 scale) U.S. Geological Survey quadrangle maps and aerial imagery (Maxell et al. 2009). MTNHP field crews surveyed all mapped lentic sites as well as those water bodies found incidentally in the field within a 200-meter radius around mapped features (Maxell et al. 2009). Field crews conducted surveys from the end of May through July in eastern Montana and from the end of May through August in western Montana to coincide with the end of the breeding season when eggs, larvae, and metamorphs can be located and identified more easily. Sites were surveyed once due to time and financial constraints.

Field crews used timed visual encounters and dipnet surveys to locate species (Maxell et al. 2009). Other data collected included habitat information (wetland type, photographs, vegetation, area, water depth), water conditions (pH, turbidity, temperature), fish presence/absence and amphibians present (species, approximate number, life stage).

The presence of amphibian species is determined more reliably through the direct observation of egg masses, larvae and metamorphs, so I included known breeding sites only. A species was considered present at a site if there was at least one observation of an egg mass, larvae, or metamorph for that species. Wetland types surveyed included lake/pond, wetland marsh, backwater/oxbow, spring/seep, active beaver pond, inactive beaver pond, multipooled areas consisting of a complex of wetlands, and reservoir/stockpond habitat types. Only sites without fish were included because fish presence has been shown to be an important influence on amphibians' choice of breeding sites (Knapp et al., 2003, Werner et al., 2007). Without fish presence, I could better tease out other important habitat requirements in the wetland and surrounding landscape that influence breeding site selection.

Data Analysis

For this project I examined eight (Table 1) of the 13 endemic amphibian species that occur throughout Montana. Species were excluded from the project because they were not lentic wetland breeding species (*Ascaphus montanus, Plethodon idahoensis, Dicamptodon aterrimus),* or there were not enough observations for statistical analysis (*Bufo cognatus, Scaphiopus bombifrons).*

Data collected in the western montane portions of Montana (strata 1-7) were analyzed and modeled separately from data collected in the eastern portion of Montana containing the Northwestern glaciated and great plains (strata 11-12). I used multivariate analysis of variance (MANOVA) using Statistical Package for the Social Sciences (SPSS) to assess differences in wetland-level and landscape-level factors for the western and eastern amphibian species separately. A lack of significance would indicate no difference between species in each group, so that models could be constructed for all species in either the western or eastern group. However, using a MANOVA, I determined that there was a significant difference ($p \leq 0.001$) between each species for wetland-level and landscape-level factors in the western and eastern groups of amphibians.

Based on the results of the MANOVA, I carried out a hierarchical cluster analysis with average linkage to determine if there were any subgroups of amphibians that used similar habitat types. The purpose of cluster analysis is to identify a set of groups that are similar to one another and different from other groups (McCune and Grace 2002). The form of cluster analysis used was Hierarchical Clustering which allows the user to define a standard Euclidian distance, select a linking method to form clusters, and create a dendogram that illustrates the distance at which clusters are formed. For the purposes of this project, I used a squared Euclidian distance to measure the distance between different species and an environmental variable to put more emphasis on outliers so that species that are far apart are more apparent. The method used for the cluster analysis was average linkage within groups, which measures the homogeneity of environmental variables between species. I conducted the cluster analysis on both the western and eastern group of amphibians. The western toad (*Bufo boreas*) and the Columbia spotted frog (*Rana luteiventris*) formed one new group in the west (Figure 2) and the Woodhouse's toad (*Bufo woodhousii*) and the boreal chorus frog (*Pseudacris maculata*) created another new group in the east (Figure 3). Therefore, models were constructed for the two new sets of groups created in the cluster analysis and for the other four species individually (Table 1). Models were created for two separate populations of *Ambystoma tigrinum* (Appendix A) because one population occurs in the montane region of the state while the other population occurs in the more arid plains region of the state. It was assumed that the landscape variables important to the montane population may differ from the landscape variables that are important to the plains population.

Spatial Scale Definitions

I considered four different spatial scales to determine what factors influence species presence. I constructed a set of models based on wetland-level biotic and abiotic environmental variables measured at the wetland site. I then constructed models based on landscape-level factors at three spatial scales: 500, 1,000, and 2,000 m measured as the radius of a circle from the center of the wetland. These distances were selected based on known maximum seasonal migration distances for some of the species that occur in Montana (Table 2). For instance, some amphibians like the long- toed salamander, are only known to seasonally migrate up to 600 m (J. Pierson, unpublished data, as cited in Maxell 2000). Other amphibians migrate longer distances. The western toad will migrate up to 2,440 m between seasonal habitats (Breden 2004) and disperse up to 3,000 m (Bull 2009). The Columbia spotted frog typically migrates between 100 and 1,609 m, but has been found to disperse as far as 7,000 m (Maxell 2009). The Woodhouse's toad has been found migrating up to 2,000 m (Werner et al, 2004). The northern leopard frog will seasonally migrate and disperse up to 1,000 m (Dole 1968, Seburn et al., 1997). Other amphibian species have shorter seasonal migration distances including 162 m for the tiger salamander (Pechmann et al., 2001), 250 m for the boreal chorus frog, and 400 m or more for the Pacific treefrog (Werner et al., 2004).

Wetland Habitat Parameters

Wetland habitat variables that describe local patch quality were measured at each wetland site as part of the MTNHP amphibian survey. Of the wetland habitat variables that were measured as part of the assessment, I included four variables known to influence amphibian presence including elevation, maximum depth, wetland surface area, and area of emergent vegetation (Table 3). Elevation was measured from 7.5 minute (1:24,000 scale) U.S. Geological Survey quadrangle maps. Elevation provides a surrogate for temperature and climate ranges that may affect distribution of some amphibian species.

The maximum water depth of a wetland was estimated in meters at each site and was then placed into one of three depth categories: less than 1 m, between 1 and 2 m, and greater than 2 m. Because amphibians require water bodies that contain water long enough for the development of larvae, I assumed that they would select sites of a certain depth. Wetland surface area (m^2) was calculated from field measurements of the wetland's length and width. Many studies have indicated that wetland surface area is not an important influence on site occupancy or species richness (Hecnar and M'Closkey 1996, Knutson et al.1999, Snodgrass et al. 2000); however, several other studies found that this was an important predictor especially when the pond was isolated (Findlay and Houlahan 1997, Vos and Chardon 1998, Laan and Verboom1998, Werner et al. 2007, Bertrand et al. 2010), suggesting wetland surface area may be an important predictor of breeding site selection in fragmented landscapes

The area of emergent vegetation (m^2) was estimated in the field for each wetland. I presumed that this would be an important predictor variable for several reasons: amphibians often use vegetation as an anchor for egg masses, larvae of some species may forage among plants, and areas of vegetation act as a refuge from predators for the developing larvae. Other studies have found a significant relationship between species occupancy and richness with area of emergent vegetation (Vos and Chardon, 1998, Mazerolle et al., 2005, Van Buskirk, 2005, Maxell 2009).

Landscape Habitat Parameters

Landscape variables were extracted from National Land Cover Data (NLCD) provided by the Multi-Resolution Land Characteristics Consortium (http://www.epa.gov/mrlc) using ArcGIS 3.3 (ESRI, 380 New York Street, Redlands, CA 92373-8100). Most of the landscape metrics (Table 3) used in the habitat models were calculated with the Arcview extension Analytical Tools Interface for Landscape Assessments (ATtILA) available at http://www.epa.gov/nerlesd1/land-sci/attila/index.htm.

Landscape variables were measured at each landscape scale of 500, 1,000 and 2,000 m for both occupied and unoccupied sites for each species or group of species. Although local wetland habitat variables were included in models for all species, landscape variables were only included in models for species depending on their geographic region. For instance, percent forest was only included in models for species that occur in the western montane portion of the state since the eastern portion of the state is primarily grasslands.

Landscape variables were included in the models because of support in the literature suggesting they are important predictors of either presence or species richness. The presence of some amphibian species in wetlands is positively associated to increased forest cover because it provides dispersal corridors for juveniles seeking out new water bodies, connects important foraging and over wintering sites, and provides cool, moist places for adults to burrow (Findlay and Houlahan 1997, Laan and Verboom 1999, Knutson et al. 1999, Houlahan and Findlay 2003, Van Buskirk 2005, Mazerolle et al. 2005). Distance to forest has also been indicated as a good predictor of breeding site selection for some amphibians (Guerry and Hunter 2002, Houlahan and Findlay 2003) so it was also included in models. This metric was estimated in the field at each wetland site. Both forest core and forest edge were calculated using GIS spatial analysis since these metrics have been good predictors of breeding site selection in similar studies. Some amphibians avoid forest edges, staying within forest cores (Gibbs 1998), while other studies have found that forest edges may provide habitat for some amphibians (Knutson et al. 1999).

Many amphibian species are negatively associated with forest cover and positively associated with open areas including grasslands (Guerry and Hunter 2002). Therefore, I included percent natural grass in models for particular species. In some cases, amphibians may be negatively associated with wetlands that are surrounded by grasslands since this type of landscape is often dryer and more exposed to predators (Rittenhouse and Semlitsch 2006).

Anthropogenic factors including the proportion of agricultural and urban land surrounding a breeding area may influence whether or not amphibians use a site. Agricultural areas can be a hostile place for amphibians to cross in order to access a breeding site and can therefore isolate wetland-breeding areas (Gray et al. 2004). However, a positive association between amphibian abundance and agricultural landscapes were found in Wisconsin (Knutson et al. (1999). I included percent agriculture as a variable because it may affect the presence of amphibians in eastern Montana where a significant proportion of the landscape is in agricultural use. Urban cover, including roads, often acts as a barrier to juvenile dispersal and access to foraging and over wintering sites for adults. Many studies have confirmed that there is a significant negative association between road density and site occupancy and species richness (Findlay and Houlahan 1997, Gibbs 1998, Knutson et al. 1999, Houlahan and Findlay 2003, Gray et al. 2004). The percent urban variable included in a portion of the candidate models was calculated from the NLCD. The variable includes low intensity to high intensity developed areas consisting of impervious surfaces and buildings.

Wetland and pond density have also been shown to have a positive association with site occupancy (Knutson et al. 1999, Houlahan and Findlay 2003, Rustigian et al. 2003, Mazerolle et al. 2005). In many of my candidate models, I used the percentage of area in the landscape covered by waterbodies and emergent herbaceous wetlands to predict presence. I assumed that there would be a positive association between amphibian presence and these two variables because an increased area of waterbodies and wetlands indicate more potential foraging and over-wintering sites for adults and new breeding sites for dispersing juveniles. In addition to looking at the percentage of area in the landscape covered by wetland and waterbodies, I measured the Euclidian distance in meters between a wetland site to the next nearest known breeding site of a particular amphibian species and to the next nearest wetland or waterbody. Both variables were calculated in ArcGIS 9.2. These variables represent connectivity between seasonal habitat types that amphibians require and indicate whether or not breeding site isolation affects site occupancy.

Statistical Analysis

Model Development

I used an information-theoretic approach (Burnham and Anderson, 2002) to develop a set of *a priori* candidate models based on environmental variables. This method selects the best approximating model that explains the presence of amphibians in lentic wetland breeding sites. Only environmental variables thought to be important in explaining breeding site selection were used in the models. A maximum of four variables were included in each model because as the number of parameters in a model increase, so does the variance (Burnham and Anderson 2002). In addition, the more variables in a model, the more difficult it is to make realistic recommendations to land managers.

Prior to any analysis, I assessed multicollinearity in predictors by testing for pairwise correlations between variables using Pearson's correlation analysis (Graham 2003). A correlation analysis was conducted for each species or group of species because habitat variables selected for models varied by species life history traits. Correlation coefficients of $r \geq 0.45$ were either combined by first standardizing the variables (Equation 1) and then averaging them (Equation 2), or they were subjected to a principle component analysis (PCA).

The following equations were used to standardize and average two correlated variables:

$$(1)\quad ZF1 = \frac{\text{Environmental variable 1} - \text{Mean of all values of Environmental Variable 1}}{\text{Standard Deviation of Environmental Variable 1}}$$

$$ZF2 = \frac{\text{Environmental variable 2} - \text{Mean of all values of Environmental Variable 2}}{\text{Standard Deviation of Environmental Variable 2}}$$

$$(2)\quad \frac{ZF1 + ZF2}{2}$$

Correlation coefficients greater than 0.45 occurred for some environmental variables at all three landscape scales; however, other variables were only highly correlated at one or two landscape scales. If variables were found to correlate at one spatial scale, then those variables were combined through averaging or PCA at all three broad spatial scales. Variables that were combined using PCA were multiplied by the scaled coefficients of the principle components (Gotelli and Ellison 2004). These scaled coefficients were obtained by first dividing 1 by the square root of their components' corresponding eigenvalue and then multiplying the coefficient (Gotelli and Ellison 2004). Both first and second components were used. These methods were conducted on each species or group of species, because environmental variables differed between species depending on the geographic distribution of the sites that were sampled.

Once correlations between variables were addressed, candidate models were constructed *a priori* for each species or group of species. I developed a suite of 26 candidate models for each species that included wetland, landscape, and a combination of wetland and landscape scales. This set of candidate models was comprised of five wetland-level models including a core model that includes all of the wetland-level variables, eleven landscape models that includes a landscape core model that includes all the landscape-level variables, and nine combination models. I also included a global model containing all the environmental variables considered for a species. Model development methods are discussed for each species or group of species below.

Ambystoma macrodactylum

The wetland-level variables emergent vegetation and surface area were significantly correlated (r = 0.62) for this species, so these variables were standardized and averaged to create a new variable called area of emergent vegetation (A of EM). Landscape variables that were significantly correlated at all three landscape scales included percent wetland and percent water (500 m: r = 0.86, 1,000 m: r = 0.775, 2,000 m: r = 0.776) and percent forest and percent natural grass (500 m: r = -0.830, 1,000 m: r = -0.845, 2,000 m: r = -0.866). There was an inverse relationship between percent forest and percent natural grass, where one or the other dominated the landscape. Percent wetland and percent agriculture were correlated (r = 0.471) at the broadest landscape scale of 2,000 m. Wetlands may be associated with agricultural landscapes because both typically occur in valleys and low lying areas. The variable distance to nearest known breeding site was correlated with percent forest (1,000 m: r = -0.596, 2,000 m: r = -0.620) and percent natural grass (1,000 m: r = 0.557, 2,000 m: r = 0.557) at the two broadest landscape scales. Specifically, distance to nearest known breeding site decreased with percent forest. As the percentage of grassland increases, the distance between known breeding sites increases.

A PCA was employed to combine percent wetland, percent waterbody, and percent agriculture for each broad spatial scale (Table 4). The first component of this PCA had high positive values for percent wetland, percent waterbody, and percent agriculture, therefore a new variable called percent aquatic (%Aq) was created that accounts for 68% to 70% of the observed variation over all three spatial scales. This variable reflects aquatic areas in agricultural landscapes. The second axis of the PCA had high positive values for percent agriculture; therefore, a new variable for percent agriculture was created from these coefficients for all spatial scales. This component explained 23% to 27% of the variation over all the scales. Together both components explained 92% to 95% of the variation over all three scales.

A PCA was also used to combine percent forest, percent natural grass and distance to nearest known breeding site (Table 5). There was an inverse relationship between percent forest and natural grass, where percent natural grass increased with little forest cover. The new variable created from this first PC axis called Open Landscape explains 68% to 79% of the variation over the three landscape scales. A second new variable was created from the second axis called Distance occupied (DistOcc), where high values reflect landscapes where there is increased distances to the nearest known breeding site. This component explained 17% to 26% of the variation over the three landscape scales. Once correlations had been addressed there were twelve final environmental variables (Table 6) used in different combinations to construct 26 habitat models (Table 7).

Ambystoma tigrinum(west)

For the tiger salamander population in the western portion of the state, several environmental variables were determined to be correlated. Percent forest and percent natural grass were correlated at 500 m (r = -0.713) and 2,000 m (r = -0.721). Open landscapes dominated by grasses had a decreased percentage of forest cover, and in forested landscapes there was a decrease in grass cover. Because of this inverse relationship, and since these variables did not correlate with any other variables, I assessed them in different models and did not combine them.

Percent wetland and percent waterbody were correlated at 2,000 m (r = 0.726) and were therefore combined at all landscape scales by standardizing and averaging, creating a new variable percent aquatic (% Aq). Once pairwise correlations had been addressed there were fourteen final variables (Table 8) used in different combinations for the twenty-six habit models (Table 9).

Ambystoma tigrinum (east)

For the eastern population of tiger salamanders, percent wetland and percent waterbody were significantly correlated at the 1,000 and 2,000 m landscape scales (r = 0.497 and r = 0.686 respectively) and were therefore standardized and averaged for all three landscape scales. The new variable was called percent aquatic (% Aq). Once pairwise correlations had been addressed there were ten final environmental variables (Table 10) used in the twenty-six habitat models (Table 11).

Bufo boreas/ Rana luteiventris

Variables that were found to correlate at 500, 1,000 and 2,000 m were percent wetland and percent waterbody (r = 0.793, r = 0.788 and r = 0.814 respectively). Percent wetland and percent agriculture were highly correlated at the broadest spatial scales of 1,000 and 2,000 m (r = 0.42 and r = 0.509), while percent waterbody was highly correlated (r = 0.42) to percent agriculture only at 2,000 m. Because these three variables were highly correlated to one another at one landscape scale, they were subjected to a PCA (Table 12). For component 1, variables with high values reflect agricultural landscapes with increased cover of wetlands and water. The new variable created from this first PCA axis is called percent aquatic (%Aq). In Component 2 there was an inverse relationship between percent wetland and percent waterbody with percent agriculture indicating that as the percent of agriculture increases the amount of wetland and water decreases. Therefore, the new variable created from the second PCA axis is called percent agriculture (% AGT). Component 1 explained 68% to 73% and component 2 explained 21% to 25% of the overall variation at the three landscape scales. There was also an inverse relationship between percent forest and percent natural grass ($r = -0.736$, $r = -0.786$ and $r = -0.823$) at 500, 1,000 and 2,000 m. These two variables were therefore assessed in separate models. Once pairwise correlations had been addressed fourteen final environmental variables (Table 13) were used in different combinations in the twenty-six habitat models for this species (Table 14).

Pseudacris regilla

Three variables at the local level were correlated for this species including emergent vegetation and surface area ($r = 0.461$) and depth and surface area ($r = 0.479$). Therefore all three variables were subjected to a PCA to create two new variables (Table 15). Since emergent vegetation and surface area have much higher coefficients than depth in the first component, a new variable was created where high values reflect a wetland with increased surface area and therefore increased area of emergent vegetation. The new variable created from this first component was called area of emergent vegetation (A of EM). In the second component, depth has a very high value indicating that it explains most of component 2.

There is an inverse relationship between emergent vegetation and depth indicating that as a wetland gets deeper emergent vegetation decreases. Because depth dominates this component the newly created variable was called depth (DP).

Percent forest and percent natural grass were inversely correlated at all three landscape scales (500 m: r = -0.736, 1,000 m: r = -0.812, 2,000 m: r = -0.832). Percent forest was also inversely correlated to percent agriculture at all three-landscape scales (500 m: r = -0.651, 1,000 m: r = -0.684, 2,000 m: r = -0.696). Percent agriculture was correlated to percent natural grass at the 1,000 m (r = 0.502) and 2,000 m (r = 0.531) landscape scales. Percent natural grass was also correlated to the variable distance to forest at all three spatial scales (500 m: r = 0.447, 1,000 m: r = 0.472, 2,000 m: r = 0.454). All four variables were subjected to a PCA where two new variables were created from the first two components. Scaled coefficients (Table 16) for the first two components were similar for the 500 m and 1,000 m landscape scales, however, at the 2,000 m landscape scale coefficients changed. For the first two landscape scales, high values in component 1 reflect an open landscape dominated by both natural grass and agriculture and little forest cover. The new variable created from this component was called percent open landscape (% Open). High values in the second component reflect a landscape that is dominated by agriculture farther from forests and little natural grass cover. The new variable created from this component was called percent agriculture (%AGT).

At the 2,000 m scale, the second component is dominated by the variable distance to forest where high values of this coefficient reflects an increased distance to forest. The new variable from component 2 at the 2,000 m landscape scale was called distance forest (DistFor).

Percent waterbody and percent wetland were found to correlate at all three landscape scales (500 m: r = 0.903, 1,000 m: r = 0.897, 2,000 m: r = 0.919). A new variable called percent aquatic (%Aq) was created by standardizing and then averaging the two variables.

Once all correlations had been addressed by both standardizing and averaging or by employing a PCA, eleven final environmental variables (Table 17) were used in twenty-six models for this species (Table 18).

Bufo woodhousii/Pseudacris maculata

The variables percent wetland and percent waterbody were correlated at all three spatial scales (500 m: r = 0.456, 1,000 m: r = 0.644, 2,000 m: r = 0.863). The variables were combined by standardizing and then averaging to create a new variable called percent aquatic (%Aq). Once correlations had been addressed, ten final variables (Table 19) were used in different combinations for the twenty-six models (Table 20).

Rana pipiens

Percent wetland and percent waterbody were found to be significantly correlated at all three landscape scales (500 m: r = 0.983, 1,000 m: r = 0.995, 2,000 m: r = 0.999). They were combined by standardizing and averaging to create the new variable percent aquatic (%Aq). Once correlations had been addressed, ten final variables (Table 21) were used in different combinations for twenty-six habitat models (Table 22).

Model Selection

To predict the presence of amphibians in Montana, I compared the relative likelihood of all 26 models for each species. The relative likelihood is the standard measurement of a model's goodness-of-fit using logistic regression. Logistic regression is often used in cases where there is a binary outcome as in this case of presence or absence. The dependent variable in this project is the presence or absence of amphibians at a site and the selected environmental variables are the independent explanatory variables. The relative likelihood reflects the odds that the observed values of the dependant variable are predicted from the independent variables. The expected probability of the response variable in logistic regression is on a scale of 0 and 1, where absence is equal to 0 and presence is equal to 1.

I used SPSS to perform the logistic regression which measures a model's goodness-of-fit as –2 times the log of the likelihood (-2LL). Smaller –2LL values indicates a better fit of the model. In addition to the relative likelihood, logistic regression gives an odds ratio of the probability that an event will occur to the probability that an event will not occur. These results are given as coefficients for the independent variable (i.e. environmental variables) where the coefficient value indicates the change in the odds ratio for a one-unit change in that explanatory variable (Dicus 2002). A positive coefficient means that as the environmental variable's value increases so does the odds ratio. For example, if the coefficient for percent wetland were positive for a particular species, it would indicate that as percent wetland increases the odds that a site is occupied also increases. Conversely, if there is a negative coefficient the odds ratio decreases as the environmental explanatory variable's value increases. For example, if the coefficient for percent urban was negative for a particular species, it would indicate that the odds of a site being occupied by that species decreases when percent urban increases.

In order to test the overall fit of my logistic regression models for each species or group of species, I used the Hosmer and Lemeshow chi-square test of goodness-of-fit.

When the goodness of fit test statistic is found non-significant, this indicates that the model prediction is not significantly different from observed values. Therefore, the model fits the data at an acceptable level.

A model selection approach was used to rank the candidate models based on their ability to predict the presence or absence of amphibians in Montana. I used Akaike's Information Criterion (AIC_c), a bias corrected version of AIC for a small sample size, as a method to rank models based on their support from the data (Burnham and Anderson 2002). This version of AIC is encouraged when the ratio of the sample size to the number of parameters in the global model is small (n/K< 40). Because the sample sizes for some of the species included in this project are small, I used the bias corrected version for all species so that the results would be comparable. When the ratio of n/K is large, the AIC and AIC_c are similar and typically select the same model (Burnham and Anderson, 2002). In order to determine if the data were over-dispersed, a variance inflation factor (ĉ) was estimated from the goodness-of-fit chi-square statistic (X^2) of the global model and its degrees of freedom (Burnham and Anderson, 2002). In cases where ĉ >1, modifications to the equation that calculates AIC_c were made following the principles of quasi-likelihood and an over-dispersion factor ($QAIC_c$) was calculated. $QAIC_c$ is calculated by dividing the log-likelihood for each candidate model by the variance inflation factor (ĉ) (Burnham and Anderson 2002).

AIC_c values do not mean much on their own since the constant is unknown and the values are dependant on sample size. In addition, AIC_c values are only comparable to other values in the same model set (Burnham and Anderson 2002). Therefore, the minimum AIC_c value of a model set is subtracted from each other models AIC_c value. These AIC_c

differences (Δ_i) are a valuable way to compare the level of empirical support for each model. The larger the Δ_i, the less support there is for a model. Models with a Δ_i between 0 and 2 are considered to have substantial support, models with a Δ_i between 2 and 4 have moderate support, and models with Δ_i between 4 and 7 have significantly less support. Another way to evaluate model selection uncertainty using AIC_c values is to calculate what are called Akaike weights (w_i). These values are considered to be the weight of evidence in support of a model as the best of all those in a model set. The sum of all the Akaike weights in a model set add up to 1, so that the higher the weight the more support there is for that particular model.

Evidence ratios were calculated to determine the weight of evidence in support of the model with the highest w_i . This is done by dividing the weight of the best model by the weight of every other model in the set. Models with an evidence ratio that is within 10% of the model with the highest weight are considered to have a substantial level of support (Royall 1997, Van Buskirk 2005). Akaike weights were also used to calculate importance weights for individual parameters included in the model set. This was done by summing the weights of all models that contains a particular parameter (Burnham and Anderson 2002).

In order to address model selection uncertainty, where several models are weighted similarly and there is no one "best" model, I calculated model averaged estimates and their standard errors by using model averaging (Burnham and Anderson 2002). This method uses the w_i to weight the parameter estimates from each model. This is accomplished by first multiplying the raw parameter estimate for a variable from the regression model output by the w_i of each model that the predictor variable occurs in. These new weighted parameter estimates are then summed across all the models. A weighted unconditional standard error was calculated for each weighted parameter estimate. This was accomplished by summing the weighted unconditional standard error (Equation 3) of a parameter across all the models where it was present. Large standard errors that are two times greater than the parameter estimate itself are generally considered unreliable (Burnham and Anderson 2002). To determine the precision of a model averaged parameter estimates (MAE), confidence intervals (95%) were calculated using the unconditional standard errors (Equation 4). Model averaged estimates that have a confidence interval that overlaps zero are considered unreliable predictors. The sign in front of a model averaged estimate indicates whether there is a positive or negative association between it and the presence or absence of amphibians at a site.

(3) $SE^2 + (\text{model-averaged estimate} - \text{raw parameter estimate})^2 * \text{model weight}$

(4) $\text{Upper 95\% CI} = MAE + (1.95 * SE) \qquad \text{Lower 95\% CI} = MAE - (1.95 * SE)$

Spatial Autocorrelation

Non-independence between spatially distributed variables can lead to erroneous assumptions about the relationships between environmental variables and the presence of amphibians at a site. This lack of independence between spatially dependent variables can therefore affect the predictive power of a model. Spatial dependence occurs when observations that are made in a close proximity are similar while observations made far apart are often dissimilar (Fortin and Dale 2005). Spatial dependence is measured as spatial autocorrelation because a variable may be correlated to itself up to a certain distance (Gergel and Turner 2002). To determine if the outcomes of the predictive models used in this project were spatially autocorrelated, Global Moran’s Index (Moran’s I) function was used to evaluate whether the deviance residuals of the logistic model were clustered, dispersed or random. The Moran's I for the best supported models was calculated using ArcGIS 9.3. This spatial statistic tool uses both site locations and deviance residuals of the logistic model to determine spatial autocorrelation. A Moran's I near 1.0 indicates clustering while a Moran's I closer to -1.0 indicates dispersion; a Moran's I of 0 indicates randomness. In order to determine the significance of the Moran's I, a Z-score is calculated to assist in rejecting or accepting the null hypothesis of Moran's I. The null hypothesis is that there is no spatial clustering of the sites or values. A Z-score that is not within the desired significance level of $P = 0.05$ rejects the null hypothesis.

Model Validation

Models were validated using data that were collected by me in the summer of 2007 following the methods developed by the MTNHP. In addition, amphibian data collected by the MTNHP not used in the calibration of the original models were used in the validation process. Only fishless sites were considered so that the analysis would be consistent with model calibration results. The same methods were followed for each species or group of species that were used for the original set of data. This includes calculating new variables for highly correlated environmental covariates using either the standardization and averaging method or PCA. The models were validated with the new set of data using logistic regression. The method of validation used was a cross tabulation that assesses the predicted classification of cells versus the observed classification of cells as developed by Hosmer and Lemeshow (1989). Common measurements from the cross tabulation method include the rate of commission and omission, the rate of positive commission, and positive ratios. The rate of commission is the percentage of cells that are correctly classified as either present or absent by the predictive model. The rate of omission is the percentage of cells that are incorrectly classified as either present or absent. The rate of positive commission is calculated as the percentage of cells that correctly classified observed presences. The positive ratio is the ratio of all cells classified as present to the number of cells correctly classified as present. Models with a high rate of positive commission and a small positive ratio perform better.

RESULTS

Ambystoma macrodactylum

Landscape models were best supported by the data for the long toed salamander. Model selection results for models that have a $QAIC_c$ difference less than seven are summarized in Table 23. At the 500 m scale, the best supported model included the variables percent aquatic in an agricultural landscape, distance to forest, percent open landscape and distance to the nearest known breeding site. The evidence ratio for this model was four times greater than the next best supported model (Model 15) and twenty times greater than the landscape core model (Model 16). According to modeled averaged estimates, all variables within this model were important in influencing the presence of long-toed salamanders (Table 24). Although this model had substantial weight at this scale, it was not supported at the 1,000 and 2,000 m scales.

The next best supported model at the 500 m scale included the landscape variables percent aquatic in an agricultural landscape, distance to forest, forest core and distance to the next nearest known breeding site. The only variable that differed between this model and the best supported model was Forest Core. However, only the parameter estimate for the variable Distance to Forest had a 95% confidence interval that did not overlap one in the entire model. The best supported model at both the 1,000 and 2,000 m scales was the global model.

Significant associations between environmental variables and the presence of the long-toed salamander were determined using model averaged estimates (Table 24). Associations with the variable percent aquatic in an agricultural landscape (%Aq) were significant at the 500 and 1,000 m scale, with a negative coefficient indicating an inverse relationship with the presence of this species. This variable also had a high importance weight (Table 25) at all three spatial scales. Distance to the nearest forest also had a high importance weight at all three spatial scales, and according to the model averaged estimate, there is a negative relationship with the presence of the long-toed salamander at all three spatial scales. This indicates that a site is more likely to be unoccupied as the distance to forest increases. The variable percent open landscape also had a high importance weight at all three spatial scales and a significant negative association with the presence of this species at a breeding site at the 500 m scale. The variable distance to the nearest breeding site had a high importance weight over all three spatial scales and had a positive relationship between presence and increasing distance to the nearest known breeding site at the 500 m scale. According to the habitat associations determined through model averaged estimates, the probability of long-toed salamander presence at a breeding site is highest at sites that are not surrounded by agriculture but are surrounded by forested areas and have an increased distance to the next nearest breeding site.

Spatial Autocorrelation

The best models at all three spatial scales were found to have significant spatial autocorrelation. The Moran's I for the best model at 500 m was 0.05 ($P = 0.01$). The next best supported model at this scale had a Moran's I of 0.07 (P = 0.01). At the 1,000 m scale, the best model had a Moran's I of 0.05 (P = 0.01). At the 2,000 m scale, the best model had a Moran's I of 0.05 (P = 0.01).

Model Validation

A validation test was performed on models with substantial support using a separate set of data as a form of cross tabulation. Tables summarizing the results are located in Appendix C. For the purposes of this project, I looked at both rates of positive commission and positive ratios. The rate of positive commission is calculated as the percentage of cells that correctly classified observed presences. The positive ratio is the ratio of all cells classified as present to the number of cells correctly classified as present. Models with a high rate of positive commission and a small positive ratio perform better. The best performing model from models with similar rates of positive commission is the one with the lowest positive ratio.

At the 500 m scale, the overall rate of positive commission for the best supported models 8, 15 and 16 were 90%, 91% and 90% respectively. The positive ratios for these same models were 1.107, 1.100, and 1.106, respectively. Although the results are very close between the validation models, the Landscape model (Model 16) at this scale has the lowest positive rate of commission and lowest positive ratio and is therefore considered the better performing model out of the three.

At the 1,000 m scale, the overall positive commission for the Global model was 95% and its positive ratio was 1.05. At the 2,000 m scale, the overall rate of positive commission was 91% for both the Landscape Core model and the Global model. The positive rate of commission was 1.10 for both models. These results indicate that both models perform equally well. The validation results at all three broad spatial scales suggest that the best supported models performed equally on the validation set of data as on the original dataset.

Ambystoma tigrinum (West)

Four models had support at the 500 m scale and included landscape variables or a combination of local wetland and landscape variables (Table 26). Models that differ from the best supported model by <2 (i.e. any model with a $\Delta AIC_c < 2$) are considered equally supported as the best model. The best supported model included the variables distance to nearest forest, percent natural grass and distance to the nearest known breeding site. The second best supported model included the variables distance to the nearest forest, percent forest and distance to the nearest known breeding site. The only differences between these two models were the variables percent natural grass and percent forest which may account for an evidence ratio of only 1.82. The third best supported model included the variables percent aquatic, distance to the nearest forest, amount of forest core and distance to the nearest known breeding site. The evidence ratio between this model and the best supported model was only 2.18. The fourth model that had substantial support included the variables percent aquatic, distance to the nearest forest, percent forest, and distance to the nearest known breeding site. The evidence ratio between this model and the best supported model was 2.34. Similar environmental variables among the models may account for equivalent levels of support. The variable distance to forest was consistent throughout the best supported models and has a high importance weight (Table 28) and a significant positive association (Table 27) with the presence of tiger salamanders. These results indicate that tiger salamanders are more likely to be present at wetlands that are located in open areas away from forested areas.

The best supported model at the 1,000 m scale was the Landscape Core model followed closely by the Global model (Table 26). The evidence ratio between these two models was 2.48. A third model at this scale had some support and included the variables distance to forest, percent natural grass and distance to nearest known breeding site. However, all of the variables included in this model had a 95% confidence interval that overlapped one, indicating no significant association (Table 27). The only variable with a significant association at this scale was percent aquatic, which was included in both the Landscape Core and Global model. Interestingly, the variable distance to the nearest known breeding site was in all the top models and had a high importance weight (Table 28) at all three spatial scales; however, the variables model averaged estimate did not indicate a significant association. This may be attributed to multicollinearity interactions between this variable and other environmental covariates in the models.

The best supported models at the 2,000 m scale were similar to models that were well supported at 500 m. One model had substantial support at this scale and includes the variables distance to nearest forest, percent natural grass and distance to the nearest known breeding site. The evidence ratio for this model is ten times greater than the next best supported model and nineteen times greater than the third best supported model. The second best supported model at this scale includes the variables distance to nearest forest, percent forest and distance to the nearest known breeding site. The only differences between these two best supported models are the variables percent natural grass and percent forest. Percent natural grass has a higher importance weight at this scale (Table

28), but is not considered to have a significant effect on the model's performance according to its model averaged estimate (Table 27). The variable distance to the nearest known breeding site has the highest importance weight at all three spatial scales however the model averaged estimate is 0.00. This could also be attributed to interactions between this variable and other environmental covariates.

Spatial Autocorrelation

A significant spatial autocorrelation was not detected for any of the best supported models at the 500 m scale. The Moran's I for the best model at 500 m was 0.67 (P = 0.17). The other three models had similar Moran's I including 0.726 (P = 0.13) for Model 13, 0.607 (P = 0.211) for Model 15, and 0.795 (P = 0.102) for Model 8. At the 1,000 m scale, no significant spatial autocorrelation was detected for either the landscape model (Moran's I = 0.134, P = 0.833) or the global model (Moran's I = 0.138, P = 0.828). At the 2,000 m scale, models were determined to be clustered and therefore spatially autocorrelated. The best model had a Moran's I of 0.486 (P = 0.000), while the next best supported models had similar Moran's I including 0.523 (P = 0.000) for Model 13, 0.516 (P = 0.000) for Model 15, and 0.287 (P = 0.01) for Model 16.

Model Validation

Validation results (Appendix C) at the 500 m scale indicate that the best supported models from the original data set were also well supported with the validation data set. Models 24 and 16 had slightly greater predictive power with an overall rate of positive commission of 94% and a positive ratio of 2.06 compared to the original better supported models 14, 13, 15 and 8 which all had the same rate of positive commission of 91% and a positive ratio of 2.1. At the 1,000 m scale, the best supported models from the original data were equally supported with the validation data, with overall rate of positive commission equal to 91%, 91% and 94% for models 16, 26 and 14 respectively. Again, the least supported model from the original data set had slightly greater predictive power with the validation data set. At the 2,000 m scale, the three best supported models were also well supported with the validation data with rates of positive commission ranging from 94% for the best supported model 14 to 88% for models 15 and 16. All other models had high rates of positive commission equal to 91%. Positive ratios ranged from 1.06 for the best supported model to 1.14 for the least supported models.

Ambystoma tigrinum (East)

Wetland level and combination models were best supported at all three spatial scales (Table 29). At the 500 and 1,000 m scales, the same models were determined to have the same level of support. The two models with substantial support ($\Delta AIC_c < 2$) at both scales included wetland level variables. The best supported model at both the 500 and 1,000 m scales included the variables elevation, area of emergent vegetation, and surface area. The second best supported model at both scales included the variable elevation and had an evidence ratio of 1.36 with the best model. At the 2,000 m scale, there were five models with substantial support. The variable elevation was included in all five models. At all three landscape scales, the models had equivalent levels of support with evidence ratios that ranged from 1.36 to 4.33 at the 500 m scale, 1.36 to 3.45 at the 1,000 m scale, and 1.35 to 1.96 at the 2,000 m scale. The model averaged estimates (Table 30) and the importance weights (Table 31) for all three landscape scales indicate that elevation is an important variable in predicting presence of this species. The model averaged estimate indicates a negative relationship. Therefore, this species is less likely to be present at a site with increasing elevation.

Spatial Autocorrelation

The best supported models at all three spatial scales were determined to be spatially correlated. The Moran's I for the best models at both the 500 and 1,000 m landscape scales were -2.24 (P = 0.008) for Model 2 and -1.833 (P = 0.03) for Model 1. The negative Moran's I for both these models indicate that sites are spatially dispersed on the landscape. A dispersed spatial pattern can also lead to spatial autocorrelation because similar features repel other similar features. At the 2,000 m scale the best models were also all significantly spatially autocorrelated. The best supported model at this scale had a Moran's I of -2.428 (P = 0.004). The next best supported models had similar Moran's I including -2.429 (P = 0.004) for Model 18 and -3.201 (P = 0.000) for Model 26.

Validation Results

Validation results (Appendix C) at all three broad landscape scales indicate that the best supported models from the original data set were also well supported with the validation data set. At the 500 m scale, models 2, 5, 23, 17 and 18 predicted presence every time with an overall rate of positive commission of 100% and a positive ratio of one. Model 1 had a slightly lower overall rate of positive commission of 99%. Results were similar at the 1,000 m scale, with models 2, 5, 23, 17 and 18 having a 100% rate of positive commission and a positive ratio of one. Model 1 again had a slightly lower overall rate of positive commission of 97%. At the 2,000 m scale, all models had an overall rate of positive commission of 100% and a positive ratio of one.

Bufo boreas/Rana luteiventris

Landscape models were best supported for this group. The same model was the best supported at all three spatial scales with increasing support at larger scales. This model includes the variables percent aquatic sites in an agricultural landscape, distance to the nearest forest, percent forest, and distance to the nearest breeding site (Table 32). This model had the most support at the 2,000 m scale, suggesting that this is an important scale for the management and protection of these two species.

Across all three spatial scales, model averaged 95% confidence intervals for the logistic regression coefficients did not include 0 for percent aquatic in an agricultural landscape and percent forest (Table 33). These results indicate a negative association with both these variables across all three spatial scales. At the 1,000 m scale, the model averaged 95% confidence interval did not overlap 0 for the variable percent forest, indicating that there was an additional positive association with percent forest at this scale. Variables included in the best model also had the highest importance weights (Table 34). The variable distance to the nearest breeding site had a high importance weight at all three scales but its model averaged estimate and 95% confidence interval were 0. The results indicate that both species are attracted to sites in close proximity to forested areas and away from agricultural landscapes.

Spatial Autocorrelation

A significant autocorrelation was not detected in the best model at the 500 and the 2,000 m scale but was detected at the 1,000 m scale; the Moran's I for 500, 1,000, and 2,000 m scales were -0.07 (P = 0.556), -0.292 (P = 0.021), and -0.21 (P = 0.087).

Validation Results

The overall rate of positive commission for the best model was 73% (positive ratio of 1.5) at 500 m, 71% (positive ratio of 1.6) at 1,000 m, and 60% (positive ratio of 1.8) at 2,000 m. Full table of results can be found in Appendix C.

Pseudacris regilla

Combination models were best supported at all three landscape scales (Table 35). The best model at 500 and 1,000 m included the variables elevation, percent agriculture, forest edge, and distance to the next nearest known breeding site. Support for this model increased with increasing spatial scale. The next best supported model at the 500 and 1,000 m scale was similar except that the variable forest edge was replaced with percent open landscape in the second best model. The similarity between models could account for small evidence ratios of 1.07 at 500 m and 1.28 at 1,000 m for Model 23. The evidence ratio between the best model and the global model was 29.7 at 500 m and 22.7 at 1,000 m. The global model had substantial support at the 2,000 m scale and surpassed model 23. The evidence ratio for the global model at this scale was 2.74, indicating model uncertainty. The best model at the 2,000 m scale was similar to the best models at the other two landscape scales, except that distance to forest was included in the model. No significant associations were found for this species (Table 36). The variables percent agriculture/distance forest, distance to nearest known breeding site, and elevation had the highest importance weights at all three scales (Table 37).

Spatial Autocorrelation

A significant spatial autocorrelation was not detected in the best models at all three landscape scales. The Moran’s I for the best model at the 500, 1,000 and 2,000 m scales was -0.18 (P = 0.696), -0.59 (P = 0.303), and 0.25 (P = 0.568) respectively. The Moran's I for the next best supported model at the 500 and 1,000 m scales was -0.173 (P = 0.707) and -0.682 (P = 0.237) respectively.

Validation Results

Validation results (Appendix C) at all three broad landscape scales indicated that the best supported models from the original data set were equally well supported with the validation data set. The three models predicted presence accurately at the three landscape scales with an overall rate of positive commission of 100% and a positive ratio of one.

Bufo woodhousii/Pseudacris maculata

Combination models that included both landscape and local wetland habitat variables had substantial support (Table 38). The best model was well supported at all three spatial scales and included the variables elevation, percent aquatic sites, percent natural grass and distance to the nearest breeding site. This model had an increasing level of support at broader landscape scales. The next best model had substantial support at both 500 m and 1,000 m scales but had no support at the 2,000 m scale. The evidence ratio between the two models with support was 1.41 at the 500 m scale and 1.58 at the 1,000 m scale. Small evidence ratios can be attributed to the similarity of variables between the models. At the 2,000 m scale only model 17 had substantial support from the data.

Model averaged estimates (Table 39) and importance weights (Table 40) indicate that the variables elevation and percent natural grass have a significant association with both these species. A negative association with the variable elevation signifies that sites at a higher elevation are less likely to be used by this species. A positive association with the variable percent natural grass indicates that both species are attracted to sites surrounded by a natural landscape dominated by grasses. At the 2,000 m scale, a significant negative association with the variable percent aquatic sites indicates that upland areas may be extremely important. The importance weight for this variable increased with increasing scale. Alternatively, the variable emergent vegetation had a high importance weight at the 500 and 1,000 m scales but was not important at the 2,000 m scale. The variable distance to the nearest breeding site was present in the best supported models and had high importance weights at all three spatial scales; however, the model average estimate did not indicate a significant association with the presence of these species.

Spatial Autocorrelation

A significant spatial autocorrelation was not detected in the best models at all three landscape scales. The Moran's I for the best model at the 500, 1000 and 2000 m scales was 0.488 ($P = 0.3$), 0.036 ($P = 0.517$), and 0.014 ($P = 0.756$) respectively. The Moran's I for the next best supported model at the 500 and 1000 m scales was 0.592 ($P = 0.211$) and 0.04 ($P = 0.486$) respectively.

Validation Results

Validation results (Appendix C) at all three broad landscape scales indicate that the best supported models from the original data set were equally well supported with the validation data set. The overall rate of positive commission for the best model was 99% with a positive ratio of one at all three spatial scales. Model 24, the next best supported model, had an overall rate of positive commission of 96% (positive ratio of 1) at 500 m and 100% (positive ratio of 1) at 1,000 m.

Rana pipiens

Combination models were best supported at all three landscape scales (Table 41). The best supported model at 500 m included the variables elevation, area of emergent vegetation, percent natural grass, and distance to the nearest known breeding site. However, this model was not substantially better than the next best supported model (Model 23) with an evidence ratio of only 2.74. The only differences between these two models were the variables distance to the nearest known breeding site and distance to the nearest water body. The third best supported model (Model 17) at 500 m also had substantial support from the data with an evidence ratio of 3.65. The only difference between this model and the best supported model were the variables emergent vegetation and percent aquatic.

The best model (Model 17) at 1,000 m had substantial support despite having the least support out of the models at 500 meters. At the 2,000 m scale, the same models that were well supported at the 500 m scale were again the best supported. However, at this scale the w_i for Models 17, 23 and 24 were nearly equal, indicating model uncertainty at this scale.

Percent natural grass was the only variable to have a significant association with the presence of this species and this association only occurred at the 500 m scale. Importance weights (Table 43) also indicate that the variables percent natural grass and elevation are important predictors. The variable percent urban had a significant association at the 500 m landscape scale but was not included in the best supported models.

Spatial Autocorrelation

The best supported models were spatially autocorrelated at the 500 m scale but randomly distributed at the 1,000 and 2,000 m scales. The deviance residuals for Model 24 were determined to be clustered with a Moran's I of 0.264 (P = 0.000) at the 500 m scale and random with a Moran's of 0.003 (P = 0.808) at the 2,000 meter scale. Model 23 had a Moran's I of 0.703 (P = 0.00) at 500 m and -0.0007 (P = 0.849) at 2,000 m. Model 17 was well supported at all three spatial scales and had a Moran's I of 0.198 (P = 0.008) at 500 m, 0.007 (P = 0.777) at 1,000 m, and 0.006 (P = 0.803) at 2,000 m.

Validation Results

Validation results (Appendix C) at all three broad landscape scales indicated that the best supported models from the original data set were equally well supported with the validation data set. All three models predicted presence accurately with an overall rate of positive commission of 100% and a positive ratio of one at all three landscape scales.

DISCUSSION

Results indicate that breeding site selection is primarily influenced by environmental factors measured at a landscape scale or a combination of local and landscape scales for the eight amphibian species included in this project. The following is a discussion of the significant habitat associations and effective management scale for each species.

Ambystoma macrodactylum

Habitat associations were more apparent and were explained by fewer models at the 500 m scale. The reduced candidate models were not supported at the broader scales. These results coincide with the seasonal migration and juvenile dispersal distances known for this species (600 m). The highest ranked models included only landscape variables. Two *a priori* models containing similar landscape variables were well supported. The best model predicted that long-toed salamanders were more likely to use isolated breeding sites closer to forest and with more forest cover. Sites were less likely to be used where agriculture and open landscapes dominated. Similar relationships were determined in Idaho, where this species is most often found in fishless, more isolated sites surrounded by forest and further from agriculture (Goldberg and Waits 2009). Wetland level habitat variables did not influence breeding site selection for this species. Importance weights for landscape variables were greater than importance weights for the wetland level variables. These results suggest that to be effective, conservation efforts for this species must consider these landscape factors.

A positive association between forest cover and amphibian presence has been reported in the literature for many amphibians (Knutson et al 1999, Mazerolle et al. 2005) and specifically for the long-toed salamander in western Montana (Naughton et al., 2000) and Idaho (Goldberg and Waits 2009). In Montana, long-toed salamander abundance was found to decrease with the loss of intact forest cover. In fact, a 70% decrease in salamander abundance was observed in an area where logging occurred (Naughton et al. 2000). Goldberg and Waits (2009) found that low and high density forest had the highest relative importance in their habitat models. Percent forest may be an important habitat component for this species because of the microclimactic stability that forest canopies provide (Dupuis et al. 1995, Naughton et al. 2000). Removal of forest canopy leads to increased temperatures and decreased soil moisture which many amphibians cannot tolerate

(Goldberg and Waits 2009). This could also explain why the variable percent aquatic in an agricultural landscape was negatively associated with the presence of this species and was determined to have a high relative importance at both 500 and 1000 m. In Idaho, agriculture was most predictive of breeding site selection within 30 m (Goldberg and Waits 2009). The negative association with distance to forest and agriculture, and positive association with forest cover, may reflect the physiological restraints of this species (Goldberg and Waits 2009).

There was a positive association between presence and distance to the nearest known breeding site at the 500 m scale. This relationship could be attributed to low levels of exchange between populations through adult migration or juvenile dispersal (Funk and Dunlap 1999, Tallmon et al. 2000). Long-toed salamander populations have been shown to be genetically similar among ponds within a basin, indicating that regional populations act as mating units (Tallmon et al. 2000). However, there was substantial genetic variation between populations located in different basins. These results indicate that populations are often spatially isolated by long distances and landscape barriers like ridges. Long-toed salamanders may also use more isolated breeding sites because they are less likely to contain fish (Maxell 2009, Goldberg and Waits 2009, Tallmon et al. 2000).

Based on the results of this project, effective management of this species must occur at a landscape scale that includes seasonal habitat areas and dispersal corridors. An adequate buffer zone of 600 m surrounding a breeding site should include intact forested areas and little agricultural land. Wetlands selected for restoration or reintroduction should be fishless with a 600 m buffer dominated by forest.

Ambystoma tigrinum

Habitat associations of the tiger salamander in the southwestern part of Montana were explained by several models at all three spatial scales that included only landscape variables. These results suggest that conservation efforts for this species would be most effective when landscape factors are considered. The best model at the 500 m scale was the only model that had support at all three spatial scales, with increasing support with increasing spatial scale. The lack of support for just one model at the 500 and 1,000 m scales may be attributed to the flexibility with which this species uses terrestrial habitat (Porej et al. 2004). One model had most of the support at the 2,000 m scale, indicating that an increased distance to forest and higher percentage of areas dominated by natural grass are important landscape features. Other studies have also shown that the composition of landscape features at broader landscape scales is important for the tiger salamander. Porej et al. (2004) found that the best habitat models for the tiger salamander were measured outside of a core terrestrial zone between 200 m and 1 km. Their study also found the presence of tiger salamanders to be negatively associated with the length of roads and with the average linear distance to the five nearest wetlands. My study did not find a significant association between the presence of this species and the variable percent urban or with the variable distance to the nearest known breeding site or waterbody. However, distance to the nearest breeding site was included in all of the top models and the variable percent aquatic was an important variable at 1,000 m based on model averaged estimates. This may indicate that wetland density, not distance to other wetlands, is important to this species. A study in Montana determined that the presence of tiger salamanders was mainly influenced by the presence of emergent vegetation followed by fish presence or absence

(Maxell 2009). In this project, local level habitat variables did not influence breeding site selection for this species in the western part of the state.

In contrast, wetland level habitat models had substantial support for the eastern population of tiger salamanders. However, the only habitat association identified with the model averaged estimated was elevation. Presence was negatively associated with elevation indicating that sites are less likely to be occupied with increased elevation. Local level variables also had the highest importance weights. Several models had support at all three spatial scales which may be attributed to this species flexibility in terrestrial habitat use (Porej et al. 2004, Madison and Farrand 1998). Friable soils suitable for burrowing or the presence of animal burrows near breeding sites may also be more important environmental factors to this species (Maxell et al. 2009).

Bufo boreas

The habitat associations of the western toad were explained by the same model at all three spatial scales with increasing support with increasing scale. The best model predicted that western toads were more likely to use sites with a higher percentage of forest cover and a decreasing distance to forest. Aquatic sites were less likely to be used when the surrounding landscape is dominated by agriculture. The model was best supported at the 2,000 m scale, indicating that broader landscape scales are important for the management of this species. Intact broad landscapes are important to the western toad because they use three different types of habitat annually: breeding sites, summer range for foraging, and overwintering sites (Loeffler 2001). Western toads have been shown to migrate far distances to reach their different habitat requirements including 1.5 km from summer habitat to overwintering sites (Bartelt 2000), 2.5 km from overwintering sites to breeding sites (Breden 2004) and up to 500 m per day (Adams et al. 2005). They have been found to use terrestrial habitat 75% of the time (Bartelt 2000) and are primarily associated with forest habitat (Loeffler 2001). Streams (Adams et al. 2005) and wetlands (Loeffler 2001) are other important habitat features for both juveniles and adults.

Based on the results of this project, effective management of this species must take into consideration seasonal habitat areas and dispersal corridors at a landscape scale. Habitat models were best supported at the 2,000 m scale which corresponds with seasonal migration distances this species travels to access necessary habitat. An adequate buffer zone surrounding a breeding site should include intact forested areas. Wetlands selected for restoration or reintroduction should be located adjacent to large intact areas of forest.

Rana luteiventris

The habitat associations of the Columbia spotted frog were also explained by the same model at all three spatial scales with increasing support with increasing scale. The best model predicted that Columbia spotted frogs were likely to use sites with a higher percentage of forest cover and a decreasing distance to forest. Sites were less likely to be used with an increasing presence of agriculture. The model had the most support at the 2,000 m scale, indicating that broader landscape scales are important for the management of this species. This spatial scale corresponds with seasonal migration distances up to 2,000 m to reach spatially separated habitat patches for breeding, foraging, and over-wintering. Characteristics of breeding sites in Montana are small fishless ponds with a silt substrate bordered by forest, while foraging sites include many wetland types, and over-wintering areas are typically large, deep, and rocky lakes (Pilliod et al. 2002). Female Columbia spotted frogs have been found to travel up to 2,066 m round trip to access these different habitat requirements. In addition, travel routes between these seasonal habitats are usually the shortest distance straight line routes so that frogs often cross upland forested areas (Pilliod et al. 2002). High juvenile dispersal rates up to 62% annually have been found for some populations of Columbia spotted frogs in Montana (Funk et al. 2004). Dispersing juveniles traveled up to 5,000 m over large elevation gains to reach new habitat areas. These results suggest that juvenile dispersal influences the population dynamics of this species through extinction and recolonization (Funk et al. 2004, Funk et al. 2005). Therefore, the conservation of this species not only depends on important interconnected aquatic habitats but also on dispersal corridors for juveniles.

A positive habitat association between percent forest and a negative association with distance to forest was expected. Most breeding sites in Montana are surrounded by forest and these forested areas are used by this species to migrate to different habitat components (Pilliod et al. 2002). Columbia spotted frogs in Idaho were also positively associated with density of forest (Goldberg and Waits 2009). Results from my study indicate that percent forest within 1,000 m of a breeding site is most important. Local level wetland characteristics were not important variables based on the results of this study. However, high solar insulation was an important predictor in Idaho (Goldberg and Waits 2009), and ephemeral wetlands with emergent vegetation were more likely to be occupied in Montana (Maxell 2009). In Utah, Columbia spotted frogs were commonly found in permanent ponds with consistent water temperatures, and in ponds that contained a high cover of emergent vegetation (Welch and MacMahon 2005). However, the study in Utah only considered local level variables and did not incorporate landscape level variables into their models. Within wetland characteristics are probably more important at sites where fish are present.

Based on the results of this project, effective management of this species must take into consideration seasonal habitat areas and dispersal corridors at a landscape scale. Habitat models were best supported at the 2,000 m scale which corresponds with seasonal migration distances this species travels to access necessary habitat. An adequate buffer zone surrounding a breeding site should include intact forested areas. Wetlands selected for restoration or reintroduction should be located adjacent to large intact areas of forest.

Pseudacris regilla

Breeding site selection by the Pacific treefrog was explained by the same three models at all three spatial scales. The best models included both wetland and landscape variables. The same model was the relative best at all three spatial scales and indicates that this species is more likely to occur at sites closer to forest and away from agriculture. There was increasing support for the best model at increasing spatial scales. A positive association to forest edge indicates that this species uses areas adjacent to forests rather than within large forested areas. Studies in Idaho also show that this species was associated with low density forests (Goldberg and Waits 2009). Results from my study differed from results in Idaho in that there was a negative association between open landscapes and agriculture for the Pacific treefrog in Montana. In Utah, the Pacific treefrog was highly associated with the presence of non-native fish (Pearl et al. 2005). Fish presence and emergent vegetation cover were determined to be an important factor in site occupancy for this species in Montana (Maxell 2009). Isolated wetlands were also important to this species in Idaho (Goldber and Waits 2009). Distance to the nearest known breeding site was included in the best models but did not have a significant association with the presence of this species.

The best supported model had a higher Akaike weight at 2,000 m which does not coincide with the known seasonal migration distances of this species. Pacific treefrogs are known to migrate up to 1,000 m but they typically reside within 400 m of a breeding pond (Schaub and Larson 1978). Significant associations between habitat variables based on model averaged estimates may not have occurred because they were measured at too broad of a spatial scale or that this species is flexible in its habitat preferences. Significant association may not have occurred because the combination of these variables is more important compared to their individual importance.

Bufo woodhousii

Habitat associations of the Woodhouse's toad were more apparent and were explained by a fewer number of models at the 2,000 m scale, indicating this is an important scale for the management of this species. Not much is known regarding the seasonal migration distances of adults between complimentary habitats; however, juveniles have been observed dispersing up to 2,000 m (Maxell et al. 2009). Two models were well supported at the 500 and 1,000 m scales and included both local and landscape level variables. The same model had the relative highest support from the data at all three spatial scales with increasing support with increasing scale. The best model predicted that the Woodhouse's toad was more likely to use sites at lower elevations that are surrounded by upland areas dominated by natural grass. This model had substantial support at 2,000 m. The variable percent aquatic is negatively associated with breeding site selection at this broad landscape scale. A negative association with increased aquatic areas may be explained by the use of upland habitats by adults for foraging and over-wintering. The second best supported model at 500 and 1,000 m indicates that emergent vegetation is important at a small scale, but at a broader scale, landscape variables become increasingly important.

The results of my habitat models indicate that the effective management scale for this species occurs at 2,000 m. This scale corresponds with the known dispersal distances of juveniles of this species. Local level wetland characteristics, including the amount of emergent vegetation, may be important at a small scale. Therefore, restoring wetlands to create habitat for this species should consider these local level wetland factors.

Broad landscapes dominated by upland grasses and a higher percentage of aquatic sites around breeding sites should be protected or restored for the conservation of this species.

Pseudacris maculata

Habitat associations of the boreal chorus frog were explained by the same combination model at all three spatial scales. This model indicates that the boreal chorus frog is more likely to occur at lower elevation sites surrounded by open upland landscapes dominated by natural grasses. In addition, sites with a higher percentage of aquatic sites within 2,000 m are more likely to be used as a breeding site. The best model had substantially more support at the 2,000 m scale, indicating that broad landscape scales are important for the management of this species. However, this scale is much larger than this species' seasonal migration and juvenile dispersal distances. This could be attributed to models that were constructed for both the Woodhouse's toad and the boreal chorus frog. Running models on species with differing seasonal migration and juvenile dispersal distances may have construed the true effective scale of the boreal chorus frog. Similar studies have found that habitat variables measured at both a 500 m scale (Price et al. 2004) and 1,000 m scale (Trenham et al. 2003) effectively predict the occurrence of the boreal chorus frog. A second well supported model at the 500 and 1,000 m scales also suggests that emergent vegetation cover is important at smaller landscape scales.

A negative association with elevation was to be expected since this species is found at low to mid elevations in Montana (Maxell et al. 2009). A positive association with the habitat variable percent natural grass corresponds with this species preference of open canopy sites (Skelly et al. 1999) that are surrounded by upland grassland and herbaceous cover (Trenham et al. 2003). The significant association between the presence of this species and upland habitat features suggests that upland areas adjacent to breeding sites are critical for the protection of this species and that protecting breeding sites alone is not sufficient. A positive association between the variable percent aquatic at 2,000 m indicates that areas with an increased density of wetlands may be important to the success of a breeding site. Trenham et al. (2003) found a positive association between boreal chorus frog site occupancy and the number of wetland patches within 1,000 m of a wetland. The density or number of wetlands in the vicinity of a breeding site may be important as complimentary habitat for foraging or may provide potential dispersers for rescue and recolonization following an extinction event (Trenham et al. 2003). The variable distance to the nearest known breeding site was also in the two best models, indicating that pond isolation is an important influence on the presence of this species at a site (Marsh and Trenham 2001, Trenham et al. 2003). Even though this variable did not have a significant model averaged estimate, it may influence breeding site selection in combination with the other habitat variables in the models.

The second best supported model at the 500 and 1,000 m scales included the variable emergent vegetation. Emergent vegetation may be important in breeding sites for several reasons including boreal chorus frogs attach egg masses to emergent vegetation (Corn and Livo 1989), and emergent vegetation can act as a refuge from predators (Corn et al. 1997). Emergent vegetation was determined to be important to site occupancy of the boreal chorus frog in Montana followed by hydroperiod (Maxell 2009). This species is found more often in wetlands with intermediate to temporary hydroperiods (Skelly et al. 1999, Maxell et al. 2009) which can be attributed to poor survivorship in the presence of predators like fish which occur in more permanent water bodies (Skelly 1995, Skelly et al. 1999, Maxell 2009).

The results of my habitat models indicate that wetland level characteristics, including the area of emergent vegetation, are important at a small scale. However, broad landscapes (1,000 m) dominated by upland natural grass and a higher percentage of aquatic sites are also very important to the preservation of this species. Breeding sites that are surrounded by these landscape parameters should be protected and restoration sites should be selected based on these parameters.

Rana pipiens

Combination models including both wetland and landscape level factors were best supported for this species. This could be attributed to the three distinct habitats that this species requires including a breeding pond in the spring, grassy upland areas for foraging in the summer, and a deep permanent water body for over-wintering (Pope et al. 2000). Germaine and Hayes (2009) also found that site occupancy was best predicted by combination models at a 1,000 m scale that included the variables average midsummer pond depths, fewer ponds occupied by bull frogs (*Rana catesbeiana*) and carp (*Cyperinus carpio*), and increased herbaceous cover adjacent to breeding ponds. Similarly, Pope et al. (2009) determined that the mean pH of a breeding pond, the amount of emergent vegetation on the north side of a pond in shallower water, the amount of perennial forage crops within 1,000 m of a breeding pond, and the number of sites with chorusing northern leopard frogs within 1,500 m, were important determinants of site occupancy.

The best model with the most support occurred at the 1,000 m scale. This indicates that this is an important scale for the protection and management of this species. This broad landscape scale corresponds with the maximum distance that the northern leopard frog is known to travel in order to reach complementary seasonal habitats (Dole 1968). The best model suggests that elevation, density of aquatic sites, the presence of natural grass, and distance to the nearest known breeding site are important factors in the presence of this species.

Significant habitat associations were present at only the 500 m scale. The three models that were well supported at the 500 m scale had two consistent habitat variables: elevation and percent natural grass. Percent natural grass was the only variable in the best models at this scale with a significant association with presence. The positive association with percent natural grass indicates that the amount of upland habitat dominated by natural grasses surrounding a breeding site is an important habitat component for this species at this scale. This is consistent with results from previous studies indicating that the northern leopard frogs' summer habitat typically consists of grassy wet meadows or fields adjacent to breeding sites (Knutson et al. 1999, Pope et al. 2000, Pember et al. 2002, Germaine and Hayes 2009). Eighty-three percent of northern leopard frog observations in a study conducted by Pember et al. (2002) were in areas dominated by natural grass, aquatic emergent vegetation, and wet meadows. Grasslands surrounding breeding sites are important to the northern leopard frog in the summer for foraging, cover for protection from predators, and for retaining moisture (Dole 1968, Seburn et al. 1997, Germaine and Hayes 2009). Surprisingly, there was also a significant positive association with the variable percent urban at the 500 m scale based on model average estimates. This relationship may be attributed to the fact that the northern leopard frog prefers more permanent water bodies (Skelley 1999, Knutson et al. 1999, Maxell 2009). In eastern Montana, permanent water bodies are typically reservoirs and stock ponds that have roads associated with them.

Based on the results of this project, effective management of this species must take into consideration seasonal habitat areas and dispersal corridors at a landscape scale. Habitat models were best supported at the 1,000 m scale which corresponds with seasonal migration distances this species travels to access necessary habitat and juvenile dispersal distances. Intact areas consisting of natural grasses should be protected around breeding sites at this scale. Restoration sites should be selected in areas that have intact grassland in the buffer.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The results of this study indicate that the occurrences of amphibians in Montana are influenced by landscape level factors or a combination of wetland and landscape level factors. Models with landscape variables or a combination of wetland and landscape variables were best supported for all of the species in the study except for the eastern population of tiger salamanders. However, other variables may be important that were not included in the models, including presence of fish, presence of bullfrogs, and pond permanence (Maxell 2009). In addition, some variables may not have been associated with the occurrence of amphibians because of the location of sample sites. For instance, the absence of strong effects of urban land cover could be attributed to a higher number of sites assessed on public land located away from urban areas or because presence rather than abundance was considered.

In the past, the protection and management of amphibians has been focused on the quality of wetland breeding habitat and not until recently have complimentary habitats surrounding breeding areas been considered. The results of this project demonstrated that landscape influences are important in relation to the seasonal migrations of adults between breeding, foraging, and over-wintering habitats. Therefore, the most effective management scale will differ among species based on adult habitat preferences, life history traits, and population dynamics (Price et al 2005). Associations of species with landscape variables at spatial scales broader than just the area of breeding habitat indicate the distribution of favorable habitat that can guide in targeting conservation area, restoration, and reintroduction of amphibian species in Montana.

Many amphibian populations depend on immigration from nearby occupied sites to sustain or recolonize a population following an extinction event. This increases the vulnerability of amphibian populations to habitat fragmentation. Therefore, not only is it important to protect seasonal habitats but also the dispersal corridors connecting breeding ponds. An interesting result of this study was that the variable distance to the next nearest breeding site was included in almost all of the best models which indicate it is important to breeding site selection. However, it rarely had a significant association with presence based on model average estimates. It is therefore unclear if it is acting independently. Further analysis in the future would help to tease out these interactions to develop a more defined relationship between this variable and amphibian presence.

The results of this investigation of habitat associations at multiple scales emphasizes the importance of maintaining intact landscapes around amphibian breeding ponds in order to meet the habitat requirements of amphibians during all stages of their life cycle. We can no longer expect the management of breeding sites alone to be sufficient in reversing the significant declines in amphibian populations. We must identify high quality habitat specific to a particular species and the scale at which those habitat associations occur so that intact areas of high quality can be protected and degraded areas can be restored.

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Table 1

Table 1. List of the eight amphibian species included in the project with common and scientific names, abbreviations used in this document, and number of sites where amphibians were present and absent.

WEST				EAST			
Species or Group of Species:	**Abbreviation**	**Number of Sites with Presence**	**Number of Sites with Absence**	**Species or group of Species:**	**Abbreviation**	**Number of Sites with Presence**	**Number of Sites with Absence**
Long-toed Salamander (*Ambystoma macrodactylum)*	AMMA	397	270	Tiger Salamander (*Ambystoma tigrinum)*	AMTI	66	27
Tiger Salamander (*Ambystoma tigrinum)*	AMTI	36	85	Woodhouses's Toad/ Boreal Chorus frog (*Bufo woodhousii/Pseudacris maculata)*	BUWO/PSMA	130	28
Pacific Treefrog (*Pseudacris regilla)*	PSRE	44	146	Northern Leopard frog (*Rana pipiens)*	RAPI	34	26
Western Toad/ Columbia Spotted Frog (*Bufo boreas/Rana luteiventris)*	BUBO/RALU	383	341				
Validation data set							
WEST				**EAST**			
Species or Group of Species:	**Abbreviation**	**Number of Sites with Presence**	**Number of Sites with Absence**	**Species or group of Species:**	**Abbreviation**	**Number of Sites with Presence**	**Number of Sites with Absence**
Long-toed Salamander (*Ambystoma macrodactylum)*	AMMA	311	272	Tiger Salamander (*Ambystoma tigrinum)*	AMTI	67	26
Tiger Salamander (*Ambystoma tigrinum)*	AMTI	34	85	Woodhouses's Toad/ Boreal Chorus frog (*Bufo woodhousii/Pseudacris maculata)*	BUWO/PSMA	126	29
Pacific Treefrog (*Pseudacris regilla)*	PSRE	16	13	Northern Leopard frog (*Rana pipiens)*	RAPI	33	27
Western Toad/ Columbia Spotted Frog (*Bufo boreas/Rana luteiventris)*	BUBO/RALU	40	44				

Table 2. Preferred adult seasonal habitat (Maxell et al. 2009), seasonal migration distances between preferred habitat, and juvenile dispersal distances for each species.

	Breeding	Foraging	Overwinter	Migration	Dispersal
Long-toed salamander	Ephemeral/ Permanent sites without fish near forested areas	Terrestrial habitats near forested areas	Terrestrial habitats near forested areas	Up to 600 Meters[1]	Up to 600 Meters[1]
Tiger Salamander	Temporary/ Permanent sites	Terrestrial habitats with friable soils	Terrestrial habitats with friable soils	~ 162 Meters[2]	~ 229 Meters[3]
Western Toad	Fringes of lakes, ponds, slow moving streams and backwater channels of rivers	Wetlands, forests, sagebrush, meadows and floodplains	Terrestrial habitats	Up to 2,440 Meters[4]	~ to 3,000 Meters[5]
Woodhouse's Toad	Fringes of lakes, ponds, and reservoirs, depressional wetlands and irrigation ditches	Floodplain and riparian areas with friable soils, upland native grassland	Terrestrial habitats	Unknown	Up to 2,000 Meters[1]
Columbia Spotted Frog	Fringes of lakes without fish and shallow ponds with emergent vegetation	Fringe of aquatic areas and adjacent terrestrial habitats	Deep permanent aquatic areas	Up to 2,000 Meters[6]	7,000 Meters[1]
Pacific Treefrog	Ephemeral/ Permanent sites with emergent vegetation and without fish	Adjacent to forested areas	Terrestrial habitats	Up to 1,000 Meters[1]	Unknown
Northern Leopard frog	Ephemeral/ Permanent sites with emergent vegetation	Fringe of aquatic areas and in adjacent terrestrial habitats	Deep permanent aquatic areas	Up to 1,000 Meters[7]	Up to 1,000 Meters[8]
Boreal chorus frog	Permanent/ Ephemeral sites with emergent vegetation and without fish	Grasslands, shrublands and forests adjacent to aquatic sites	Terrestrial habitats	~ 250 Meters[9]	~ 700 Meters[9]

[1] Sources: Maxell et al. (2009)
[2] Sources: Semlitsch (1983)
[3] Sources: Gehlbach (1967)
[4] Sources: Breden (2004)
[5] Sources: Bull (2009)
[6] Sources: Engle (2001) and Pilliod (2002)
[7] Sources: Dole (1968)
[8] Sources: Seburn et al. (1997)
[9] Sources: Spencer (1964)

Table 3. Independent variables used in habitat models to predict breeding site selection.

Variable	Abbreviation	Method of Measurement
Local		
Elevation	EL	7.5-minute (1:24,000 scale) U.S. Geological Survey quadrangle maps
Depth	DP	Estimated in field (M)
Surface Area	SA	Calculated from estimated length and width of wetland (M^2)
Emergent Vegetation	EM	Estimated in the field (M^2)
Landscape		
Percent Forest	%FOR	NLCD*
Percent Wetland	%WET	NLCD
Percent Waterbody	%WAT	NLCD
Percent Natural Grass	%NG	NLCD
Percent Agriculture	%AGT	NLCD
Percent Urban	%URB	NLCD
Forest Core	Fcore	NLCD
Forest Edge	Fedge	NLCD
Distance Forest	Dfor	Estimated in the field (M)
Distance to nearest waterbody	DistWat	Euclidian distance (M) measured with Hawth's Tools
Distance to nearest known breeding site	DistOcc	Euclidian distance (M) measured with Hawth's Tools

* National Land Cover Data (NLCD)

Table 4. Scaled coefficients of the first two eigenvectors for percent wetland, percent water and percent agriculture.

	Component 1	**Component 2**
500 meters		
%WET	0.657	-0.254
%WAT	0.653	-0.28
%AGT	0.377	0.926
	68%	27%
1000 meters		
%WET	0.641	-0.284
%WAT	0.633	-0.329
%AGT	0.433	0.901
	67%	26%
2000 meters		
%WET	0.633	-0.247
%WAT	0.609	-0.426
%AGT	0.479	0.87
	70%	23%

Table 5. Scaled coefficients of the first two eigenvectors for percent forest, percent natural grass and distance to nearest known breeding site.

	Component 1	**Component 2**
500 meters		
%FOR	-0.646	0.209
%NG	0.639	-0.322
DistOcc	0.417	0.907
	68%	26%
1000 meters		
%FOR	-0.609	0.319
%NG	0.599	-0.415
DistOcc	0.519	0.853
	78%	17%
2000 meters		
%FOR	-0.612	0.293
%NG	0.597	-0.439
DistOcc	0.519	0.849
	79%	17%

Table 6. Final habitat variables included in 26 habitat models for *Ambystoma macrodactylum*. Landscape variables were derived from National Land Cover Data (NLCD) and local scale variables were estimated in the field.

Variable	Abbreviation	Method of Measurement	Units
Local			
Elevation	EL	7.5-minute (1:24,000 scale) U.S. Geological Survey quadrangle maps	Feet
Depth	DP	Estimated in field	Meters
Area of emergent vegetation	Area of Em Veg	Standardizing and averaging the original variables Surface Area and Area of Emergent Vegetation (Equations 1 & 2)	Meters squared
Landscape			
Percent aquatic in agricultural landscape	% AQ in Ag	Combined from NLCD in first component of PCA[1] (Table 4)	Percentage of area[2]
Percent of open landscape not dominated by forest	% Open	Combined from NLCD in first component of PCA (Table 5)	Percentage of area
Percent urban	% URB	NLCD	Percentage of area
Percent agriculture	% AGT	NLCD	Percentage of area
Distance to forest from site	Dfor	Estimated in field	Meters
Forest core	Fcore	NLCD	Meters squared
Forest edge	Fedge	NLCD	Meters squared
Distance to nearest waterbody from site	DistWat	Euclidian distance from centroid of site to the nearest waterbody of any kind	Meters
Distance to nearest known breeding area from site	DistOcc	Euclidian distance from centroid of site to the nearest known breeding site of this species	Meters

[1] PCA stands for Principle Component Analysis

[2] Percentage of area within a 500, 1,000, or 2,000 meter radius around centroid of wetland

Table 7. Local, landscape, and combination models for *Ambystoma macrodactylum*.

Model #	Candidate Models	*k*
	Local Models	
1	EL	1
2	EL, Area of Em veg	2
3	Area of Em Veg, DP	2
4	Area of Em Veg	1
5	Local Core	3
	Landscape Models	
6	% Aq	1
7	% Aq, DistOcc	2
8	% Aq, Dfor, % Open , DistOcc	4
9	% Aq, Dfor, % Open, Fedge	4
10	% Aq, Dfor, % Open, % URB	4
11	% Aq, Dfor, % AGT	3
12	% Aq, Dfor, % Open, DistWat	4
13	Dfor, % Open, DistOcc	3
14	Dfor, % Open, Fedge	3
15	% Aq, Dfor, Fcore, DistOcc	3
16	Landscape Core	9
	Combination Models	
17	EL, % Aq, % Open, Dfor	4
18	Area of Em. Veg., DP, % Aq, Dfor	4
19	Area of Em. Veg., DP, % Open, Dfor	4
20	EL, Area of Em. Veg., % Aq, % Open	4
21	DP, Area of Em. Veg., Dfor, % URB	4
22	EL, Dfor, Fedge, DistOcc	4
23	EL, Dfor, % Open, DistOcc	4
24	Area of Em. Veg., % Aq, Fcore, Dfor	4
25	Area of Em. Veg., % AGT, DistWat	3
26	Global	12

Table 8. Final habitat variables included in 26 habitat models for *Ambystoma tigrinum*. Landscape variables were derived from National Land Cover Data (NLCD) and local scale variables were estimated in the field.

Variable	Abbreviation	Method of Measurement	Units
Local			
Elevation	EL	7.5-minute (1:24,000 scale) U.S. Geological Survey quadrangle maps	Feet
Depth	DP	Estimated in field	Meters
Surface area	SA	Calculated from estimated length and width of wetland	Meters squared
Emergent vegetation	EM	Area estimated in field	Meters squared
Landscape			
Percent aquatic	% AQ	Standardizing and averaging the original variables Surface Area and Area of Emergent Vegetation (Equations 1 & 2)	Percentage of area[1]
Percent forest	% FOR	NLCD	Percentage of area
Percent natural grass	% NG	NLCD	Percentage of area
Percent urban	% URB	NLCD	Percentage of area
Percent agriculture	% AGT	NLCD	Percentage of area
Distance to forest from site	Dfor	Estimated in field	Meters
Forest core	Fcore	NLCD	Meters squared
Forest edge	Fedge	NLCD	Meters squared
Distance to nearest waterbody from site	DistWat	Euclidian distance from centroid of site to the nearest waterbody of any kind	Meters
Distance to nearest known breeding area from site	DistOcc	Euclidian distance from centroid of site to the nearest known breeding site of this species	Meters

[1] Percentage of area within a 500, 1,000, or 2,000 meter radius around centroid of wetland

Table 9. Local, landscape and combination models for western population of *Ambystoma tigrinum*.

Model #	Candidate Models	*k*
	Local Models	
1	EL	1
2	EL, EM, SA	3
3	SA, DP	2
4	EM, SA	2
5	Local Core	4
	Landscape Models	
6	% Aq	1
7	% Aq, DistOcc	2
8	% Aq, Dfor, % FOR, DistOcc	4
9	% Aq, Dfor, Fedge	3
10	% Aq, Dfor, % FOR, % URB	4
11	% Aq, Dfor, % AGT, DistWat	4
12	% Aq, Dfor % NG, DistWat	4
13	Dfor, % FOR, DistOcc	3
14	Dfor, % NG, DistOcc	3
15	% Aq, Dfor, Fcore, DistOcc	4
16	Landscape Core	10
	Combination Models	
17	EL, % Aq, % FOR, Dfor	4
18	EM, DP, % Aq, % FOR	4
19	SA, DP, % FOR, Dfor	4
20	EM, SA, % Aq, % NG	4
21	DP, EM, Dfor, % URB	4
22	EL, % Aq, Dfor, Fedge	4
23	EL, % Aq, % NG, Dfor	4
24	SA, Fcore, Dfor, DistOcc	4
25	EM, SA, % AGT, DistWat	4
26	Global	14

Table 10. Final habitat variables included in 26 habitat models for *Ambystoma tigrinum*. Landscape variables were derived from National Land Cover Data (NLCD) and local scale variables were estimated in the field.

Variable	Abbreviation	Method of Measurement	Units
Local			
Elevation	EL	7.5-minute (1:24,000 scale) U.S. Geological Survey quadrangle maps	Feet
Depth	DP	Estimated in field	Meters
Surface area	SA	Calculated from estimated length and width of wetland	Meters squared
Emergent vegetation	EM	Area estimated in field	Meters squared
Landscape			
Percent aquatic	% AQ	Standardizing and averaging the original variables Surface Area and Area of Emergent Vegetation (Equations 1 & 2)	Percentage of area[1]
Percent natural grass	% NG	NLCD	Percentage of area
Percent urban	% URB	NLCD	Percentage of area
Percent agriculture	% AGT	NLCD	Percentage of area
Distance to nearest waterbody from site	DistWat	Euclidian distance from centroid of site to the nearest waterbody of any kind	Meters
Distance to nearest known breeding area from site	DistOcc	Euclidian distance from centroid of site to the nearest known breeding site of this species	Meters

[1] Percentage of area within a 500, 1,000, or 2,000 meter radius around centroid of wetland

Table 11. Local, landscape and combination models for eastern population of *Ambystoma tigrinum*.

Model #	Candidate Models	*k*
	Local Models	
1	EL	1
2	EL, EM, SA	3
3	EM, DP	2
4	SA, DP	2
5	Local Core	4
	Landscape Models	
6	% Aq	1
7	% Aq, DistOcc	2
8	% Aq, % NG, DistOcc	3
9	% Aq, % NG, % AGT, DistOcc	4
10	% Aq, % NG, % URB, DistWat	4
11	% NG, DistOcc	2
12	% NG, % AGT	2
13	% NG, % URB	2
14	% AGT, DistOcc	2
15	%URB, DistWat	2
16	Landscape Core	6
	Combination Models	
17	EL, EM, % Aq, % NG	4
18	EL, % Aq, % NG, % AGT	4
19	EM, DP, % NG, DistOcc	4
20	SA, DP, % NG, % AGT	4
21	SA, DP, % Aq, % URB	4
22	EM, SA, % AGT, DistWat	4
23	EL, EM, % NG, DistWat	4
24	SA, DP, % NG, DistOcc	4
25	EM, SA, DP, DistWat	4
26	Global	10

Table 12. Scaled coefficients of the first two PCA eigenvectors for percent wetland, percent water and percent agriculture.

	Component 1	**Component 2**
500 meters		
%WET	0.636	-0.299
%WAT	0.632	-0.326
%AGT	0.34	0.661
	69%	25%
1000 meters		
%WET	0.634	-0.288
%WAT	0.625	-0.258
%AGT	0.456	0.643
	68%	24%
2000 meters		
%WET	0.625	-0.266
%WAT	0.606	-0.427
%AGT	0.491	0.865
	73%	21%

Table 13. Final habitat variables included in 26 habitat models for *Bufo boreas* and *Rana luteiventris*. Landscape variables were derived from National Land Cover Data (NLCD) and local scale variables were estimated in the field.

Variable	Abbreviation	Method of Measurement	Units
Local			
Elevation	EL	7.5-minute (1:24,000 scale) U.S. Geological Survey quadrangle maps	Feet
Depth	DP	Estimated in field	Meters
Surface area	SA	Calculated from estimated length and width of wetland	Meters squared
Emergent vegetation	EM	Area estimated in field	Meters squared
Landscape			
Percent aquatic	% AQ	Combined from NLCD in first component of PCA[1] (Table 12)	Percentage of area[2]
Percent forest	% FOR	NLCD	Percentage of area
Percent natural grass	% NG	NLCD	Percentage of area
Percent urban	% URB	NLCD	Percentage of area
Percent agriculture	% AGT	Combined from NLCD in second component of PCA (Table 12)	Percentage of area
Distance to forest from site	Dfor	Estimated in field	Meters
Forest core	Fcore	NLCD	Meters squared
Forest edge	Fedge	NLCD	Meters squared
Distance to nearest waterbody from site	DistWat	Euclidian distance from centroid of site to the nearest waterbody of any kind	Meters
Distance to nearest known breeding area from site	DistOcc	Euclidian distance from centroid of site to the nearest known breeding site of this species	Meters

[1] PCA stands for Principle Component Analysis

[2] Percentage of area within a 500, 1,000, or 2,000 meter radius around centroid of wetland

Table 14. Local, landscape and combination models for *Bufo boreas* and *Rana luteiventris*.

Model #	Candidate Models	*k*
	Local Models	
1	EL	1
2	EL, EM, SA	3
3	SA, DP	2
4	EM, SA	2
5	Local Core	4
	Landscape Models	
6	% Aq	1
7	% Aq, DistOcc	2
8	% Aq, Dfor, % FOR, DistOcc	4
9	% Aq, Dfor, % FOR, Fedge	4
10	% Aq, Dfor, % FOR, % URB	4
11	% Aq, Dfor, % NG, % AGT	4
12	% Aq, Dfor, % NG, DistWat	4
13	Dfor, % FOR, DistOcc	3
14	Dfor, % FOR, Fedge	3
15	% Aq, Dfor, Fcore	3
16	Landscape Core	10
	Combination Models	
17	EL, % Aq, % FOR, Dfor	4
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4
19	DP, SA, % FOR, Dfor	4
20	DP, SA, % Aq, % NG	4
21	DP, EM, Dfor, % URB	4
22	EL, Dfor, Fedge, DistOcc	4
23	EL, Dfor, % NG, DistOcc	4
24	SA, % Aq, Fcore, Dfor	4
25	EM, SA, % AGT, DistWat	4
26	Global	14

Table 15. Scaled coefficients of the first two PCA eigenvectors for percent wetland, percent water and percent agriculture.

	Component 1	**Component 2**
Local Level		
Emergent vegetation	0.664	-0.359
Depth	0.267	0.951
Surface area	0.714	0.045
	50%	34%

Table 16. Scaled coefficients of the first two PCA eigenvectors for the variables distance to forest, percent forest, percent natural grass, and percent agriculture.

	Component 1	Component 2
500 meters		
Dfor	0.449	0.512
%FOR	-0.661	0.238
%NG	0.5	-0.554
%AGT	0.333	0.612
1000 meters		
Dfor	0.172	0.682
%FOR	-0.696	-0.081
%NG	0.689	-0.146
%AGT	-0.102	0.712
	50%	33%
2000 meters		
Dfor	-0.111	0.898
%FOR	0.667	0.182
%NG	-0.697	-0.1
%AGT	0.238	-0.387
	50%	25%

Table 17. Final habitat variables included in 26 habitat models for *Pseudacris regilla*. Landscape variables were derived from National Land Cover Data (NLCD) and local scale variables were estimated in the field.

Variable	Abbreviation	Method of Measurement	Units
Local			
Elevation	EL	7.5-minute (1:24,000 scale) U.S. Geological Survey quadrangle maps	Feet
Depth	DP	Second component of PCA[1] (Table 15)	Meters
Area of emergent vegetation	Area of Em Veg	First component of PCA (Table 15)	Meters squared
Landscape			
Percent aquatic	% AQ	Standardizing and averaging the original variables Surface Area and Area of Emergent Vegetation (Equations 1 & 2)	Percentage of area[2]
Percent of open landscape dominated by grassland and agriculture	% Open	Combined from NLCD in first component of PCA (Table 16)	Percentage of area
Percent agriculture (only at 500 and 1000 meters)	% AGT	Determined by second component of PCA (Table 16)	Percentage of area
Percent urban	% URB	NLCD	Percentage of area
Distance to forest from site (Only at 2000 meters)	Dfor	Determined by second component of PCA (Table 16)	Meters
Forest core	Fcore	NLCD	Meters squared
Forest edge	Fedge	NLCD	Meters squared
Distance to nearest waterbody from site	DistWat	Euclidian distance from centroid of site to the nearest waterbody of any kind	Meters
Distance to nearest known breeding area from site	DistOcc	Euclidian distance from centroid of site to the nearest known breeding site of this species	Meters

[1] PCA stands for Principle Component Analysis

[2] Percentage of area within a 500, 1,000, or 2,000 meter radius around centroid of wetland

Table 18. Local, landscape and Combination Models for *Pseudacris regilla*.

Model #	Candidate Models	*k*
	Local Models	
1	EL	1
2	EL, Area of Em Veg	2
3	Area of Em Veg, DP	2
4	Area of Em Veg	1
5	Local Core	3
	Landscape Models	
6	% Aq	1
7	%Aq, DistOcc	2
8	% Aq, % Open	2
9	% Aq, % Open, % AGT/Dfor, Fedge	4
10	% Aq, % AGT/Dfor, DistOcc	3
11	% Aq, % URB, % Open, DistWat	4
12	% AGT/Dfor, Fedge, DistOcc	3
13	% AGT/Dfor, % Open, DistOcc	3
14	% Aq, Fcore, % AGT/Dfor	2
15	% Open, % AGT/Dfor, % URB, DistWat	4
16	Landscape Core	8
	Combination Models	
17	EL, % Aq, % Open	3
18	Area of Em. Veg., DP, % Aq, %AGT/Dfor	4
19	EL, DP, % Open, % AGT/Dfor	4
20	Area of Em. Veg., DP, % Aq, % Open	4
21	EL, Area of Em. Veg., % Open, Fcore	4
22	EL, % AGT/Dfor, Fedge, DistOcc	4
23	EL, % AGT/Dfor, % Open, DistOcc	4
24	Area of Em. Veg., DP, % Aq, % URB	4
25	EL, % Open, % AGT/Dfor, DistWat	4
26	Global	11

Table 19. Final habitat variables included in 26 habitat models for *Bufo woodhousii* and *Pseudacris maculata*. Landscape variables were derived from National Land Cover Data (NLCD) and local scale variables were estimated in the field.

Variable	Abbreviation	Method of Measurement	Units
Local			
Elevation	EL	7.5-minute (1:24,000 scale) U.S. Geological Survey quadrangle maps	Feet
Depth	DP	Estimated in field	Meters
Surface area	SA	Calculated from estimated length and width of wetland	Meters squared
Emergent vegetation	EM	Area estimated in field	Meters squared
Landscape			
Percent aquatic	% AQ	Standardizing and averaging the original variables Surface Area and Area of Emergent Vegetation (Equations 1 & 2)	Percentage of area[1]
Percent natural grass	% NG	NLCD	Percentage of area
Percent urban	% URB	NLCD	Percentage of area
Percent agriculture	% AGT	NLCD	Percentage of area
Distance to nearest waterbody from site	DistWat	Euclidian distance from centroid of site to the nearest waterbody of any kind	Meters
Distance to nearest known breeding area from site	DistOcc	Euclidian distance from centroid of site to the nearest known breeding site of this species	Meters

[1] Percentage of area within a 500, 1,000, or 2,000 meter radius around centroid of wetland

Table 20. Local, landscape and combination models for *Bufo woodhousii* and *Pseudacris maculata*.

Model #	Candidate Models	*k*
	Local Models	
1	EL	1
2	EL, EM, SA	3
3	EM, DP	2
4	SA, DP	2
5	Local Core	4
	Landscape Models	
6	% Aq	1
7	% Aq, DistOcc	2
8	% Aq, % NG, DistOcc	3
9	% Aq, % NG, % AGT, DistOcc	4
10	% Aq, % NG, % URB, DistWat	4
11	% NG, DistOcc	2
12	% NG, % AGT	2
13	% NG, % URB	2
14	% AGT, DistOcc	2
15	% URB, DistWat	2
16	Landscape Core	6
	Combination Models	
17	EL, % Aq, % NG, DistOcc	4
18	EL, EM, % AGT, DistOcc	4
19	EM, DP, % Aq, % NG	4
20	SA, DP, % NG, % AGT	4
21	SA, DP, % Aq, % URB	4
22	EM, DP, % AGT, DistWat	4
23	EL, EM, % NG, DistWat	4
24	EL, EM, % NG, DistOcc	4
25	EM, SA, DP, DistWat	4
26	Global	10

Table 21. Final habitat variables included in 26 habitat models for *Rana pipiens*. Landscape variables were derived from National Land Cover Data (NLCD) and local scale variables were estimated in the field.

Variable	Abbreviation	Method of Measurement	Units
Local			
Elevation	EL	7.5-minute (1:24,000 scale) U.S. Geological Survey quadrangle maps	Feet
Depth	DP	Estimated in field	Meters
Surface area	SA	Calculated from estimated length and width of wetland	Meters squared
Emergent vegetation	EM	Area estimated in field	Meters squared
Landscape			
Percent aquatic	% AQ	Standardizing and averaging the original variables Surface Area and Area of Emergent Vegetation (Equations 1 & 2)	Percentage of area[1]
Percent natural grass	% NG	NLCD	Percentage of area
Percent urban	% URB	NLCD	Percentage of area
Percent agriculture	% AGT	NLCD	Percentage of area
Distance to nearest waterbody from site	DistWat	Euclidian distance from centroid of site to the nearest waterbody of any kind	Meters
Distance to nearest known breeding area from site	DistOcc	Euclidian distance from centroid of site to the nearest known breeding site of this species	Meters

[1] Percentage of area within a 500, 1,000, or 2,000 meter radius around centroid of wetland

Table 22. Local, landscape and combination models for *Rana pipiens*.

Model #	*Candidate Models*	*k*
	Local Models	
1	EL	1
2	EL, EM, SA	3
3	EM, SA, DP	3
4	SA, DP	2
5	Local Core	4
	Landscape Models	
6	% Aq	1
7	% Aq, DistOcc	2
8	% Aq, % NG, DistOcc	3
9	% Aq, % NG, % AGT, DistOcc	4
10	% Aq, % NG, % URB, DistWat	4
11	% NG, DistOcc	2
12	% NG, % AGT	2
13	% NG, % URB	2
14	% AGT, DistOcc	2
15	% URB, DistWat	2
16	Landscape Core	6
	Combination Models	
17	EL, % Aq, % NG, DistOcc	4
18	EL, EM, % AGT, DistOcc	4
19	EM, DP, % Aq, % NG	4
20	SA, DP, % NG, % AGT	4
21	SA, DP, % Aq, % URB	4
22	EM, DP, % AGT, DistWat	4
23	EL, EM, % NG, DistWat	4
24	EL, EM, % NG, DistOcc	4
25	EM, SA, Depth, DistWat	4
26	Global	10

Table 23. Ranking of habitat models for *Ambystoma macrodactylum* for three spatial scales. Only those models with $\Delta QAIC_c \leq 7$ are shown. Models with $\Delta QAIC_c \leq 2$ have substantial support for making inferences, while $\Delta QAIC_c$ between 2 and 4 have moderate support and $\Delta QAIC_c$ between 4 and 7 have considerably less support.

Model #	**Candidate Models**	$QAIC_c$	$\Delta QAIC_c$	w_i
	500 METERS			
8	**% Aq**, **Dfor, % Open**, **DistOcc**	284.71	0.00	0.770
15	**% Aq**, **Dfor**, Fcore, DistOcc	287.52	2.81	0.189
16	Landscape Core	290.73	6.02	0.038
	1,000 METERS			
26	Global	707.02	0.00	0.982
	2,000 METERS			
26	Global	291.92	0.00	0.646
16	Landscape Core	293.29	1.38	0.325

Model averaged estimates are based on the full set of logistic regression candidate models. Bold variables indicate those variables that have parameter estimates with 95% confidence intervals that do not overlap 1, and are therefore considered to have a significant association with *Ambystoma macrodactylum* presence.

Table 24. *Ambystoma macrodactylum* habitat associations at 500, 1,000, and 2,000 m landscape scales based on model averaged estimates and 95% confidence intervals.

	MAE	SE	Lower 95% CI	Upper 95% CI
500 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent vegetation	0.000	0.000	0.000	0.000
Depth	0.000	0.000	-0.001	0.001
% Aquatic in agricultural landscape	**-0.086**	**0.023**	**-0.132**	**-0.041**
% Agriculture	0.000	0.001	-0.003	0.003
% Open landscape	**-0.026**	**0.011**	**-0.046**	**-0.005**
% Urban	-0.002	0.007	-0.015	0.012
Distance forest	**-0.031**	**0.005**	**-0.041**	**-0.021**
Forest core	0.006	0.006	-0.005	0.018
Forest edge	0.000	0.001	-0.003	0.002
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	**0.012**	**0.005**	**0.002**	**0.022**
Constant	0.926	0.436	0.076	1.777
1,000 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent vegetation	0.000	0.000	0.000	0.000
Depth	-0.308	0.193	-0.684	0.067
% Aquatic in agricultural landscape	**-0.167**	**0.033**	**-0.231**	**-0.102**
% Agriculture	-0.013	0.056	-0.122	0.096
% Open landscape	-0.016	0.022	-0.060	0.027
% Urban	0.470	0.500	-0.505	1.446
Distance forest	**-0.032**	**0.007**	**-0.046**	**-0.018**
Forest core	0.006	0.028	-0.049	0.061
Forest edge	0.046	0.040	-0.032	0.124
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.009	0.014	-0.018	0.036
2,000 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent vegetation	0.000	0.000	0.000	0.000
Depth	-0.198	0.143	-0.476	0.081
% Aquatic in agricultural landscape	-0.067	0.122	-0.305	0.171
% Agriculture	-0.018	0.066	-0.147	0.111
% Open landscape	-0.015	0.024	-0.062	0.032
% Urban	**0.782**	**0.304**	**0.188**	**1.375**
Distance forest	**-0.032**	**0.007**	**-0.045**	**-0.018**
Forest core	0.009	0.031	-0.051	0.068
Forest edge	0.011	0.050	-0.086	0.109
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.009	0.014	-0.019	0.037

Model averaged estimates were based on the full set of regression models (Appendix B). Letters and numbers in bold face indicate when the 95% confidence interval for coefficients did not overlap 0.

Table 25. Importance weights calculated for each variable at each spatial scale.

	500		**1,000**		**2,000**
% Aquatic in agricultural landscape	0.999	% Aquatic in agricultural landscape	1.000	% Aquatic in agricultural landscape	0.999
Distance forest	0.999	Distance forest	1.000	% Open	0.999
Distance occupied	0.999	Distance occupied	0.998	Distance forest	0.999
% Open	0.810	% Open	0.990	Distance occupied	0.988
Forest core	0.229	Forest core	0.981	% Agriculture	0.971
% Agriculture	0.040	% Agriculture	0.971	% Urban	0.971
% Urban	0.040	% Urban	0.971	Forest core	0.971
Forest edge	0.040	Forest edge	0.971	Forest edge	0.971
Distance waterbody	0.040	Distance waterbody	0.971	Distance waterbody	0.971
Elevation	0.002	Elevation	0.648	Elevation	0.646
Emergent vegetation	0.002	Emergent vegetation	0.646	Emergent vegetation	0.646
Depth	0.002	Depth	0.646	Depth	0.646

Table 26. Ranking of habitat models for *Ambystoma tigrinum* (west) for three spatial scales. Only those models with $\Delta QAIC_c \leq 7$ are shown. Models with $\Delta QAIC_c \leq 2$ have substantial support for making inferences, while $\Delta QAIC_c$ between 2 and 4 have moderate support and $\Delta QAIC_c$ between 4 and 7 have considerably less support.

Model #	**Candidate Models**	AIC_c	ΔAIC_c	w_i
	500 METERS			
14	**Dfor,** % NG, DistOcc	70.53	0.00	0.368
13	**Dfor**, % FOR, DistOcc	71.73	1.20	0.202
15	% Aq, **Dfor**, Fcore, DistOcc	72.10	1.56	0.169
8	% Aq, **Dfor**, % FOR , DistOcc	72.23	1.70	0.157
24	SA, Fcore, **Dfor**, DistOcc	73.65	3.12	0.078
16	Landscape Core	76.27	5.73	0.021
	1,000 METERS			
16	Landscape Core	76.40	0.00	0.632
26	Global	78.22	1.82	0.255
14	Dfor, % NG, DistOcc	79.86	3.46	0.112
	2,000 METERS			
14	**Dfor,** % NG, DistOcc	67.99	0.00	0.779
13	**Dfor**, % FOR, DistOcc	72.69	4.70	0.074
16	Landscape Core	73.88	5.90	0.041
15	% Aq, **Dfor**, Fcore, DistOcc	74.07	6.08	0.037
8	% Aq, **Dfor**, % FOR , DistOcc	74.34	6.36	0.032
24	SA, Fcore, **Dfor**, DistOcc	74.50	6.51	0.030

Bold variables indicate those variables that have parameter estimates with 95% confidence intervals that do not overlap 1, and are therefore considered to have a significant association with *Ambystoma tigrinum* presence.

Table 27. *Ambystoma tigrinum* (western population) habitat associations at 500, 1,000, and 2,000 m landscape scales based on model averaged estimates and 95% confidence intervals.

	MAE	SE	Lower 95% CI	Upper 95% CI
500 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent vegetation	0.000	0.000	0.000	0.000
Surface area	0.000	0.000	0.000	0.000
depth	0.002	0.002	-0.002	0.005
% Aquatic	0.053	0.053	-0.051	0.157
% Forest	0.003	0.004	-0.005	0.010
% Natural grass	-0.071	0.045	-0.159	0.018
% Agriculture	-1.311	10.311	-21.417	18.795
% Urban	2.996	5.602	-7.928	13.921
Distance forest	**0.002**	**0.001**	**0.000**	**0.004**
Forest core	0.003	0.004	-0.005	0.011
Forest edge	-0.001	0.001	-0.003	0.002
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
Constant	1.129	0.642	-0.123	2.381
1,000 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent vegetation	0.000	0.000	0.000	0.000
Surface area	0.000	0.000	0.000	0.000
depth	0.042	0.155	-0.262	0.345
% Aquatic	**0.485**	**0.240**	**0.016**	**0.954**
% Forest	-0.921	0.866	-2.611	0.768
% Natural grass	-0.066	0.036	-0.136	0.004
% Agriculture	-4.053	2.789	-9.491	1.385
% Urban	-35.985	12673.923	-24750.136	24678.165
Distance forest	0.001	0.001	-0.001	0.003
Forest core	0.386	1.428	-2.397	3.170
Forest edge	1.365	0.760	-0.117	2.847
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
Constant	3.821	2.992	-2.014	9.657
2,000 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent vegetation	0.000	0.000	0.000	0.000
Surface area	0.000	0.000	0.000	0.000
depth	0.004	0.005	-0.006	0.015
% Aquatic	-0.012	0.028	-0.067	0.044
% Forest	0.001	0.003	-0.004	0.006
% Natural grass	-0.035	0.019	-0.072	0.002
% Agriculture	-0.005	0.036	-0.075	0.066
% Urban	-0.810	2.473	-5.633	4.013
Distance forest	**0.002**	**0.001**	**0.000**	**0.004**
Forest core	0.003	0.011	-0.018	0.024
Forest edge	-0.008	0.009	-0.026	0.010
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
Constant	1.815	1.025	-0.184	3.814

Table 28. Importance weights calculated for each variable at each spatial scale.

	500		**1,000**		**2,000**
Distance occupied	1.000	Distance occupied	0.999	Distance occupied	0.999
Distance forest	0.997	Distance forest	0.999	Distance forest	0.998
% Natural grass	0.391	% Natural grass	0.999	% Natural grass	0.825
% Forest	0.385	% Forest	0.887	% Forest	0.152
% Aquatic	0.352	% Aquatic	0.887	% Aquatic	0.116
Forest core	0.270	Forest core	0.887	Forest core	0.113
Forest edge	0.180	Forest edge	0.887	Forest edge	0.046
% Agriculture	0.023	% Agriculture	0.887	% Agriculture	0.046
% Urban	0.023	% Urban	0.887	% Urban	0.046
Distance waterbody	0.023	Distance waterbody	0.887	Distance waterbody	0.046
Surface area	0.008	Surface area	0.255	Surface area	0.035
Elevation	0.002	Elevation	0.255	Elevation	0.005
Emergent vegetation	0.002	Emergent vegetation	0.255	Emergent vegetation	0.005
depth	0.002	depth	0.255	depth	0.005

Table 29. Ranking of habitat models for *Ambystoma tigrinum* (eastern population) for three spatial scales. Only those models with $\Delta QAIC_c \leq 7$ are shown. Models with $\Delta QAIC_c \leq 2$ have substantial support for making inferences, while $\Delta QAIC_c$ between 2 and 4 have moderate support and $\Delta QAIC_c$ between 4 and 7 have considerably less support.

Model #	**Candidate Models**	AIC_c	ΔAIC_c	w_i
	500 METERS			
2	**EL,** EM, SA	57.76	0.00	0.381
1	**EL**	58.38	0.62	0.280
5	Local Core	59.89	2.12	0.132
23	**EL**, EM, % NG, DistWat	60.70	2.94	0.088
17	**EL,** EM, % Aq, % NG	61.15	3.39	0.070
18	**EL**, % Aq, % NG, % AGT	62.41	4.64	0.037
	1,000 METERS			
2	**EL**, EM, SA	57.76	0.00	0.355
1	**EL**	58.38	0.62	0.261
5	Local Core	59.89	2.12	0.123
23	**EL,** EM, % NG, DistWat	60.15	2.38	0.108
17	**EL**, EM, % Aq, % NG	60.24	2.47	0.103
18	**EL,** % Aq, % NG, % AGT	61.81	4.05	0.047
	2,000 METERS			
17	**EL**, EM, % Aq, % NG	57.17	0.00	0.247
2	**EL**, EM, SA	57.76	0.60	0.183
18	**EL,** % Aq, % NG, % AGT	58.05	0.88	0.159
1	**EL**	58.38	1.21	0.135
26	Global	58.51	1.34	0.126
23	**EL,** EM, % NG, DistWat	59.31	2.14	0.085
5	Local Core	59.89	2.72	0.063

Bold variables indicate those variables that have parameter estimates with 95% confidence intervals that do not overlap 1, and are therefore considered to have a significant association with *Ambystoma tigrinum* presence.

Table 30. *Ambystoma tigrinum* (eastern population) habitat associations at 500, 1,000, and 2,000 m landscape scales based on model averaged estimates and 95% confidence intervals.

	MAE	SE	Lower 95% CI	Upper 95% CI
500 Meters				
Elevation	**-0.0020**	**0.001**	**-0.003**	**-0.001**
Emergent vegetation	0.0000	0.000	0.000	0.000
Surface area	0.0000	0.000	0.000	0.000
Depth	-0.0027	0.076	-0.150	0.145
% Aquatic	-0.0027	0.011	-0.025	0.020
% Natural grass	0.0042	0.004	-0.004	0.012
% Agriculture	-0.0082	0.086	-0.175	0.159
% Urban	-0.1748	418.059	-815.389	815.040
Distance waterbody	0.0000	0.000	0.000	0.000
Distance occupied	0.0000	0.000	0.000	0.000
Constant	154.8753	146.249	-130.310	440.061
1,000 Meters				
Elevation	**-0.0020**	**0.001**	**-0.003**	**-0.001**
Emergent vegetation	0.0000	0.000	0.000	0.000
Surface area	0.0000	0.000	0.000	0.000
Depth	-0.0161	0.067	-0.146	0.114
% Aquatic	-0.0133	0.029	-0.071	0.044
% Natural grass	0.0062	0.006	-0.005	0.017
% Agriculture	0.0026	0.023	-0.042	0.047
% Urban	-0.0038	0.041	-0.084	0.076
Distance waterbody	0.0000	0.000	0.000	0.000
Distance occupied	0.0000	0.000	0.000	0.000
Constant	8.5625	2.452	3.781	13.344
2,000 Meters				
Elevation	**-0.0019**	**0.001**	**-0.004**	**0.000**
Emergent vegetation	0.0000	0.000	0.000	0.000
Surface area	0.0000	0.000	0.000	0.000
Depth	-0.0260	0.089	-0.199	0.147
% Aquatic	-0.2833	0.205	-0.683	0.117
% Natural grass	0.0226	0.014	-0.006	0.051
% Agriculture	-0.0574	0.134	-0.319	0.204
% Urban	3.6182	4.013	-4.207	11.443
Distance waterbody	0.0000	0.000	0.000	0.000
Distance occupied	0.0000	0.000	0.000	0.000
Constant	8.1972	2.545	3.234	13.161

Model averaged estimates were based on the full set of regression models (Appendix B). Letters and numbers in bold face indicate when the 95% confidence interval for coefficients did not overlap 0.

Table 31. Importance weights for variables included in tiger salamander (east) models.

	500		1,000		2,000
Elevation	0.997	Elevation	0.999	Elevation	0.998
Emergent vegetation	0.68	Emergent vegetation	0.691	Emergent vegetation	0.704
Surface area	0.522	Surface area	0.48	% Natural grass	0.619
% Natural grass	0.207	% Natural grass	0.26	% Aquatic	0.534
Depth	0.141	% Aquatic	0.152	Surface area	0.372
% Aquatic	0.119	Depth	0.125	% Agriculture	0.287
Distance waterbody	0.1	Distance waterbody	0.11	Distance waterbody	0.213
% Agriculture	0.049	% Agriculture	0.049	Depth	0.189
% Urban	0.012	% Urban	0.002	% Urban	0.128
Distance occupied	0.012	Distance occupied	0.002	Distance occupied	0.128

Table 32. Ranking of habitat models for *Bufo boreas* and *Rana luteiventris* for three spatial scales. Only those models with $\Delta QAIC_c \leq 7$ are shown. Models with $\Delta QAIC_c \leq 2$ have substantial support for making inferences, while $\Delta QAIC_c$ between 2 and 4 have moderate support and $\Delta QAIC_c$ between 4 and 7 have considerably less support.

Model #	**Candidate Models**	AIC_c	ΔAIC_c	w_i
	500 METERS			
8	**% Aq, Dfor,** % FOR, DistOcc	617.55	0.00	0.882
26	Global	622.84	5.29	0.062
16	Landscape Core	623.06	5.51	0.056
	1,000 METERS			
8	**% Aq**, **Dfor**, **% FOR,** DistOcc	674.12	0.00	0.828
16	Landscape Core	678.30	4.18	0.102
26	Global	679.06	4.94	0.070
	2,000 METERS			
8	**% Aq**, **Dfor**, % FOR, DistOcc	697.38	0.00	0.906
16	Landscape Core	702.59	5.21	0.067

Bold variables indicate those variables that have parameter estimates with 95% confidence intervals that do not overlap 1, and are therefore considered to have a significant association with presence.

Table 33. *Bufo boreas* and *Rana luteiventris* habitat associations at 500, 1,000, and 2,000 m broad spatial scales based on model averaged estimates and 95% confidence intervals.

	MAE	SE	Lower 95% CI	Upper 95% CI
500 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent Vegetation	0.000	0.000	0.000	0.000
Surface Area	0.000	0.000	0.000	0.000
Depth	0.004	0.010	-0.016	0.024
% Aquatic in agricultural landscape	**-0.085**	**0.018**	**-0.120**	**-0.049**
% Agriculture	-0.003	0.005	-0.014	0.007
% Forest	0.009	0.005	-0.002	0.019
Distance Forest	**-0.026**	**0.005**	**-0.036**	**-0.016**
% Natural grass	-0.002	0.002	-0.006	0.002
% Urban	0.023	0.035	-0.045	0.090
Forest core	0.001	0.001	-0.001	0.002
Forest edge	0.002	0.003	-0.003	0.008
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
1,000 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent Vegetation	0.000	0.000	0.000	0.000
Surface Area	0.000	0.000	0.000	0.000
Depth	0.005	0.011	-0.016	0.026
% Aquatic in agricultural landscape	**-0.089**	**0.019**	**-0.126**	**-0.053**
% Agriculture	-0.014	0.015	-0.043	0.016
% Forest	**0.011**	**0.006**	**0.000**	**0.022**
Distance Forest	**-0.026**	**0.005**	**-0.036**	**-0.016**
% Natural grass	-0.001	0.003	-0.006	0.004
% Urban	0.003	0.036	-0.067	0.073
Forest core	0.002	0.002	-0.002	0.005
Forest edge	0.004	0.004	-0.003	0.011
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
2,000 Meters				
Elevation	0.000	0.000	0.000	0.000
Emergent Vegetation	0.000	0.000	0.000	0.000
Surface Area	0.000	0.000	0.000	0.000
Depth	0.002	0.004	-0.006	0.010
% Aquatic in agricultural landscape	**-0.100**	**0.021**	**-0.142**	**-0.058**
% Agriculture	-0.004	0.006	-0.016	0.007
% Forest	0.011	0.012	-0.012	0.034
Distance Forest	**-0.028**	**0.006**	**-0.040**	**-0.016**
% Natural grass	-0.002	0.002	-0.006	0.002
% Urban	0.000	0.018	-0.035	0.034
Forest core	0.000	0.001	-0.001	0.002
Forest edge	0.001	0.002	-0.004	0.006
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000

Model averaged estimates were based on the full set of regression models (Appendix B). Letters and numbers in bold face indicate when the 95% confidence interval for coefficients did not overlap 0.

Table 34. Importance weights for variables included in *Bufo boreas* and *Rana luteiventris* habitat models.

	500		1,000		2,000
% Aquatic in agricultural landscape	1.000	% Aquatic in agricultural landscape	1.000	Distance Forest	1.000
% Forest	1.000	% Forest	1.000	Distance occupied	1.000
Distance Forest	1.000	Distance Forest	1.000	% Aquatic in agricultural landscape	0.998
Distance occupied	1.000	Distance occupied	1.000	% Forest	0.998
% Agriculture	0.118	% Agriculture	0.242	% Natural grass	0.094
% Natural grass	0.118	% Natural grass	0.242	% Agriculture	0.092
% Urban	0.118	% Urban	0.242	% Urban	0.092
Forest core	0.118	Forest core	0.242	Forest core	0.092
Forest edge	0.118	Forest edge	0.242	Forest edge	0.092
Distance waterbody	0.118	Distance waterbody	0.242	Distance waterbody	0.092
Elevation	0.062	Elevation	0.070	Elevation	0.027
Emergent vegetation	0.062	Emergent vegetation	0.070	Emergent vegetation	0.025
Surface Area	0.062	Surface Area	0.070	Surface Area	0.025
Depth	0.062	Depth	0.070	Depth	0.025

Table 35. Ranking of habitat models for the *Pseudacris regilla* for three spatial scales. Only those models with $\Delta QAIC_c \leq 7$ are shown. Models with $\Delta QAIC_c \leq 2$ have substantial support for making inferences, while $\Delta QAIC_c$ between 2 and 4 have moderate support and $\Delta QAIC_c$ between 4 and 7 have considerably less support.

Model #	**Candidate Models**	AIC_c	ΔAIC_c	w_i
	500 METERS			
22	EL, % AGT, Fedge, DistOcc	78.56	0.00	0.505
23	EL, % AGT, % Open, DistOcc	78.71	0.15	0.469
26	Global	85.30	6.73	0.017
	1,000 METERS			
22	EL, % AGT, Fedge, DistOcc	78.17	0.00	0.544
23	EL, %AGT, % Open, DistOcc	78.67	0.50	0.424
26	Global	84.44	6.27	0.024
	2,000 METERS			
22	EL, Dfor, Fedge, DistOcc	76.63	0.00	0.580
26	Global	78.64	2.01	0.212
23	EL, Dfor, % Open, DistOcc	78.77	2.14	0.199

Bold variables indicate those variables that have parameter estimates with 95% confidence intervals that do not overlap 1, and are therefore considered to have a significant association with presence or absence.

Table 36. *Pseudacris regilla* habitat associations at 500, 1,000, and 2,000 m landscape scales based on model averaged estimates and 95% confidence intervals.

Variable	MAE	SE	Lower 95% CI	Upper 95% CI
500 meters				
Elevation	0.000	0.000	0.000	0.000
EmVeg	0.000	0.000	0.000	0.000
Depth	0.000	0.000	0.000	0.000
% Aq	-0.013	0.013	-0.039	0.012
% Open	-0.006	0.011	-0.028	0.017
% AGT	-0.021	0.026	-0.071	0.029
% URB	0.002	0.006	-0.010	0.014
Fcore	0.000	0.002	-0.004	0.004
Fedge	0.016	0.019	-0.022	0.054
Dist water	0.000	0.000	0.000	0.000
Dist Occ	0.000	0.000	0.000	0.000
Constant	3.943	1.349	1.313	6.573
1,000 Meters				
Elevation	0.000	0.000	0.000	0.000
EmVeg	0.000	0.000	0.000	0.000
Depth	0.000	0.000	0.000	0.000
% Aq	-0.004	0.005	-0.013	0.006
% Open	-0.008	0.016	-0.039	0.024
% AGT	-0.020	0.026	-0.072	0.031
% URB	0.015	0.027	-0.039	0.068
Fcore	-0.001	0.005	-0.010	0.008
Fedge	0.027	0.036	-0.042	0.097
Dist water	0.000	0.000	0.000	0.000
Dist Occ	0.000	0.000	0.000	0.000
Constant	3.783	1.522	0.814	6.752
2,000 Meters				
Elevation	0.000	0.000	0.000	0.000
EmVeg	0.000	0.000	0.000	0.000
Depth	0.000	0.000	0.000	0.000
% Aq	-0.054	0.067	-0.185	0.076
% Open	-0.171	0.200	-0.561	0.220
Dfor	0.038	0.117	-0.190	0.267
% URB	0.724	0.666	-0.574	2.022
Fcore	-0.105	0.106	-0.312	0.103
Fedge	0.009	0.164	-0.312	0.329
Dist water	0.000	0.000	0.000	0.000
Dist Occ	0.000	0.000	0.000	0.000
Constant	2.885	2.715	-2.410	8.180

Model averaged estimates were based on the full set of regression models (Appendix B). Letters and numbers in bold face indicate when the 95% confidence interval for coefficients did not overlap 0.

Table 37. Importance weights for variables included in *Pseudacris regilla* habitat models.

	500		1000		2000
% Agriculture	1.000	% Agriculture	1.000	Distance forest	0.999
Distance occupied	1.000	Distance occupied	1.000	Distance occupied	0.999
Elevation	0.994	Elevation	0.992	Elevation	0.991
% Open landscape	0.574	Forest edge	0.571	Forest edge	0.798
Forest edge	0.433	% Open landscape	0.451	% Open landscape	0.414
%Aquatic	0.011	%Aquatic	0.026	%Aquatic	0.216
Area of emergent vegetation	0.009	Area of emergent vegetation	0.024	% Urban	0.215
Depth	0.009	Depth	0.024	Forest core	0.215
% Urban	0.009	% Urban	0.024	Distance waterbody	0.215
Forest core	0.009	Forest core	0.024	Area of emergent vegetation	0.212
Distance waterbody	0.009	Distance waterbody	0.024	Depth	0.212

Table 38. Ranking of habitat models for the *Bufo woodhousii* and *Pseudacris maculata* for three spatial scales. Only those models with $\Delta QAIC_c \leq 7$ are shown. Models with $\Delta QAIC_c \leq 2$ have substantial support for making inferences, while $\Delta QAIC_c$ between 2 and 4 have moderate support and $\Delta QAIC_c$ between 4 and 7 have considerably less support.

Model #	Candidate Models	AIC_c	ΔAIC_c	w_i
	500 METERS			
17	**EL,** % Aq, **% NG**, DistOcc	61.48	0.00	0.560
24	**EL**, EM, **% NG**, DistOcc	62.16	0.68	0.398
	1,000 METERS			
17	**EL,** % Aq, **% NG**, DistOcc	58.95	0.00	0.595
24	**EL**, EM, **% NG**, DistOcc	59.87	0.91	0.377
	2,000 METERS			
17	**EL, % Aq**, **% NG**, DistOcc	46.93	0.00	0.978

Bold variables indicate those variables that have parameter estimates with 95% confidence intervals that do not overlap 1, and are therefore considered to have a significant association with presence.

Table 39. *Bufo woodhousii* and *Pseudacris maculata* habitat associations at 500, 1,000, and 2,000 m landscape scales based on model averaged estimates and 95% confidence intervals.

	MAE	SE	Lower 95% CI	Upper 95% CI
500 Meters				
Elevation	**-0.002**	**0.000**	**-0.002**	**-0.002**
Emergent vegetation	0.000	0.000	0.000	0.000
Surface area	0.000	0.000	0.000	0.000
Depth	-0.010	0.011	-0.032	0.012
% Aquatic	-0.054	0.067	-0.185	0.077
% Natural grass	**0.036**	**0.013**	**0.010**	**0.063**
% Agriculture	-0.001	0.005	-0.009	0.008
% Urban	0.037	13.863	-26.996	27.071
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
Constant	7.422	1.938	3.642	11.201
1,000 Meters				
Elevation	**-0.002**	**0.000**	**-0.002**	**-0.002**
Emergent vegetation	0.000	0.000	0.000	0.000
Surface area	0.000	0.000	0.000	0.000
Depth	-0.007	0.008	-0.022	0.009
% Aquatic	-0.128	0.136	-0.393	0.137
% Natural grass	**0.046**	**0.016**	**0.015**	**0.077**
% Agriculture	0.000	0.001	-0.002	0.001
% Urban	0.349	17.728	-34.220	34.919
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
Constant	6.226	1.607	3.093	9.360
2,000 Meters				
Elevation	-0.002	0.001	-0.004	0.000
Emergent vegetation	0.000	0.000	0.000	0.000
Surface area	0.000	0.000	0.000	0.000
Depth	-0.016	0.020	-0.056	0.024
% Aquatic	**-1.108**	**0.335**	**-1.763**	**-0.454**
% Natural grass	**0.049**	**0.020**	**0.010**	**0.088**
% Agriculture	-0.003	0.014	-0.030	0.025
% Urban	0.360	0.679	-0.964	1.684
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
Constant	7.850	2.112	3.732	11.968

Model averaged estimates were based on the full set of regression models (Appendix B). Letters and numbers in bold face indicate when the 95% confidence interval for coefficients did not overlap 0.

Table 40. Importance weights for variables included in *Bufo woodhousii* and *Pseudacris maculata* habitat models.

	500		1,000		2,000
Elevation	1.00	Elevation	1.00	Elevation	1.00
% Natural grass	0.982	% Natural grass	0.994	% Natural grass	1.00
Distance occupied	0.968	Distance occupied	0.979	Distance occupied	1.00
% Aquatic	0.567	% Aquatic	0.601	% Aquatic	0.997
Emergent vegetation	0.431	Emergent vegetation	0.402	Emergent vegetation	0.022
Distance waterbody	0.024	Distance waterbody	0.022	Distance waterbody	0.019
Surface area	0.011	Surface area	0.007	Surface area	0.019
Depth	0.011	Depth	0.007	Depth	0.019
% Agriculture	0.009	% Agriculture	0.007	% Agriculture	0.019
% Urban	0.007	% Urban	0.006	% Urban	0.019

Table 41. Ranking of habitat models for *Rana pipiens* for three spatial scales. Only those models with $\Delta QAIC_c \leq 7$ are shown. Models with $\Delta QAIC_c \leq 2$ have substantial support for making inferences, while $\Delta QAIC_c$ between 2 and 4 have moderate support and $\Delta QAIC_c$ between 4 and 7 have considerably less support.

Model #	**Candidate Models**	AIC_c	ΔAIC_c	w_i
	500 METERS			
24	EL, EM, **% NG,** DistOcc	23.10	0.00	0.609
23	EL, EM, **% NG,** DistWat	25.12	2.02	0.222
17	EL, % AQ, **% NG**, DistOcc	25.69	2.59	0.167
	1,000 METERS			
17	EL, % AQ, % NG, DistOcc	8.73	0.00	0.995
	2,000 METERS			
17	EL, % AQ, % NG, DistOcc	8.73	0.00	0.324
23	EL, EM, % NG, DistWat	8.73	0.00	0.324
24	EL, EM, % NG, DistOcc	8.73	0.01	0.323
16	Landscape Core	13.58	4.86	0.029

Bold variables indicate those variables that have parameter estimates with 95% confidence intervals that do not overlap 1, and are therefore considered to have a significant association with presence.

Table 42. *Rana pipens* habitat associations at 500, 1000, and 2000 m broad spatial scales based on model averaged estimates and 95% confidence intervals.

	MAE	SE	Lower 95% CI	Upper 95% CI
500 Meters				
Elevation	-0.003	0.002	-0.006	0.001
Emergent vegetation	0.001	0.001	-0.001	0.002
Surface area	0.000	0.000	0.000	0.000
Depth	0.001	0.001	-0.001	0.002
% Aquatic	-0.142	0.236	-0.603	0.319
% Natural grass	**0.129**	**0.054**	**0.024**	**0.233**
% Agriculture	0.000	0.037	-0.073	0.072
% Urban	**7.022**	**2.536**	**2.076**	**11.968**
Distance waterbody	0.000	0.000	0.000	0.000
Distance occupied	0.000	0.000	0.000	0.000
Constant	4.417	6.542	-8.341	17.175
1,000 Meters				
Elevation	-0.026	1.549	-3.046	2.994
Emergent vegetation	0.000	0.000	-0.001	0.001
Surface area	0.000	0.000	0.000	0.000
Depth	0.004	1.046	-2.035	2.044
% Aquatic	-78.619	481.641	-1017.820	860.582
% Natural grass	2.601	142.217	-274.722	279.925
% Agriculture	0.003	2.506	-4.884	4.889
% Urban	-0.003	5.205	-10.152	10.147
Distance waterbody	0.000	0.001	-0.001	0.001
Distance occupied	0.000	0.053	-0.103	0.103
Constant	-143.130	9629.189	-18920.049	18633.789
2,000 meters				
Elevation	-2.182	13.134	-27.794	23.430
Emergent vegetation	0.299	1.383	-2.399	2.996
Surface area	0.000	0.000	0.000	0.000
Depth	0.000	0.967	-1.886	1.886
% Aquatic	-6.887	1039.201	-2033.330	2019.555
% Natural grass	73.775	454.352	-812.212	959.762
% Agriculture	-0.038	18.277	-35.679	35.602
% Urban	12.214	324.313	-620.197	644.625
Distance waterbody	0.021	0.184	-0.337	0.379
Distance occupied	0.001	0.017	-0.032	0.035
Constant	3656.349	23943.034	-43032.567	50345.264

Model averaged estimates were based on the full set of regression models (Appendix B). Letters and numbers in bold face indicate when the 95% confidence interval for coefficients did not overlap 0.

Table 43. Importance weights for variables included in *Rana pipiens* habitat models.

	500		1,000		2,000
% Natural grass	1	% Natural grass	1	% Natural grass	1
Elevation	0.999	Elevation	1	Elevation	0.971
Emergent vegetation	0.831	Distance occupied	0.998	Distance occupied	0.677
Distance occupied	0.778	% Aquatic	0.995	Emergent vegetation	0.647
Distance waterbody	0.223	Emergent vegetation	0.005	Distance waterbody	0.353
% Aquatic	0.169	Distance waterbody	0.002	% Aquatic	0.353
% Agriculture	0.001	% Agriculture	0	% Agriculture	0.029
% Urban	0.001	% Urban	0	% Urban	0.029
Surface area	0.001	Surface area	0	Surface area	0
Depth	0.001	Depth	0	Depth	0

Figure 1. Location of 11 geographic strata based on Level 3 ecoregions and 8-digit hydrologic unit code watersheds used in the stratified random sampling approach for MTNHP amphibian surveys.

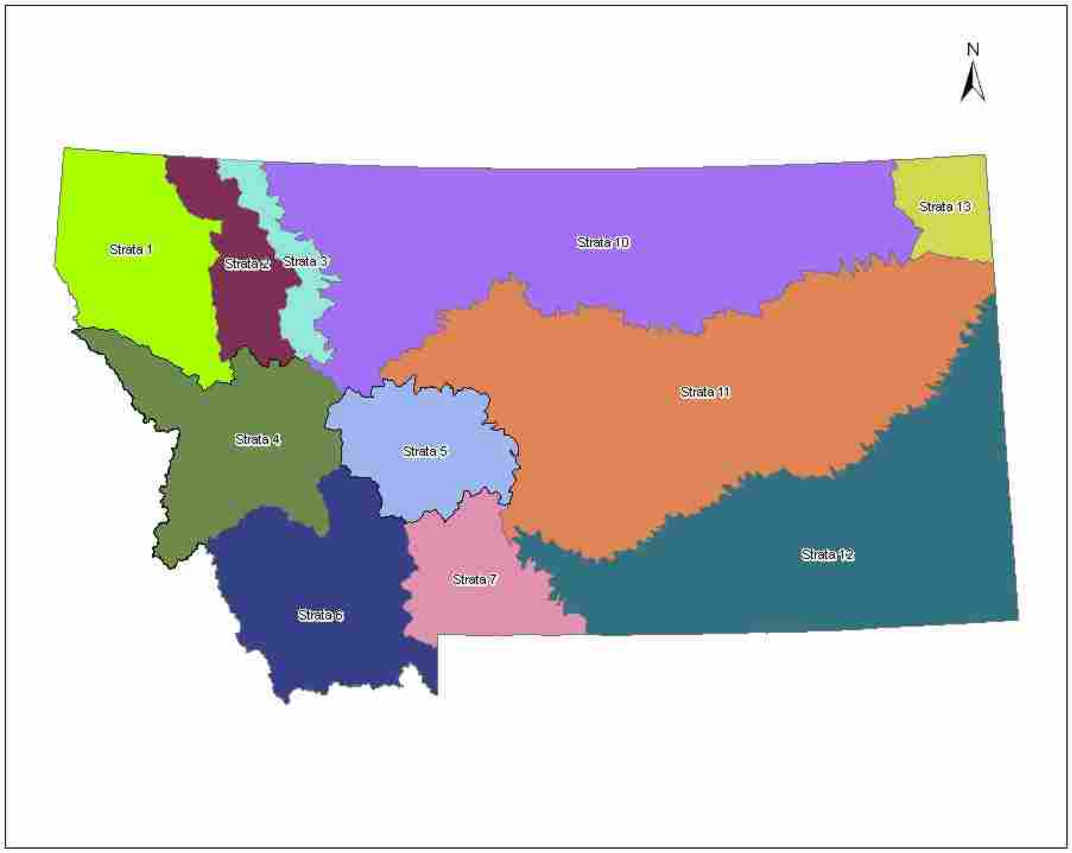


Figure 2. Dendogram from hierarchical cluster analysis showing grouping of *Bufo boreas* (BUBO) and *Rana luteiventris* (RALU).

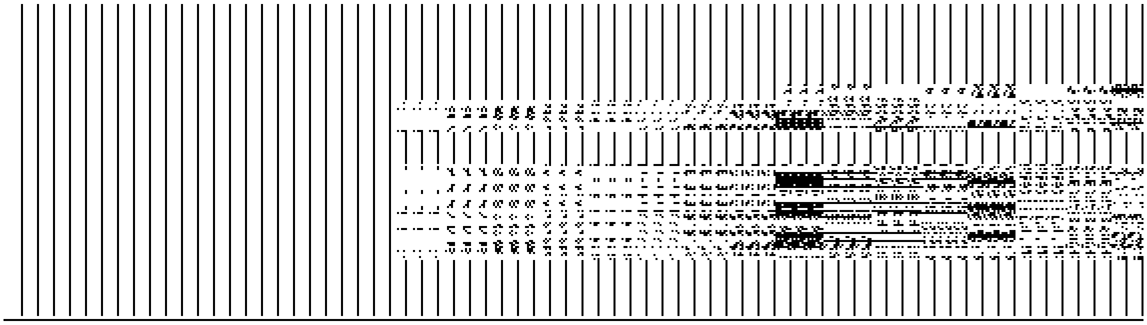
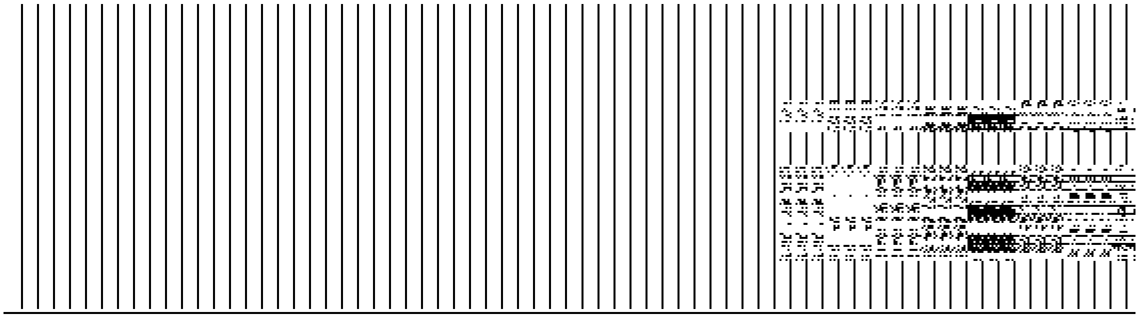


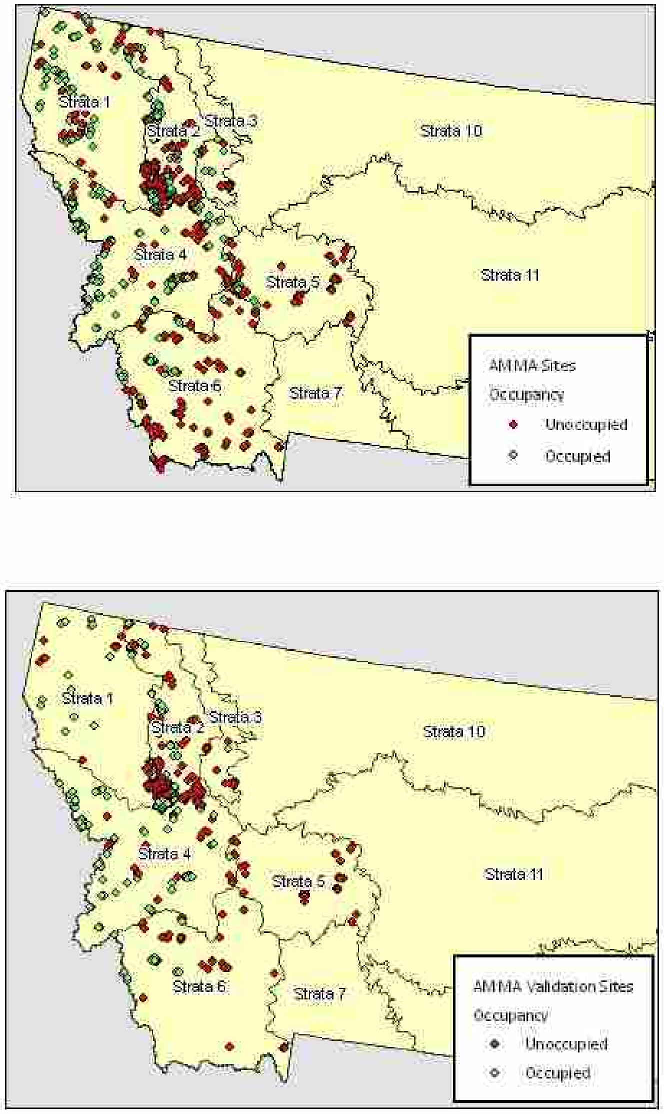
Figure 3. Dendogram from hierarchical cluster analysis showing grouping of *Bufo woodhousii* (BUWO) and *Pseudacris maculata* (PSMA).



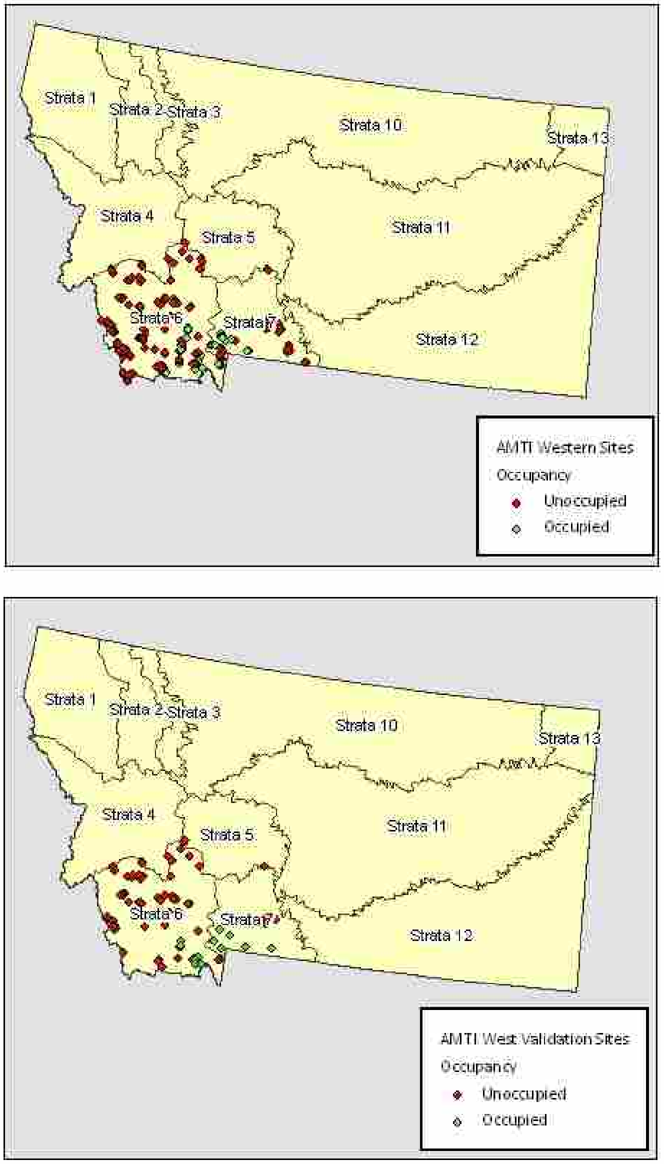
APPENDICES

APPENDIX A - Site Location Maps for each Species or Group of Species

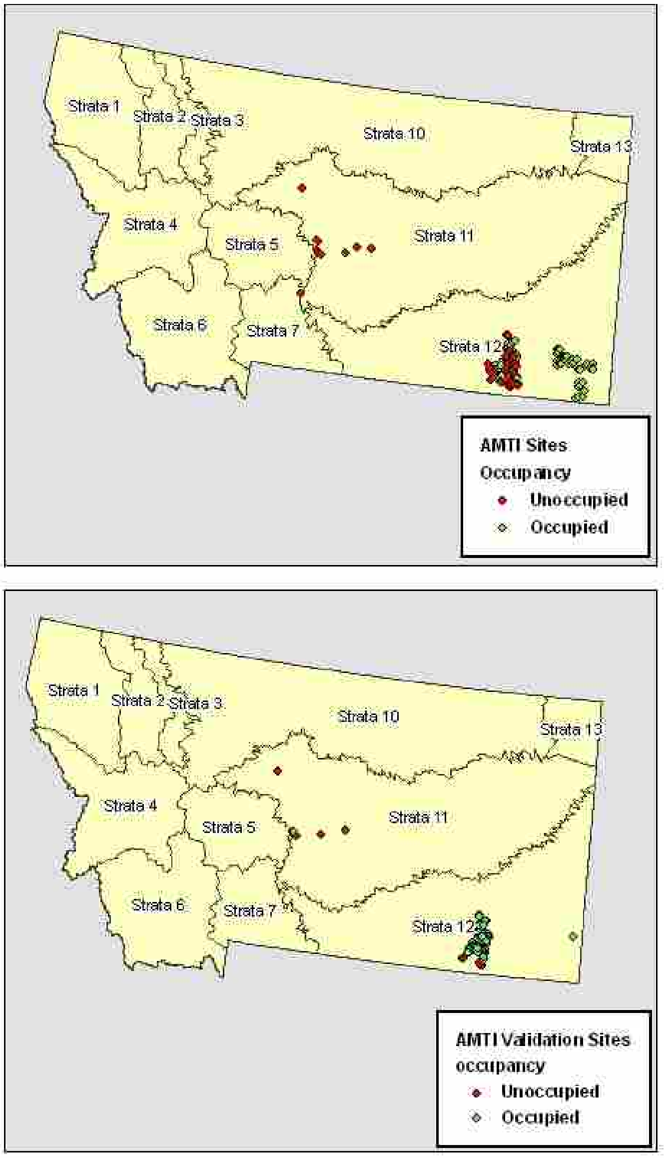
Long Toed Salamander Sites



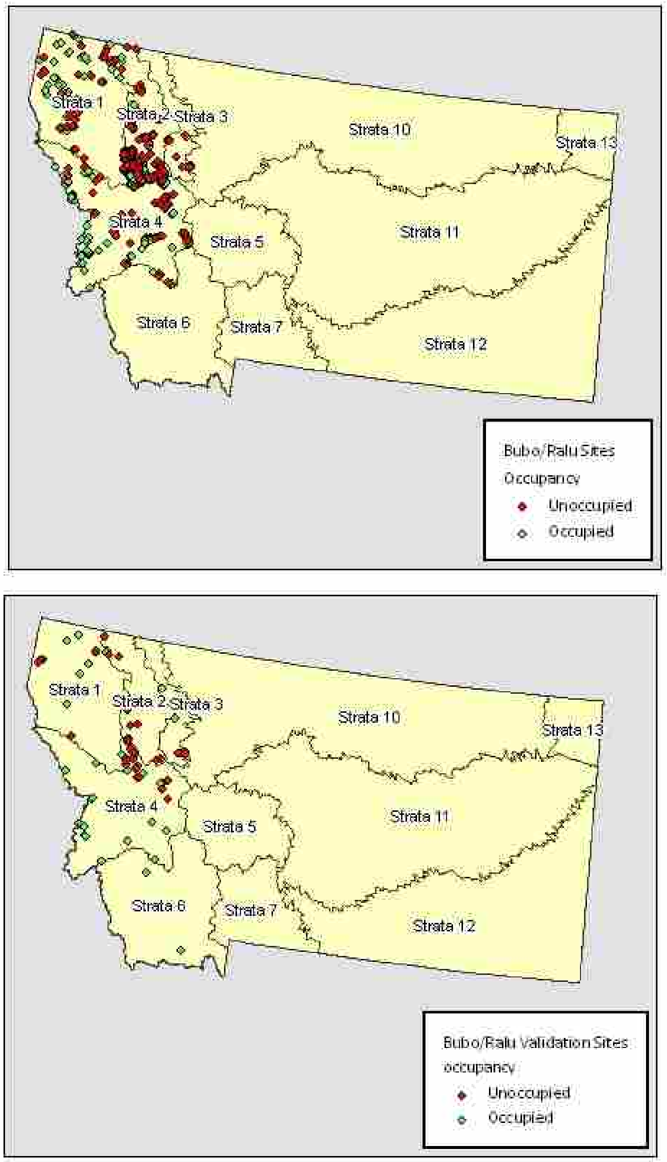
Western Montana Tiger Salamander Sites



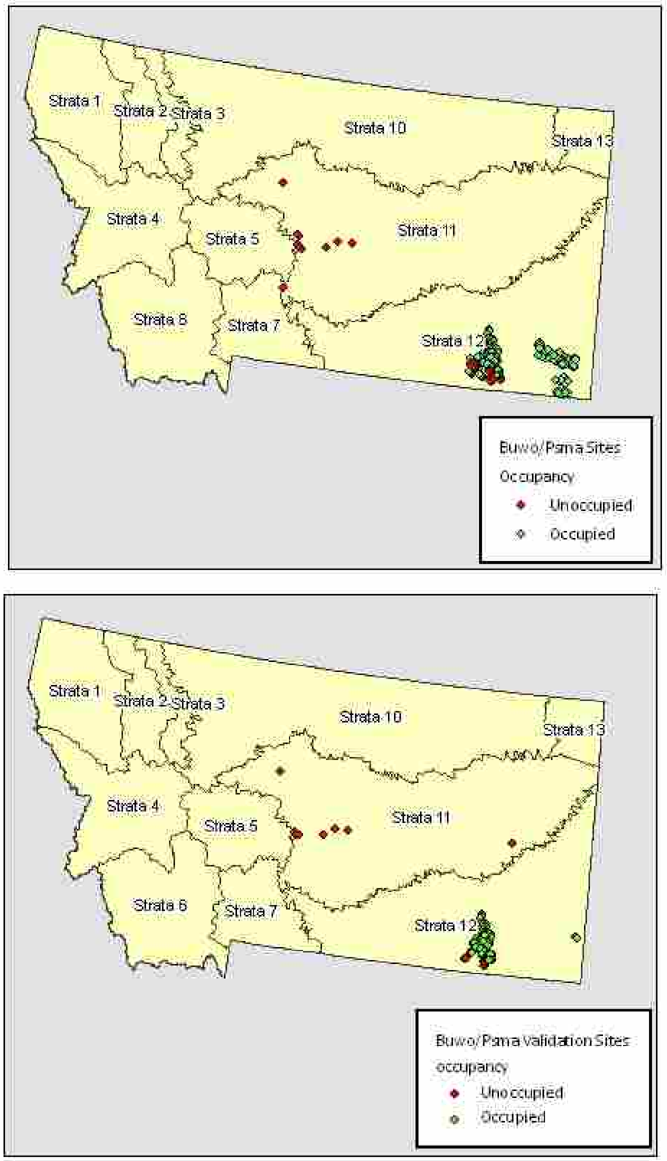
Eastern Montana Tiger Salamander Sites



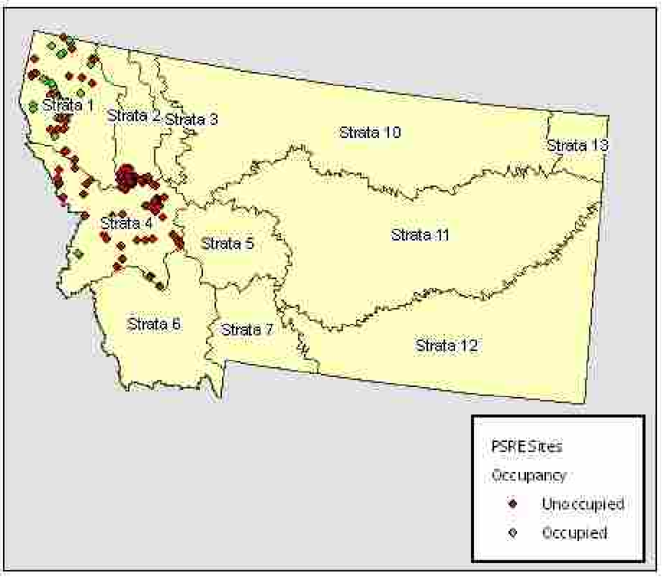
Western Toad and Columbia Spotted Frog Sites

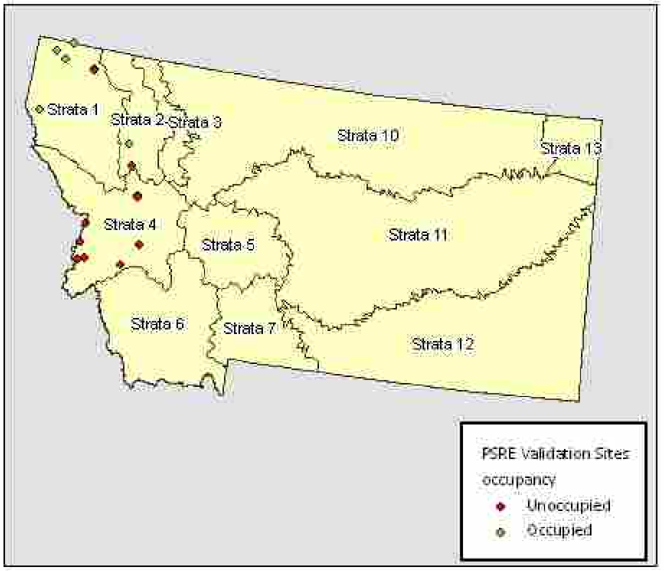


Woodhouse's Toad and Boreal Chorus Frog Sites

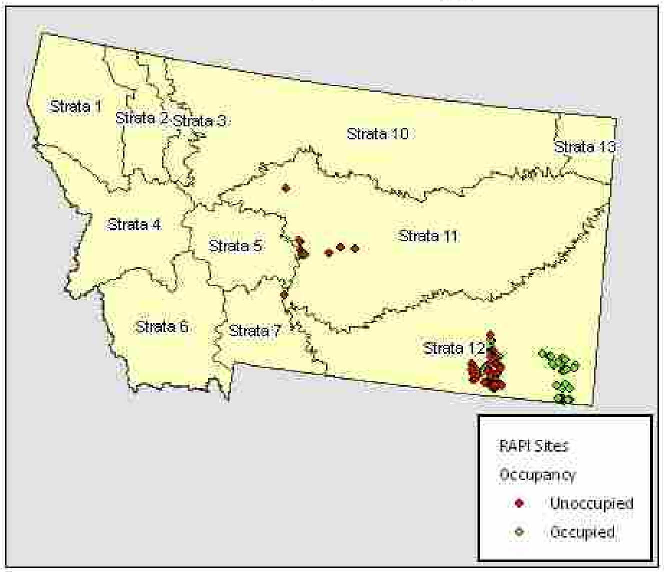


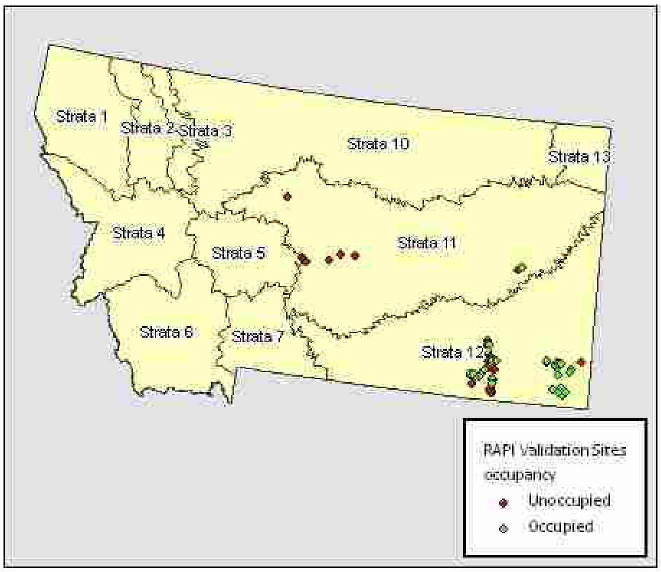
Pacific Tree Frog Sites





Northern Leopard Frog Sites





APPENDIX B - Model Results

Table B-1. *Ambystoma macrodactylum* habitat models at 500 m.

Model #	Candidate Models	*k*	$QAIC_c$	$\Delta QAIC_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	548.84	264.13	0.000	0.0000
2	Elevation, Area of Em veg	2	551.47	266.76	0.000	0.0000
3	Area of Em Veg, Depth	2	558.54	273.83	0.000	0.0000
4	Area of Em Veg	1	556.69	271.99	0.000	0.0000
5	Local Core	3	553.49	268.78	0.000	0.0000
	Landscape Models					
6	% Aq	1	532.61	247.90	0.000	0.0000
7	% Aq, DistOcc	2	469.63	184.93	0.000	0.0000
8	% Aq, Distance Forest, % Open, Distance Occupied	4	284.71	0.00	0.770	1.0000
9	% Aq, Distance Forest, % Open, Forest Edge	4	327.99	43.28	0.000	0.0000
10	% Aq, Distance Forest, % Open, % URB	4	328.37	43.66	0.000	0.0000
11	% Aq, Distance Forest, % AGT	3	396.92	112.21	0.000	0.0000
12	% Aq, Distance Forest, % Open, Distance waterbody	4	321.53	36.82	0.000	0.0000
13	Distance Forest, % Open, Distance Occupied	3	301.65	16.94	0.000	0.0002
14	Distance Forest, % Open, Forest Edge	3	343.97	59.26	0.000	0.0000
15	% Aq, Distance Forest, Forest Core, Distance Occupied	3	287.52	2.81	0.189	0.2456
16	Landscape Core	9	290.73	6.02	0.038	0.0493
	Combination Models					
17	Elevation, % Aq, % Open, Distance Forest	4	328.46	43.75	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	406.05	121.34	0.000	0.0000
19	Area of Em. Veg., Depth, % Open, Distance Forest	4	353.43	68.73	0.000	0.0000
20	Elevation, Area of Em. Veg., % Aq, % Open	4	459.78	175.07	0.000	0.0000
21	Depth, Area of Em. Veg., Distance Forest, % URB	4	426.37	141.66	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance Occupied	4	346.58	61.87	0.000	0.0000
23	Elevation, Distance Forest, % Open, Distance Occupied	4	301.44	16.73	0.000	0.0002
24	Area of Em. Veg., % Aq, Forest Core, Distance Forest	4	320.53	35.82	0.000	0.0000
25	Area of Em. Veg., % AGT, Distance waterbody	3	541.72	257.01	0.000	0.0000
26	Global	12	296.67	11.96	0.002	0.0025

Table B-2. *Ambystoma Macrodactylum* habitat models at 1,000 m.

Model #	Candidate Models	k	AIC_c	ΔAIC_c	w_i	Model Likelihood
	Local Models					
1	Elevation	1	1831.47	1124.44	0.000	0.0000
2	Elevation, Area of Em veg	2	1830.92	1123.90	0.000	0.0000
3	Area of Em Veg, Depth	2	1859.44	1152.41	0.000	0.0000
4	Area of Em Veg	1	1858.54	1151.52	0.000	0.0000
5	Local Core	3	1832.89	1125.87	0.000	0.0000
	Landscape Models					
6	% Aq	1	1780.20	1073.18	0.000	0.0000
7	% Aq, Distance occupied	2	1001.77	294.75	0.000	0.0000
8	% Aq, Distance Forest, % Open, Distance occupied	4	753.68	46.66	0.000	0.0014
9	% Aq, Distance Forest, % Open, Forest Edge	4	778.80	71.78	0.000	0.0000
10	% Aq, Distance Forest, % Open, % URB	4	776.96	69.94	0.000	0.0000
11	% Aq, Distance Forest, % AGT	3	1245.95	538.92	0.000	0.0000
12	% Aq, Distance Forest, % Open, Distance waterbody	4	745.89	38.87	0.000	0.0089
13	Distance Forest, % Open, Distance occupied	3	817.60	110.58	0.000	0.0000
14	Distance Forest, % Open, Forest Edge	3	863.33	156.31	0.000	0.0000
15	% Aq, Distance Forest, Forest Core, Distance occupied	3	750.46	43.43	0.000	0.0052
16	Landscape Core	9	715.00	7.98	0.018	0.8072
	Combination Models					
17	Elevation, % Aq, % Open, Distance Forest	4	755.10	48.08	0.000	0.0010
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	1274.29	567.27	0.000	0.0000
19	Area of Em. Veg., Depth, % Open, Distance Forest	4	878.22	171.20	0.000	0.0000
20	Elevation, Area of Em. Veg., % Aq, % Open	4	946.10	239.08	0.000	0.0000
21	Depth, Area of Em. Veg., Distance Forest, % URB	4	1109.53	402.51	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance occupied	4	864.16	157.14	0.000	0.0000
23	Elevation, Distance Forest, % Open, Distance occupied	4	819.11	112.09	0.000	0.0000
24	Area of Em. Veg., % Aq, Forest Core, Distance Forest	4	1023.54	316.52	0.000	0.0000
25	Area of Em. Veg., % AGT, Distance waterbody	3	1775.55	1068.52	0.000	0.0000
26	Global	12	707.02	0.00	0.982	1.0000

Table B-3. *Ambystoma Macrodactylum* habitat models at 2,000 m.

Model #	Candidate Models	k	$QAIC_c$	$\Delta QAIC_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	698.09	406.18	0.000	0.0000
2	Elevation, Area of Em veg	2	699.13	407.22	0.000	0.0000
3	Area of Em Veg, Depth	2	709.98	418.06	0.000	0.0000
4	Area of Em Veg	1	708.39	416.48	0.000	0.0000
5	Local Core	3	701.13	409.22	0.000	0.0000
	Landscape Models					
6	% Aq	1	685.35	393.43	0.000	0.0000
7	% Aq, Distance occupied	2	391.02	99.10	0.000	0.0000
8	% Aq, Distance Forest, % Open, Distance occupied	4	299.24	7.32	0.017	0.0257
9	% Aq, Distance Forest, % Open, Forest Edge	4	313.32	21.40	0.000	0.0000
10	% Aq, Distance Forest, % Open, % URB	4	312.59	20.67	0.000	0.0000
11	% Aq, Distance Forest, % AGT	3	488.50	196.59	0.000	0.0000
12	% Aq, Distance Forest, % Open, Distance waterbody	4	352.66	60.75	0.000	0.0000
13	Distance Forest, % Open, Distance occupied	3	320.86	28.94	0.000	0.0000
14	Distance Forest, % Open, Forest Edge	3	335.46	43.55	0.000	0.0000
15	% Aq, Distance Forest, Forest Core, Distance occupied	3	300.21	8.30	0.010	0.0158
16	Landscape Core	9	293.29	1.38	0.325	0.5027
	Combination Models					
17	Elevation, % Aq, % Open, Distance Forest	4	303.14	11.22	0.002	0.0037
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	501.61	209.70	0.000	0.0000
19	Area of Em. Veg., Depth, % Open, Distance Forest	4	341.53	49.61	0.000	0.0000
20	Elevation, Area of Em. Veg., % Aq, % Open	4	370.53	78.61	0.000	0.0000
21	Depth, Area of Em. Veg., Distance Forest, % URB	4	520.10	228.18	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance occupied	4	336.01	44.10	0.000	0.0000
23	Elevation, Distance Forest, % Open, Distance occupied	4	322.88	30.96	0.000	0.0000
24	Area of Em. Veg., % Aq, Forest Core, Distance Forest	4	404.77	112.85	0.000	0.0000
25	Area of Em. Veg., % AGT, Distance waterbody	3	677.61	385.69	0.000	0.0000
26	Global	12	291.92	0.00	0.646	1.0000

Table B-4. *Ambystoma tigrinum* (West) habitat models at 500 m.

Model #	Candidate Models	k	AIC_c	ΔAIC_c	w_i	Model Likelihood
	Local Models					
1	Elevation	1	137.85	67.32	0.000	0.0000
2	Elevation, Area of Em veg, SA	3	141.22	70.69	0.000	0.0000
3	SA, Depth	2	149.39	78.86	0.000	0.0000
4	Area of Em Veg, SA	2	149.94	79.41	0.000	0.0000
5	Local Core	4	142.77	72.24	0.000	0.0000
	Landscape Models					
6	% Aq	1	133.72	63.19	0.000	0.0000
7	% Aq, Distance occupied	2	80.00	9.47	0.003	0.0088
8	% Aq, Distance Forest, % FOR , Distance occupied	4	72.23	1.70	0.157	0.4271
9	% Aq, Distance Forest, Forest Edge	3	131.26	60.73	0.000	0.0000
10	% Aq, Distance Forest, % FOR, % URB	4	125.46	54.92	0.000	0.0000
11	% Aq, Distance Forest, % AGT, Distance waterbody	4	115.99	45.46	0.000	0.0000
12	% Aq, Distance Forest, % NG, Distance waterbody	4	111.70	41.17	0.000	0.0000
13	Distance Forest, % FOR, Distance occupied	3	71.73	1.20	0.202	0.5488
14	Distance Forest, % NG, Distance occupied	3	70.53	0.00	0.368	1.0000
15	% Aq, Distance Forest, Forest Core, Distance occupied	4	72.10	1.56	0.169	0.4573
16	Landscape Core	10	76.27	5.73	0.021	0.0568
	Combination Models					
17	Elevation, % Aq, % FOR, Distance Forest	4	126.41	55.88	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, % FOR	4	132.53	61.99	0.000	0.0000
19	SA, Depth, % FOR, Distance Forest	4	142.33	71.79	0.000	0.0000
20	Area of Em. Veg., SA, % Aq, % NG	4	122.32	51.78	0.000	0.0000
21	Depth, Area of Em. Veg., Distance Forest, % URB	4	142.02	71.48	0.000	0.0000
22	Elevation, % Aq, Distance Forest, Forest edge,	4	128.31	57.78	0.000	0.0000
23	Elevation, % Aq, % NG, Distance Forest	4	114.18	43.65	0.000	0.0000
24	SA, Forest Core, Distance Forest, Distance occupied	4	73.65	3.12	0.078	0.2106
25	Area of Em. Veg., SA, % AGT, Distance waterbody	4	136.79	66.26	0.000	0.0000
26	Global	14	81.34	10.80	0.002	0.0045

Table B-5. *Ambystoma tigrinum* (West) habitat models at 1,000 m.

Model #	Candidate Models	*k*	AIC$_c$	ΔAIC$_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	137.85	61.45	0.000	0.0000
2	Elevation, Area of Em veg, SA	3	141.22	64.82	0.000	0.0000
3	SA, Depth	2	149.39	72.99	0.000	0.0000
4	Area of Em Veg, SA	2	149.94	73.54	0.000	0.0000
5	Local Core	4	142.77	66.37	0.000	0.0000
	Landscape Models					
6	% Aq	1	146.82	70.42	0.000	0.0000
7	% Aq, Distance occupied	2	94.01	17.61	0.000	0.0002
8	% Aq, Distance Forest, % FOR , Distance occupied	4	91.57	15.17	0.000	0.0005
9	% Aq, Distance Forest, Forest Edge	3	144.71	68.31	0.000	0.0000
10	% Aq, Distance Forest, % FOR, % URB	4	137.05	60.65	0.000	0.0000
11	% Aq, Distance Forest, % AGT, Distance waterbody	4	141.81	65.41	0.000	0.0000
12	% Aq, Distance Forest, % NG, Distance waterbody	4	110.50	34.10	0.000	0.0000
13	Distance Forest, % FOR, Distance occupied	3	92.38	15.98	0.000	0.0003
14	Distance Forest, % NG, Distance occupied	3	79.86	3.46	0.112	0.1769
15	% Aq, Distance Forest, Forest Core, Distance occupied	4	92.02	15.62	0.000	0.0004
16	Landscape Core	10	76.40	0.00	0.632	1.0000
	Combination Models					
17	Elevation, % Aq, % FOR, Distance Forest	4	129.92	53.52	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, % FOR	4	140.53	64.13	0.000	0.0000
19	SA, Depth, % FOR, Distance Forest	4	141.85	65.45	0.000	0.0000
20	Area of Em. Veg., SA, % Aq, % NG	4	120.31	43.91	0.000	0.0000
21	Depth, Area of Em. Veg., Distance Forest, % URB	4	147.05	70.65	0.000	0.0000
22	Elevation, % Aq, Distance Forest, Forest edge,	4	134.71	58.31	0.000	0.0000
23	Elevation, % Aq, % NG, Distance Forest	4	108.56	32.16	0.000	0.0000
24	SA, Forest Core, Distance Forest, Distance occupied	4	92.28	15.88	0.000	0.0004
25	Area of Em. Veg., SA, % AGT, Distance waterbody	4	143.16	66.76	0.000	0.0000
26	Global	14	78.22	1.82	0.255	0.4029

Table B-6. *Ambystoma tigrinum* (West) habitat models at 2,000 m.

Model #	Candidate Models	k	AIC_c	ΔAIC_c	w_i	Model Likelihood
	Local Models					
1	Elevation	1	137.85	69.87	0.000	0.0000
2	Elevation, Area of Em veg, SA	3	141.22	73.24	0.000	0.0000
3	SA, Depth	2	149.39	81.41	0.000	0.0000
4	Area of Em Veg, SA	2	149.94	81.95	0.000	0.0000
5	Local Core	4	142.77	74.79	0.000	0.0000
	Landscape Models					
6	% Aq	1	148.32	80.33	0.000	0.0000
7	% Aq, Distance occupied	2	80.93	12.95	0.001	0.0015
8	% Aq, Distance Forest, % FOR , Distance occupied	4	74.34	6.36	0.032	0.0416
9	% Aq, Distance Forest, Forest Edge	3	147.74	79.76	0.000	0.0000
10	% Aq, Distance Forest, % FOR, % URB	4	139.43	71.45	0.000	0.0000
11	% Aq, Distance Forest, % AGT, Distance waterbody	4	135.98	68.00	0.000	0.0000
12	% Aq, Distance Forest, % NG, Distance waterbody	4	109.09	41.10	0.000	0.0000
13	Distance Forest, % FOR, Distance occupied	3	72.69	4.70	0.074	0.0953
14	Distance Forest, % NG, Distance occupied	3	67.99	0.00	0.779	1.0000
15	% Aq, Distance Forest, Forest Core, Distance occupied	4	74.07	6.08	0.037	0.0478
16	Landscape Core	10	73.88	5.90	0.041	0.0524
	Combination Models					
17	Elevation, % Aq, % FOR, Distance Forest	4	137.63	69.64	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, % FOR	4	146.60	78.61	0.000	0.0000
19	SA, Depth, % FOR, Distance Forest	4	147.25	79.26	0.000	0.0000
20	Area of Em. Veg., SA, % Aq, % NG	4	121.13	53.14	0.000	0.0000
21	Depth, Area of Em. Veg., Distance Forest, % URB	4	151.23	83.25	0.000	0.0000
22	Elevation, % Aq, Distance Forest, Forest edge,	4	140.73	72.74	0.000	0.0000
23	Elevation, % Aq, % NG, Distance Forest	4	109.84	41.85	0.000	0.0000
24	SA, Forest Core, Distance Forest, Distance occupied	4	74.50	6.51	0.030	0.0385
25	Area of Em. Veg., SA, % AGT, Distance waterbody	4	142.51	74.53	0.000	0.0000
26	Global	14	78.13	10.15	0.005	0.0063

Table B-7. *Ambystoma tigrinum* (East) habitat models at 500 m.

Model #	Candidate Models	*k*	AIC$_c$	ΔAIC$_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	58.38	0.62	0.280	0.7352
2	Elevation, Area of Em. Veg., SA	3	57.76	0.00	0.381	1.0000
3	Area of Em. Veg., Depth	2	116.11	58.34	0.000	0.0000
4	SA, Depth	2	108.12	50.35	0.000	0.0000
5	Local Core	4	59.89	2.12	0.132	0.3461
	Landscape Models					
6	% Aq	1	113.90	56.13	0.000	0.0000
7	% Aq, Distance occupied	2	88.24	30.47	0.000	0.0000
8	% Aq, % NG, Distance occupied	3	81.63	23.86	0.000	0.0000
9	% Aq, % NG, % AGT, Distance occupied	4	81.36	23.59	0.000	0.0000
10	% Aq, % NG, % URB, Distance waterbody	4	114.45	56.68	0.000	0.0000
11	% NG, Distance occupied	2	79.52	21.76	0.000	0.0000
12	% NG, % AGT	2	106.21	48.44	0.000	0.0000
13	% NG, % URB	2	111.11	53.35	0.000	0.0000
14	% AGT, Distance occupied	2	86.25	28.49	0.000	0.0000
15	Percent Urban, Distance waterbody	2	112.65	54.88	0.000	0.0000
16	Landscape Core	6	67.40	9.63	0.003	0.0081
	Combination Models					
17	Elevation, Area of Em. Veg., % Aq, % NG	4	61.15	3.39	0.070	0.1837
18	Elevation, % Aq, % NG, % AGT	4	62.41	4.64	0.037	0.0981
19	Area of Em. Veg., Depth, % NG, Distance occupied	4	83.58	25.82	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	102.33	44.57	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	109.87	52.10	0.000	0.0000
22	Area of Em. Veg., SA, % AGT, Distance waterbody	4	104.85	47.08	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	60.70	2.94	0.088	0.2301
24	SA, Depth, % NG, Distance occupied	4	79.72	21.95	0.000	0.0000
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	110.26	52.49	0.000	0.0000
26	Global	10	65.29	7.52	0.009	0.0232

Table B-8. *Ambystoma tigrinum* (East) habitat models at 1,000 m.

Model #	Candidate Models	*k*	AIC$_c$	ΔAIC$_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	58.38	0.62	0.261	0.7352
2	Elevation, Area of Em. Veg., SA	3	57.76	0.00	0.355	1.0000
3	Area of Em. Veg., Depth	2	116.11	58.34	0.000	0.0000
4	SA, Depth	2	108.12	50.35	0.000	0.0000
5	Local Core	4	59.89	2.12	0.123	0.3461
	Landscape Models					
6	% Aq	1	112.89	55.13	0.000	0.0000
7	% Aq, Distance occupied	2	85.02	27.26	0.000	0.0000
8	% Aq, % NG, Distance occupied	3	77.92	20.16	0.000	0.0000
9	% Aq, % NG, % AGT, Distance occupied	4	78.42	20.66	0.000	0.0000
10	% Aq, % NG, % URB, Distance waterbody	4	112.80	55.03	0.000	0.0000
11	% NG, Distance occupied	2	76.90	19.14	0.000	0.0001
12	% NG, % AGT	2	107.04	49.28	0.000	0.0000
13	% NG, % URB	2	110.43	52.66	0.000	0.0000
14	% AGT, Distance occupied	2	84.68	26.91	0.000	0.0000
15	Percent Urban, Distance waterbody	2	113.95	56.19	0.000	0.0000
16	Landscape Core	6	80.66	22.90	0.000	0.0000
	Combination Models					
17	Elevation, Area of Em. Veg., % Aq, % NG	4	60.24	2.47	0.103	0.2907
18	Elevation, % Aq, % NG, % AGT	4	61.81	4.05	0.047	0.1323
19	Area of Em. Veg., Depth, % NG, Distance occupied	4	80.43	22.67	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	102.88	45.11	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	108.83	51.07	0.000	0.0000
22	Area of Em. Veg., SA, % AGT, Distance waterbody	4	105.75	47.99	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	60.15	2.38	0.108	0.3036
24	SA, Depth, % NG, Distance occupied	4	78.81	21.05	0.000	0.0000
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	110.54	52.78	0.000	0.0000
26	Global	10	67.68	9.91	0.002	0.0070

Table B-9. *Ambystoma tigrinum* (East) habitat models at 2,000 m.

Model #	Candidate Models	K	AICc	ΔAICc	w_i	Model Likelihood
	Local Models					
1	Elevation	1	58.38	1.21	0.135	0.5457
2	Elevation, Area of Em. Veg., SA	3	57.76	0.60	0.183	0.7423
3	Area of Em. Veg., Depth	2	116.11	58.94	0.000	0.0000
4	SA, Depth	2	108.12	50.95	0.000	0.0000
5	Local Core	4	59.89	2.72	0.063	0.2569
	Landscape Models					
6	% Aq	1	107.61	50.44	0.000	0.0000
7	% Aq, Distance occupied	2	81.61	24.44	0.000	0.0000
8	% Aq, % NG, Distance occupied	3	75.11	17.94	0.000	0.0001
9	% Aq, % NG, % AGT, Distance occupied	4	76.55	19.38	0.000	0.0001
10	% Aq, % NG, % URB, Distance waterbody	4	109.71	52.54	0.000	0.0000
11	% NG, Distance occupied	2	76.42	19.25	0.000	0.0001
12	% NG, % AGT	2	108.14	50.97	0.000	0.0000
13	% NG, % URB	2	111.50	54.33	0.000	0.0000
14	% AGT, Distance occupied	2	85.07	27.90	0.000	0.0000
15	Percent Urban, Distance waterbody	2	115.13	57.96	0.000	0.0000
16	Landscape Core	6	66.44	9.28	0.002	0.0097
	Combination Models					
17	Elevation, Area of Em. Veg., % Aq, % NG	4	57.17	0.00	0.247	1.0000
18	Elevation, % Aq, % NG, % AGT	4	58.05	0.88	0.159	0.6440
19	Area of Em. Veg., Depth, % NG, Distance occupied	4	79.84	22.67	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	103.82	46.65	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	107.76	50.59	0.000	0.0000
22	Area of Em. Veg., SA, % AGT, Distance waterbody	4	109.59	52.42	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	59.31	2.14	0.085	0.3428
24	SA, Depth, % NG, Distance occupied	4	78.02	20.85	0.000	0.0000
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	110.54	53.37	0.000	0.0000
26	Global	10	58.51	1.34	0.126	0.5121

Table B-10. *Bufo boreas/ Ralu luteiventris* habitat models at 500 m.

Model #	Candidate Models	*k*	AIC$_c$	ΔAIC$_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	898.26	280.72	0.000	0.0000
2	Elevation, Area of Em Veg, SA	3	901.17	283.62	0.000	0.0000
3	SA, Depth	2	898.71	281.16	0.000	0.0000
4	Area of Em Veg, SA	2	899.15	281.60	0.000	0.0000
5	Local Core	4	902.28	284.73	0.000	0.0000
	Landscape Models					
6	% Aq	1	850.88	233.33	0.000	0.0000
7	% Aq, Distance occupied	2	764.13	146.58	0.000	0.0000
8	% Aq, Distance Forest, % Forest, Distance occupied	4	617.55	0.00	0.882	1.0000
9	% Aq, Distance Forest, % FOR, Forest Edge	4	710.44	92.89	0.000	0.0000
10	% Aq, Distance Forest, % FOR, % URB	4	712.48	94.94	0.000	0.0000
11	% Aq, Distance Forest, % NG, % AGT	4	714.72	97.17	0.000	0.0000
12	% Aq, Distance Forest, % NG, Distance waterbody	4	708.66	91.11	0.000	0.0000
13	Distance Forest, % FOR, Distance occupied	3	652.04	34.49	0.000	0.0000
14	Distance Forest, % FOR, Forest Edge	3	740.70	123.16	0.000	0.0000
15	% Aq, Distance Forest, Forest Core	3	712.42	94.87	0.000	0.0000
16	Landscape Core	10	623.06	5.51	0.056	0.0636
	Combination Models					
17	Elevation, % Aq, % FOR, Distance Forest	4	701.56	84.02	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	715.09	97.54	0.000	0.0000
19	Depth, SA, % FOR, Distance Forest	4	739.54	121.99	0.000	0.0000
20	Depth, SA, % Aq, % NG	4	849.44	231.89	0.000	0.0000
21	Depth, Area of Em. Veg., Distanve Forest, % URB	4	752.02	134.47	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance occupied	4	645.75	28.20	0.000	0.0000
23	Elevation, Distance Forest, % NG, Distance occupied	4	644.18	26.64	0.000	0.0000
24	SA, % Aq, Forest Core, Distance Forest	4	713.79	96.25	0.000	0.0000
25	Area of Em. Veg., SA, % AGT, Distance waterbody	4	857.02	239.47	0.000	0.0000
26	Global	14	622.84	5.29	0.062	0.0708

Table B-11. *Bufo boreas/ Ralu luteiventris* habitat models at 1,000 m.

Model #	Candidate Models	*k*	AIC$_c$	ΔAIC$_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	898.26	224.14	0.000	0.0000
2	Elevation, Area of Em Veg, SA	3	901.17	227.05	0.000	0.0000
3	SA, Depth	2	898.71	224.59	0.000	0.0000
4	Area of Em Veg, SA	2	899.15	225.03	0.000	0.0000
5	Local Core	4	902.28	228.16	0.000	0.0000
	Landscape Models					
6	% Aq	1	850.35	176.23	0.000	0.0000
7	% Aq, Distance occupied	2	805.69	131.57	0.000	0.0000
8	% Aq, Distance Forest, % FOR, Distance occupied	4	674.12	0.00	0.828	1.0000
9	% Aq, Distance Forest, % FOR, Forest Edge	4	709.45	35.33	0.000	0.0000
10	% Aq, Distance Forest, % FOR, % URB	4	711.48	37.36	0.000	0.0000
11	% Aq, Distance Forest, % NG, % AGT**	4	712.42	38.30	0.000	0.0000
12	% Aq, Distance Forest, % NG, Distance waterbody	4	714.01	39.89	0.000	0.0000
13	Distance Forest, % FOR, Distance occupied	3	704.94	30.82	0.000	0.0000
14	Distance Forest, % FOR, Forest Edge	3	740.48	66.36	0.000	0.0000
15	% Aq, Distance Forest, Forest Core	3	711.77	37.65	0.000	0.0000
16	Landscape Core	10	678.30	4.18	0.102	0.1235
	Combination Models					
17	Elevation, % Aq, % FOR, Distance Forest	4	701.51	27.39	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	716.49	42.37	0.000	0.0000
19	Depth, SA, % FOR, Distance Forest	4	739.54	65.42	0.000	0.0000
20	Depth, SA, % Aq, % NG	4	852.02	177.90	0.000	0.0000
21	Depth, Area of Em. Veg., Distance Forest, % URB	4	753.95	79.83	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance occupied	4	703.07	28.95	0.000	0.0000
23	Elevation, Distance Forest, % NG, Distance occupied	4	697.05	22.93	0.000	0.0000
24	SA, % Aq, Forest Core, Distance Forest	4	712.93	38.81	0.000	0.0000
25	Area of Em. Veg., SA, % AGT, Distance waterbody	4	895.17	221.05	0.000	0.0000
26	Global	14	679.06	4.94	0.070	0.0847

Table B-12. *Bufo boreas/ Ralu luteiventris* habitat models at 2,000 m.

Model #	Candidate Models	k	AIC$_c$	ΔAIC$_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	898.26	200.88	0.000	0.0000
2	Elevation, Area of Em Veg, SA	3	901.17	203.78	0.000	0.0000
3	SA, Depth	2	898.71	201.32	0.000	0.0000
4	Area of Em Veg, SA	2	899.15	201.77	0.000	0.0000
5	Local Core	4	902.28	204.89	0.000	0.0000
	Landscape Models					
6	% Aq	1	858.89	161.50	0.000	0.0000
7	% Aq, Distance occupied	2	839.05	141.66	0.000	0.0000
8	% Aq, Distance Forest, % FOR, Distance occupied	4	697.38	0.00	0.906	1.0000
9	% Aq, Distance Forest, % FOR, Forest Edge	4	721.38	24.00	0.000	0.0000
10	% Aq, Distance Forest, % FOR, % URB	4	723.16	25.77	0.000	0.0000
11	% Aq, Distance Forest, % NG, % AGT	4	725.47	28.09	0.000	0.0000
12	% Aq, Distance Forest, % NG, Distance waterbody	4	721.06	23.68	0.000	0.0000
13	Distance Forest, % FOR, Distance occupied	3	723.19	25.81	0.000	0.0000
14	Distance Forest, % FOR, Forest Edge	3	746.17	48.79	0.000	0.0000
15	% Aq, Distance Forest, Forest Core	3	722.99	25.60	0.000	0.0000
16	Landscape Core	10	702.59	5.21	0.067	0.0739
	Combination Models					
17	Elevation, % Aq, % FOR, Distance Forest	4	714.81	17.43	0.000	0.0002
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	729.22	31.83	0.000	0.0000
19	Depth, SA, % FOR, Distance Forest	4	745.44	48.05	0.000	0.0000
20	Depth, SA, % Aq, % NG	4	858.58	161.20	0.000	0.0000
21	Depth, Area of Em. Veg., Distanve Forest, % URB	4	758.00	60.61	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance occupied	4	719.49	22.10	0.000	0.0000
23	Elevation, Distance Forest, % NG, Distance occupied	4	709.35	11.96	0.002	0.0025
24	SA, % Aq, Forest Core, Distance Forest	4	724.06	26.68	0.000	0.0000
25	Area of Em. Veg., SA, % AGT, Distance waterbody	4	889.96	192.57	0.000	0.0000
26	Global	14	704.57	7.18	0.025	0.0276

Table B-13. *Pseudacris regilla* habitat models at 500 m.

Model #	Candidate Models	*k*	AIC$_c$	ΔAIC$_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	162.22	83.66	0.000	0.0000
2	Elevation, Area of Em Veg	2	163.63	85.07	0.000	0.0000
3	Area of Em Veg, Depth	2	198.76	120.20	0.000	0.0000
4	Area of Em Veg	1	196.71	118.15	0.000	0.0000
5	Local Core	3	165.57	87.01	0.000	0.0000
	Landscape Models					
6	% Aq	1	191.23	112.67	0.000	0.0000
7	%Aq, Distance occupied	2	101.25	22.69	0.000	0.0000
8	% Aq, % Open	2	177.95	99.39	0.000	0.0000
9	% Aq, % Open, Distance Forest, Forest Edge	4	168.66	90.10	0.000	0.0000
10	% Aq, Distance Forest, Distance occupied	3	88.77	10.21	0.003	0.0061
11	% Aq, % URB, % Open, Distance waterbody	4	181.25	102.69	0.000	0.0000
12	Distance Forest, Forest Edge, Distance occupied	3	88.83	10.27	0.003	0.0059
13	Distance Forest, % Open, Distance occupied	3	88.87	10.31	0.003	0.0058
14	% Aq, Forest Core, Distance Forest	2	193.09	114.53	0.000	0.0000
15	% Open, Distance Forest, % URB, Distance waterbody	4	180.46	101.90	0.000	0.0000
16	Landscape Core	8	95.99	17.43	0.000	0.0002
	Combination Models					
17	Elevation, % Aq, % Open	3	137.81	59.25	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	182.81	104.25	0.000	0.0000
19	Elevation, Depth, % Open, Distance Forest	4	145.98	67.42	0.000	0.0000
20	Area of Em. Veg., Depth, % Aq, % Open	4	181.36	102.80	0.000	0.0000
21	Elevation, Area of Em. Veg., % Open, Forest Core	4	140.36	61.80	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance occupied	4	78.56	0.00	0.505	1.0000
23	Elevation, Distance Forest, % Open, Distance occupied	4	78.71	0.15	0.469	0.9291
24	Area of Em. Veg., Depth, % Aq, % URB	4	197.27	118.71	0.000	0.0000
25	Elevation, % Open, Distance Forest, Distance waterbody	4	144.67	66.11	0.000	0.0000
26	Global	11	85.30	6.73	0.017	0.0345

Table B-14. *Pseudacris regilla* habitat models at 1,000 m.

Model #	Candidate Model	K	AICc	ΔAICc	w_i	Model Likelihood
	Local Models					
1	Elevation	1	162.22	84.05	0.000	0.0000
2	Elevation, Area of Em. Veg.	2	163.63	85.45	0.000	0.0000
3	Area of Em. Veg., Depth	2	198.76	120.59	0.000	0.0000
4	Area of Em. Veg.	1	196.71	118.54	0.000	0.0000
5	Local Core	3	165.57	87.40	0.000	0.0000
	Landscape Models					
6	% Aq	1	189.77	111.60	0.000	0.0000
7	% Aq, Distance occupied	2	101.27	23.09	0.000	0.0000
8	% Aq, % Open	2	169.84	91.66	0.000	0.0000
9	% Aq, % Open, Distance Forest, Forest Edge	4	156.91	78.73	0.000	0.0000
10	% Aq, Distance Forest, Distance occupied	3	88.97	10.80	0.002	0.0045
11	% Aq, % URB, % Open, Distance waterbody	4	171.13	92.95	0.000	0.0000
12	Distance Forest, Forest Edge, Distance occupied	3	88.36	10.19	0.003	0.0061
13	Distance Forest, % Open, Distance occupied	3	88.78	10.60	0.003	0.0050
14	% Aq, Forest Core, Distance Forest	3	179.00	100.83	0.000	0.0000
15	% Open, Distance Forest, % URB, Distance waterbody	4	173.71	95.53	0.000	0.0000
16	Landscape Core	8	92.79	14.62	0.000	0.0007
	Combination Models					
17	Elevation, % Aq, % Open	3	129.51	51.33	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	181.95	103.78	0.000	0.0000
19	Elevation, Depth, % Open, Distance Forest	4	138.84	60.66	0.000	0.0000
20	Area of Em. Veg., Depth, % Aq, % Open	4	172.97	94.80	0.000	0.0000
21	Elevation, Area of Em. Veg., % Open, Forest Core	4	130.57	52.40	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance occupied	4	78.17	0.00	0.544	1.0000
23	Elevation, Distance Forest, % Open, Distance occupied	4	78.67	0.50	0.424	0.7792
24	Area of Em. Veg., Depth, % Aq, % URB	4	195.76	117.59	0.000	0.0000
25	Elevation, % Open, Distance Forest, Distance waterbody	4	137.70	59.53	0.000	0.0000
26	Global	11	84.44	6.27	0.024	0.0435

Table B-15. *Pseudacris regilla* habitat models at 2,000 m.

Model #	Candidate Model	k	AIC$_c$	ΔAIC$_c$	w_i	Model Likelihood
	Local Models					
1	Elevation	1	162.22	85.59	0.000	0.0000
2	Elevation, Area of Em. Veg.	2	163.63	87.00	0.000	0.0000
3	Area of Em. Veg., Depth	2	198.76	122.13	0.000	0.0000
4	Area of Em. Veg.	1	196.71	120.08	0.000	0.0000
5	Local Core	3	165.57	88.94	0.000	0.0000
	Landscape Models					
6	% Aq	1	188.75	112.12	0.000	0.0000
7	% Aq, Distance occupied	2	101.41	24.78	0.000	0.0000
8	% Aq, % Open	2	168.01	91.37	0.000	0.0000
9	% Aq, % Open, Distance Forest, Forest Edge	4	139.51	62.88	0.000	0.0000
10	% Aq, Distance Forest, Distance occupied	3	88.68	12.05	0.001	0.0024
11	% Aq, % URB, % Open, Distance waterbody	4	170.02	93.39	0.000	0.0000
12	Distance Forest, Forest Edge, Distance occupied	3	87.26	10.63	0.003	0.0049
13	Distance Forest, % Open, Distance occupied	3	88.77	12.14	0.001	0.0023
14	% Aq, Forest Core, Distance Forest	3	177.67	101.04	0.000	0.0000
15	% Open, Distance Forest, % URB, Distance waterbody	4	173.39	96.76	0.000	0.0000
16	Landscape Core	8	86.89	10.25	0.003	0.0059
	Combination Models					
17	Elevation, % Aq, % Open	3	127.95	51.32	0.000	0.0000
18	Area of Em. Veg., Depth, % Aq, Distance Forest	4	179.68	103.05	0.000	0.0000
19	Elevation, Depth, % Open, Distance Forest	4	139.50	62.87	0.000	0.0000
20	Area of Em. Veg., Depth, % Aq, % Open	4	171.10	94.47	0.000	0.0000
21	Elevation, Area of Em. Veg., % Open, Forest Core	4	119.31	42.68	0.000	0.0000
22	Elevation, Distance Forest, Forest edge, Distance occupied	4	76.63	0.00	0.580	1.0000
23	Elevation, Distance Forest, % Open, Distance occupied	4	78.77	2.14	0.199	0.3435
24	Area of Em. Veg., Depth, % Aq, % URB	4	194.79	118.16	0.000	0.0000
25	Elevation, % Open, Distance Forest, Distance waterbody	4	138.61	61.98	0.000	0.0000
26	Global	11	78.64	2.01	0.212	0.3658

Table B-16. *Bufo woodhousii/ Pseudacris maculata* habitat models at 500 m.

Model #	Candidate Models	k	AIC_c	ΔAIC_c	w_i	Model Likelihood
	Local Models					
1	**Elevation**	1	69.42	7.94	0.011	0.0189
2	**Elevation**, Area of Em. Veg., SA	3	73.04	11.57	0.002	0.0031
3	Area of Em. Veg., Depth	2	144.56	83.08	0.000	0.0000
4	SA, Depth	2	148.77	87.30	0.000	0.0000
5	Local Core	4	71.52	10.05	0.004	0.0066
	Landscape Models					
6	% Aq	1	148.40	86.93	0.000	0.0000
7	% Aq, Distance occupied	2	111.21	49.74	0.000	0.0000
8	% Aq, % NG, Distance occupied	3	106.16	44.68	0.000	0.0000
9	% Aq, % NG, % AGT, Distance occupied	4	106.13	44.65	0.000	0.0000
10	% Aq, % NG, % URB, Distance waterbody	4	145.16	83.69	0.000	0.0000
11	% NG, Distance occupied	2	104.71	43.23	0.000	0.0000
12	% NG, % AGT	2	137.42	75.94	0.000	0.0000
13	% NG, % URB	2	142.89	81.42	0.000	0.0000
14	% AGT, Distance occupied	2	112.18	50.71	0.000	0.0000
15	% URB, Distance waterbody	2	147.83	86.36	0.000	0.0000
16	Landscape Core	6	91.04	29.56	0.000	0.0000
	Combination Models					
17	Elevation, % Aq, % NG, Distance occupied	4	61.48	0.00	0.560	1.0000
18	Elevation, Area of Em. Veg., % AGT, Distance occupied	4	72.13	10.65	0.003	0.0049
19	Area of Em. Veg., Depth, % Aq, % NG	4	142.78	81.30	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	139.26	77.78	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	151.78	90.30	0.000	0.0000
22	Area of Em. Veg., Depth, % AGT, Distance waterbody	4	137.84	76.36	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	68.46	6.99	0.017	0.0304
24	Elevation, Area of Em. Veg., % NG, Distance occupied	4	62.16	0.68	0.398	0.7103
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	144.94	83.47	0.000	0.0000
26	Global	10	70.34	8.86	0.007	0.0119

Table B-17. *Bufo woodhousii/ Pseudacris maculata* habitat models at 1,000 m.

Model #	Candidate Models	k	AIC_c	ΔAIC_c	w_i	Model Likelihood
	Local Models					
1	Elevation	1	69.42	10.46	0.003	0.0053
2	Elevation, Area of Em. Veg., SA	3	73.04	14.09	0.001	0.0009
3	Area of Em. Veg., Depth	2	144.56	85.61	0.000	0.0000
4	SA, Depth	2	148.77	89.82	0.000	0.0000
5	Local Core	4	71.52	12.57	0.001	0.0019
	Landscape Models					
6	% Aq	1	142.15	83.20	0.000	0.0000
7	% Aq, Distance occupied	2	107.11	48.15	0.000	0.0000
8	% Aq, % NG, Distance occupied	3	99.93	40.98	0.000	0.0000
9	% Aq, % NG, % AGT, Distance occupied	4	102.03	43.07	0.000	0.0000
10	% Aq, % NG, % URB, Distance waterbody	4	135.23	76.27	0.000	0.0000
11	% NG, Distance occupied	2	102.61	43.65	0.000	0.0000
12	% NG, % AGT	2	134.49	75.54	0.000	0.0000
13	% NG, % URB	2	138.30	79.35	0.000	0.0000
14	% AGT, Distance occupied	2	113.97	55.02	0.000	0.0000
15	% URB, Distance waterbody	2	148.73	89.78	0.000	0.0000
16	Landscape Core	6	86.86	27.91	0.000	0.0000
	Combination Models					
17	Elevation, % Aq, % NG, Distance occupied	4	58.95	0.00	0.595	1.0000
18	Elevation, Area of Em. Veg., % AGT, Distance occupied	4	72.13	13.18	0.001	0.0014
19	Area of Em. Veg., Depth, % Aq, % NG	4	133.62	74.67	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	136.41	77.46	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	145.93	86.97	0.000	0.0000
22	Area of Em. Veg., Depth, % AGT, Distance waterbody	4	141.45	82.50	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	66.16	7.20	0.016	0.0273
24	Elevation, Area of Em. Veg., % NG, Distance occupied	4	59.87	0.91	0.377	0.6338
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	146.49	87.54	0.000	0.0000
26	Global	10	68.05	9.10	0.006	0.0106

Table B-18. *Bufo woodhousii/ Pseudacris maculata* habitat models at 2,000 m.

Model #	Candidate Models	k	AIC_c	ΔAIC_c	w_i	Model Likelihood
	Local Models					
1	Elevation	1	69.42	22.48	0.000	0.0000
2	Elevation, Area of Em. Veg., SA	3	73.04	26.11	0.000	0.0000
3	Area of Em. Veg., Depth	2	144.56	97.62	0.000	0.0000
4	SA, Depth	2	148.77	101.84	0.000	0.0000
5	Local Core	4	71.52	24.59	0.000	0.0000
	Landscape Models					
6	% Aq	1	121.33	74.39	0.000	0.0000
7	% Aq, Distance occupied	2	87.72	40.79	0.000	0.0000
8	% Aq, % NG, Distance occupied	3	84.73	37.80	0.000	0.0000
9	% Aq, % NG, % AGT, Distance occupied	4	86.02	39.09	0.000	0.0000
10	% Aq, % NG, % URB, Distance waterbody	4	116.85	69.92	0.000	0.0000
11	% NG, Distance occupied	2	101.52	54.59	0.000	0.0000
12	% NG, % AGT	2	129.55	82.61	0.000	0.0000
13	% NG, % URB	2	133.17	86.24	0.000	0.0000
14	% AGT, Distance occupied	2	112.70	65.76	0.000	0.0000
15	% URB, Distance waterbody	2	145.37	98.44	0.000	0.0000
16	Landscape Core	6	66.84	19.91	0.000	0.0000
	Combination Models					
17	Elevation, % Aq, % NG, Distance occupied	4	46.93	0.00	0.978	1.0000
18	Elevation, Area of Em. Veg., % AGT, Distance occupied	4	71.56	24.62	0.000	0.0000
19	Area of Em. Veg., Depth, % Aq, % NG	4	116.85	69.92	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	130.84	83.91	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	125.35	78.42	0.000	0.0000
22	Area of Em. Veg., Depth, % AGT, Distance waterbody	4	140.01	93.07	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	133.06	86.12	0.000	0.0000
24	Elevation, Area of Em. Veg., % NG, Distance occupied	4	58.45	11.51	0.003	0.0032
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	143.13	96.20	0.000	0.0000
26	Global	10	54.81	7.88	0.019	0.0195

Table B-19. *Rana pipiens* habitat models at 500 m.

Model #	Candidate Models	k	AICc	ΔAICc	w_i	Model Likelihood
	Local Models					
1	Elevation	1	44.47	21.37	0.000	0.0000
2	Elevation, Area of Em. Veg., SA	3	46.68	23.58	0.000	0.0000
3	Area of Em. Veg., SA, Depth	3	79.06	55.95	0.000	0.0000
4	SA, Depth	2	86.30	63.20	0.000	0.0000
5	Local Core	4	47.35	24.25	0.000	0.0000
	Landscape Models					
6	% Aq	1	77.99	54.89	0.000	0.0000
7	% Aq, Distance occupied	2	44.87	21.77	0.000	0.0000
8	% Aq, % NG, Distance occupied	3	35.98	12.88	0.001	0.0016
9	% Aq, % NG, % AGT, Distance occupied	4	37.96	14.86	0.000	0.0006
10	% Aq, % NG, % URB, Distance waterbody	4	69.41	46.31	0.000	0.0000
11	% NG, Distance occupied	2	37.80	14.69	0.000	0.0006
12	% NG, % AGT	2	70.48	47.38	0.000	0.0000
13	% NG, % URB	2	70.31	47.21	0.000	0.0000
14	% AGT, Distance occupied	2	52.80	29.70	0.000	0.0000
15	% URB, Distance waterbody	2	80.35	57.24	0.000	0.0000
16	Landscape Core	6	39.00	15.89	0.000	0.0004
	Combination Models					
17	Elevation, % Aq, % NG, Distance occupied	4	25.69	2.59	0.167	0.2739
18	Elevation, Area of Em. Veg., % AGT, Distance occupied	4	43.59	20.48	0.000	0.0000
19	Area of Em. Veg., Depth, % Aq, % NG	4	64.09	40.98	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	73.35	50.25	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	81.90	58.80	0.000	0.0000
22	Area of Em. Veg., Depth, % AGT, Distance waterbody	4	69.51	46.41	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	25.12	2.02	0.222	0.3644
24	Elevation, Area of Em. Veg., % NG, Distance occupied	4	23.10	0.00	0.609	1.0000
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	72.53	49.43	0.000	0.0000
26	Global	10	37.28	14.17	0.001	0.0008

Table B-20. *Rana pipiens* habitat models at 1,000 m.

Model #	Candidate Models	k	AIC_c	ΔAIC_c	w_i	Model Likelihood
	Local Models					
1	Elevation	1	44.47	35.74	0.000	0.0000
2	Elevation, Area of Em. Veg., SA	3	46.68	37.95	0.000	0.0000
3	Area of Em. Veg., SA, Depth	3	79.06	70.33	0.000	0.0000
4	SA, Depth	2	86.30	77.58	0.000	0.0000
5	Local Core	4	47.35	38.62	0.000	0.0000
	Landscape Models					
6	% Aq	1	73.09	64.36	0.000	0.0000
7	% Aq, Distance occupied	2	43.49	34.76	0.000	0.0000
8	% Aq, % NG, Distance occupied	3	30.47	21.75	0.000	0.0000
9	% Aq, % NG, % AGT, Distance occupied	4	32.77	24.04	0.000	0.0000
10	% Aq, % NG, % URB, Distance waterbody	4	58.61	49.89	0.000	0.0000
11	% NG, Distance occupied	2	37.90	29.18	0.000	0.0000
12	% NG, % AGT	2	63.96	55.24	0.000	0.0000
13	% NG, % URB	2	63.66	54.93	0.000	0.0000
14	% AGT, Distance occupied	2	53.08	44.35	0.000	0.0000
15	% URB, Distance waterbody	2	82.37	73.64	0.000	0.0000
16	Landscape Core	6	31.33	22.60	0.000	0.0000
	Combination Models					
17	Elevation, % Aq, % NG, Distance occupied	4	8.73	0.00	0.995	1.0000
18	Elevation, Area of Em. Veg., % AGT, Distance occupied	4	43.23	34.51	0.000	0.0000
19	Area of Em. Veg., Depth, % Aq, % NG	4	49.84	41.11	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	66.83	58.10	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	77.22	68.50	0.000	0.0000
22	Area of Em. Veg., Depth, % AGT, Distance waterbody	4	74.28	65.56	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	21.61	12.88	0.002	0.0016
24	Elevation, Area of Em. Veg., % NG, Distance occupied	4	20.66	11.93	0.003	0.0026
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	77.07	68.34	0.000	0.0000
26	Global	10	24.49	15.76	0.000	0.0004

Table B-21. *Rana pipiens* habitat models at 2,000 m.

Model #	Candidate Models	k	AIC_c	ΔAIC_c	w_i	Model Likelihood
	Local Models					
1	Elevation	1	44.47	35.74	0.000	0.0000
2	Elevation, Area of Em. Veg., SA	3	46.68	37.95	0.000	0.0000
3	Area of Em. Veg., SA, Depth	3	79.06	70.33	0.000	0.0000
4	SA, Depth	2	86.30	77.58	0.000	0.0000
5	Local Core	4	47.35	38.62	0.000	0.0000
	Landscape Models					
6	% Aq	1	49.28	40.56	0.000	0.0000
7	% Aq, Distance occupied	2	23.41	14.68	0.000	0.0006
8	% Aq, % NG, Distance occupied	3	24.35	15.62	0.000	0.0004
9	% Aq, % NG, % AGT, Distance occupied	4	25.85	17.12	0.000	0.0002
10	% Aq, % NG, % URB, Distance waterbody	4	46.36	37.64	0.000	0.0000
11	% NG, Distance occupied	2	36.67	27.94	0.000	0.0000
12	% NG, % AGT	2	64.78	56.05	0.000	0.0000
13	% NG, % URB	2	63.38	54.66	0.000	0.0000
14	% AGT, Distance occupied	2	53.02	44.29	0.000	0.0000
15	% URB, Distance waterbody	2	80.67	71.94	0.000	0.0000
16	Landscape Core	6	13.58	4.86	0.029	0.0881
	Combination Models					
17	Elevation, % Aq, % NG, Distance occupied	4	8.73	0.00	0.324	1.0000
18	Elevation, Area of Em. Veg., % AGT, Distance occupied	4	42.92	34.19	0.000	0.0000
19	Area of Em. Veg., Depth, % Aq, % NG	4	37.67	28.94	0.000	0.0000
20	SA, Depth, % NG, % AGT	4	67.92	59.20	0.000	0.0000
21	SA, Depth, % Aq, % URB	4	50.14	41.41	0.000	0.0000
22	Area of Em. Veg., Depth, % AGT, Distance waterbody	4	76.08	67.36	0.000	0.0000
23	Elevation, Area of Em. Veg., % NG, Distance waterbody	4	8.73	0.00	0.324	1.0000
24	Elevation, Area of Em. Veg., % NG, Distance occupied	4	8.73	0.01	0.323	0.9970
25	Area of Em. Veg., SA, Depth, Distance waterbody	4	77.07	68.34	0.000	0.0000
26	Global	10	24.49	15.76	0.000	0.0004

APPENDIX C - Model Validation Results

Ambystoma macrodactylum

Table C-1. Validation at 500 m

Model # 8

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	134	138	49%
Present	281	30	90%

Rate of Commission = 71%
Rate of Ommission = 29%
Rate of Positive Commission = 90%
Positive Ratio = 1.107

Model #15

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	133	139	49%
Present	283	28	91%

Rate of Commission = 71%
Rate of Ommission = 29%
Rate of Positive Commission = 91%
Positive Ratio = 1.10

Model #16

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	143	129	53%
Present	281	30	90%

Rate of Commission = 73%
Rate of Ommission = 27%
Rate of Positive Commission = 90%
Positive Ratio = 1.106

Table C-2. Validation at 1,000 m.

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	175	92	66%
Present	295	15	95%

Rate of Commission = 82%
Rate of Ommission = 19%
Rate of Positive Commission = 95%
Positive Ratio = 1.05

Table C-3. Validation at 2,000 m.

Model #16

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	146	121	55%
Present	281	29	91%

Rate of Commission = 74%
Rate of Ommission = 26%
Rate of Positive Commission = 91%
Positive Ratio = 1.10

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	153	114	57%
Present	282	28	91%

Rate of Commission = 75%
Rate of Ommission = 25%
Rate of Positive Commission = 91%
Positive Ratio = 1.10

Ambystoma tigrinum (West)

Table C-4. Validation at 500 m.

Model # 14

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	75	10	88%
Present	29	3	91%

Rate of Commission = 89%
Rate of Ommission = 11%
Rate of Positive Commission = 91%
Positive Ratio = 2.1

Model #13

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	74	11	87%
Present	29	3	91%

Rate of Commission = 88%
Rate of Ommission = 12%
Rate of Positive Commission = 91%
Positive Ratio = 2.1

Model #15

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	78	7	92%
Present	29	3	91%

Rate of Commission = 91%
Rate of Ommission = 8%
Rate of Positive Commission = 91%
Positive Ratio = 2.1

Model #8

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	77	8	91%
Present	29	3	91%

Rate of Commission = 91%
Rate of Ommission = 9%
Rate of Positive Commission = 91%
Positive Ratio = 2.1

Model #24

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	75	10	88%
Present	30	2	94%

Rate of Commission = 90%
Rate of Ommission = 10%
Rate of Positive Commission = 94%
Positive Ratio = 2.06

Model #16

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	75	10	88%
Present	30	2	94%

Rate of Commission = 90%
Rate of Ommission = 10%
Rate of Positive Commission = 94%
Positive Ratio = 2.06

Table C-5. Validation at 1,000 m.

Model #16

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	82	3	97%
Present	29	3	91%

Rate of Commission = 95%
Rate of Ommission = 5%
Rate of Positive Commission = 91%
Positive Ratio = 1.10

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	82	3	97%
Present	28	4	91%

Rate of Commission = 94%
Rate of Ommission = 6%
Rate of Positive Commission = 91%
Positive Ratio = 1.14

Model #14

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	79	6	93%
Present	28	4	88%

Rate of Commission = 89%
Rate of Ommission = 11%
Rate of Positive Commission = 94%
Positive Ratio = 1.14

Table C-6. Validation at 2,000 m.

Model #14

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	74	11	87%
Present	30	2	94%

Rate of Commission = 89%
Rate of Ommission = 11%
Rate of Positive Commission = 94%
Positive Ratio = 1.06

Model #13

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	74	11	87%
Present	29	3	91%

Rate of Commission = 88%
Rate of Ommission = 12%
Rate of Positive Commission = 91%
Positive Ratio = 1.10

Model #16

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	83	2	98%
Present	28	4	88%

Rate of Commission = 95%
Rate of Ommission = 5%
Rate of Positive Commission = 88%
Positive Ratio = 1.14

Model #15

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	75	10	88%
Present	28	4	88%

Rate of Commission = 88%
Rate of Ommission = 12%
Rate of Positive Commission = 91%
Positive Ratio = 1.14

Model #8

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	74	11	87%
Present	29	3	91%

Rate of Commission = 88%
Rate of Ommission = 12%
Rate of Positive Commission = 91%
Positive Ratio = 1.10

Model #24

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	75	10	88%
Present	29	3	91%

Rate of Commission = 89%
Rate of Ommission = 11%
Rate of Positive Commission = 91%
Positive Ratio = 1.10

Ambystoma tigrinum (East)

Table C-7. Validation at 500 m.

Model # 2

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #1

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	24	2	92%
Present	66	1	99%

Rate of Commission = 97%
Rate of Ommission = 3%
Rate of Positive Commission = 93%
Positive Ratio = 1.02

Model #5

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #23

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #18

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	25	1	96%
Present	67	0	100%

Rate of Commission = 99%
Rate of Ommission = 1%
Rate of Positive Commission = 100%
Positive Ratio = 1

Table C-8. Validation at 1,000 m.

Model #2

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #1

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	24	2	92%
Present	66	1	99%

Rate of Commission = 97%
Rate of Ommission = 3%
Rate of Positive Commission = 99%
Positive Ratio = 1.01

Model #5

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #23

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #18

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Table C-9. Validation at 2,000 m.

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #2

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #18

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #1

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	24	2	92%
Present	66	1	99%

Rate of Commission = 97%
Rate of Ommission = 3%
Rate of Positive Commission = 93%
Positive Ratio = 1.02

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #23

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #5

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	26	0	100%
Present	67	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Bufo boreas/ Rana luteiventris

Table C-10. Validation at 500 m.

Model #8

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	28	16	64%
Present	29	11	73%

Rate of Commission = 68%

Rate of Ommission = 32%

Rate of Positive Commission = 73%

Positive Ratio = 1.5

Model #16

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	25	19	57%
Present	35	5	88%

Rate of Commission = 71%

Rate of Ommission = 29%

Rate of Positive Commission = 88%

Positive Ratio = 1.5

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	18	59%
Present	32	8	80%

Rate of Commission = 69%

Rate of Ommission = 31%

Rate of Positive Commission = 80%

Positive Ratio = 1.6

Table C-11. Validation at 1,000 m.

Model #8

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	24	19	56%
Present	29	12	71%

Rate of Commission = 63%

Rate of Ommission = 37%

Rate of Positive Commission = 71%

Positive Ratio = 1.6

Model #16

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	27	16	63%
Present	35	6	85%

Rate of Commission = 74%
Rate of Ommission = 26%
Rate of Positive Commission = 85%
Positive Ratio = 1.5

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	30	13	70%
Present	31	10	76%

Rate of Commission = 73%
Rate of Ommission = 27%
Rate of Positive Commission = 76%
Positive Ratio = 1.4

Table C-12. Validation at 2,000 m.

Model #8

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	23	19	55%
Present	24	16	60%

Rate of Commission = 57%
Rate of Ommission = 43%
Rate of Positive Commission = 60%
Positive Ratio = 1.8

Model #16

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	22	20	52%
Present	31	9	78%

Rate of Commission = 65%
Rate of Ommission = 35%
Rate of Positive Commission = 78%
Positive Ratio = 1.6

Pseudacris regilla

Table C-13. Validation at 500 m.

Model #22

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	13	0	100%
Present	6	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #23

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	13	0	100%
Present	6	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	13	0	100%
Present	6	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Table C-14. Validation at 1,000 m.

Model #22

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	13	0	100%
Present	6	0	100%

Rate of Commission = 98%
Rate of Ommission = 2%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #23

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	13	0	100%
Present	6	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	13	0	100%
Present	6	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Table C-15. Validation at 2,000 m.

Model #22

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	13	0	100%
Present	6	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #23

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	12	1	92%
Present	6	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #26

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	13	0	100%
Present	6	0	100%

Rate of Commission = 100%
Rate of Ommission = 0%
Rate of Positive Commission = 100%
Positive Ratio = 1

Bufo woodhousii/Pseudacris maculata

Table C-16. Validation at 500 m.

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	27	1	96%
Present	126	1	99%

Rate of Commission = 99%

Rate of Ommission = 1%

Rate of Positive Commission = 99%

Positive Ratio = 1

Model #24

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	27	1	96%
Present	127	0	100%

Rate of Commission = 99%

Rate of Ommission = 1%

Rate of Positive Commission = 96%

Positive Ratio = 1

Table C-17. Validation at 1,000 m.

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	1	96%
Present	125	1	99%

Rate of Commission = 99%

Rate of Ommission = 1%

Rate of Positive Commission = 99%

Positive Ratio = 1

Model #24

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	1	96%
Present	126	0	100%

Rate of Commission = 99%
Rate of Ommission = 1%
Rate of Positive Commission = 100%
Positive Ratio = 1

Table C-18. Validation at 2,000 m.

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	2	93%
Present	124	1	99%

Rate of Commission = 98%
Rate of Ommission = 2%
Rate of Positive Commission = 99%
Positive Ratio = 1

Rana Pipiens

Table C-19. Validation at 500 m.

Model #24

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	1	96%
Present	33	0	100%

Rate of Commission = 98%
Rate of Ommission = 2%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #23

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	26	1	96%
Present	33	0	100%

Rate of Commission = 98%
Rate of Ommission = 2%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
500 Meters			
Absent	24	3	89%
Present	30	0	100%

Rate of Commission = 95%
Rate of Ommission = 5%
Rate of Positive Commission = 100%
Positive Ratio = 1

Table C-20. Validation at 1,000 m.

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
1000 Meters			
Absent	24	3	89%
Present	30	0	100%

Rate of Commission = 95%
Rate of Ommission = 5%
Rate of Positive Commission = 100%
Positive Ratio = 1

Table C-21. Validation at 2,000 m.

Model #24

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	26	1	96%
Present	33	0	100%

Rate of Commission = 98%
Rate of Ommission = 2%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #23

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	26	1	96%
Present	33	0	100%

Rate of Commission = 98%
Rate of Ommission = 2%
Rate of Positive Commission = 100%
Positive Ratio = 1

Model #17

Occupancy	*# Correct*	*# Incorrect*	*% Correct*
2000 Meters			
Absent	24	3	89%
Present	30	0	100%

Rate of Commission = 95%
Rate of Ommission = 5%
Rate of Positive Commission = 100%
Positive Ratio = 1