PREDICTING HABITAT SUITABILITY AND OCCURRENCE FOR BLANCHARD'S CRICKET FROGS (ACRIS CREPITANTS BLANCHARDI) IN NORTHWEST, OHIO

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ABSTRACT

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The cricket frog, a declining species in Northwest Ohio, has been identified as the amphibian species of greatest concern in the Midwest. A challenging task is to develop effective conservation strategies to address these declines. One successful approach uses predictive habitat models that can be readily verified and refined. The main objectives of this research were: (1) characterize the habitat where the cricket frogs are found, and (2) develop and test a model to predict occurrence of cricket frogs based on habitat suitability. I identified 13 ponds in Wood County using aerial photographs and surveyed them in 2003. Local variables were measured for each pond. Landscape variables were extracted from Geographic Information Systems data. This research applied stepwise regression and Wilcoxon signed rank sum to the data to predict occurrence and test for statistical differences among variables. Results indicate some local variables are important (temperature and vegetation) for the occurrence of cricket frogs, but they are not definitive. Some of the landscape variables were also significant for their occurrence (e.g. distance to the nearest pond). This thesis emphasizes the importance of local and large scale factors in identifying habitat for cricket frogs. The increase in the knowledge of the cricket frog's ecology is essential considering that populations of cricket frogs in the north part of their range are declining rapidly. Findings from this study will help identify suitable areas for cricket frogs and increase our understanding of the ecology of the species.

To the memory of my father Paulino Martinez-Mendoza a good friend and example in my life.

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INTRODUCTION

Background

In February 1990, at Irvine, California, a group of scientists organized a workshop to discuss concerns about possible declining populations of amphibians around the world (Wake 1990). The results indicated widespread local and global population declines, home range contractions, and even extinctions. They were concerned about reports of extinctions not only in areas impacted by humans but also in undisturbed habitats. Extinctions are considered a natural biological phenomenon, but the rate of extinctions in amphibians has increased drastically in the past two decades (Blaustein et al. 1994). These concerns lead to the formation of the Declining Amphibian Population Task Force (DAPTF) in 1991, including the states of Illinois, Indiana, Iowa, Missouri, and Ohio. The central objectives of the DAPTF are: (1) to determine the nature, extent and causes of declines of amphibians, (2) and to promote means by which declines can be halted or reversed (Davis and Menze 2002, http://www.open.ac.uk/daptf/index.htm). The exact reasons of amphibian declines around the world are not yet entirely understood.

Local habitat factors (e. g. vegetation, pH, temperature, interspecific interactions, etc.) influence the distribution and abundance of amphibian populations; however, a landscape scale approach is essential for understanding potential global effects (Pope et al. 2000). Habitat loss and fragmentation (Lehtinen et al. 1999, Debinski and Holt 2000, Bradford et al. 2003, Joly 2003, Pope et al. 2000, Rustigian et al. 2003, Weyrauch and Grubb 2003), ultraviolet radiation and predation (Alford and Richards 1999, Blaustein and Johnson 2003), acidity and toxicants (Alford and Richards 1999), introduced invasive species, environmental pollution (Russell 2002, Royte 2003), disease and parasitism (Mazzoni 2003), unsustainable land use, and global climate change are some of the potential factors affecting distribution and abundance of amphibians and reptiles worldwide. All of these factors may have impacts on species occurrence, distribution and vitality. Amphibian populations, specifically in the Midwest, have experienced changes from anthropogenic activities.

For example, habitat loss or alteration is widespread in the heavily agricultural and industrial Midwest and is undoubtedly the predominant cause of amphibian declines (Leja 1998). In Ohio, the principal pressure on native species includes habitat loss, habitat degradation of terrestrial and aquatic habitat, and the introduction of exotic species. Prior to settlement, Ohio was 95 percent forested and had a diversity of wetland habitats, mostly throughout the glaciated portions of the state. Ohio has lost 90 percent of its wetlands habitat since 1900, primarily due to agricultural draining and commercial, residential and road development (Environmental Law Institute 1998).

In the Midwest, amphibian numbers have declined with Euro-American settlement and the conversion of natural habitats to landscape dominated by agriculture (Lannoo 1998). Wetlands have been extensively drained for agriculture and residential development reducing species richness and diversity in amphibians (Brodman and Kilmurry 1998). Large-scale changes in habitat may be also partially responsible for changes in species abundance (Brodman et al. 2002). According to the first amphibian survey conducted by Frank Blanchard (1923) in Dickinson County, Iowa, seven species were found; among them, cricket frogs (***Acris crepitans***) were common but not abundant. Seventy years later, Michael Lannoo conducted another survey and found that five species persisted and two species were not found. One of the species reported absent was the cricket frog (Lannoo 1994). The Blanchard's cricket frog (***Acris crepitans blanchardi***), shown in figure 1, is the species of most concern in the Midwest. Extirpated across much of the upper Midwest, and apparently still declining at the northern borders of their current distribution, we have not been able to establish a cause-and-effect relationship between any environmental factor and cricket frog declines (Lannoo 1998).

Species Description

Blanchard's cricket frog, ***Acris crepitans blanchardi,*** is one of the smallest (adults vary in length from 1.6 to 3.8 centimeters and females are usually larger than males) frogs in Ohio and is characterized by a dark triangle between the eyes and a weakly set of defined dark stripes along the rear of its thigh. Cricket frogs have rough and warty skin and a rounded snout. Usually, they are brown, gray, olive green, or yellow with a white to yellow belly. The cricket frog is a member of the order Anura and a non-scansorial species of the tree frog family ***Hylidae***. There are three subspecies of the cricket frogs: Blanchard's Cricket Frog (***Acris crepitans blanchardi***), Eastern Cricket Frog (***Acris crepitans crepitans***), and Coastal Cricket Frog (***Acris crepitans paludicola***) (Gray et al. 2003, http://herpcenter.ipfw.edu). ***Acris crepitans blanchardi*** is named after Frank Nelson Blanchard, a professor and herpetologist at the University of Michigan, who published, in 1923, the first description of this species. The name "cricket frog" results from its characteristic call, which, consists of a fast metallic clicking similar to the sound of marbles hitting together. The calling starts slowly but then rapidly increases in rhythm. This characteristic provides an excellent means for identifying this species in its native habitat.

Ecology

During the winter (late November to late March), these organisms use natural depressions, holes, cracks, crayfish burrows and they bury themselves in the mud beneath shoreline away from water to hibernate (Gray 1971, Irwin et al. 1999). Cricket frogs emerge from hibernation in late March to early April when the air temperature increases to at least 10°C (Brenner 1969) and breed from mid-to-late May through early July in the Great Lakes region (Harding 1997). During the breeding season calls are heard during day and night and males sit on floating aquatic vegetation (e.g., floating algae mats and lily leafs) or next to the shoreline. Male frogs call to attract females and to maintain an individual's calling space (Perrill and Shepherd 1989, Burmeister et al. 1999). Female preference is biased by higher sound intensity, call rate, and lower dominant frequency (Ryan et al. 1992, Perrill and Lower 1994). Females are clasped in axillary amplexus by calling males (Gray 1983). Amplexus and egg-laying occur in warm shallows close to the calling sites (Harding 1997). Females can lay up to 400 eggs singly or in small clusters, which are attached to submerged vegetation or twigs (Wright and Wright 1949, Harding 1997). Eggs hatch within a few days and metamorphosis occur in late summer.

The average life span of an adult in wild populations is about four months and an annual turnover of the total population in 16 months (Burkett 1984). They generally survive only one breeding season and infrequently more than two seasons with only one class age represented in the population (Burkett 1984, Harding 1997). However, individuals in captivity can reach up to five years (http://herpcenter.ipfw.edu).

The cricket frog diet consists mainly of terrestrial organisms including annelids, mollusks, spiders, and various insects (e.g., larvae and beetles) and they feed throughout day and night. Food consumption is correlated with the organism body size, gender, and reproductive status (Johnson and Christiansen 1976). Predators include fish, snakes, turtles, other amphibians (e.g., American bullfrogs), birds, and small mammals.

Cricket frogs are usually found in a variety of semi- aquatic habitats. The breeding habitat consists of semi-permanent and permanent wetlands, creeks, streams, and rivers while the adult habitat is terrestrial and semi-aquatic. They inhabit muddy or sandy, flat, sunny, and sparsely vegetated areas along shorelines of ponds, lakes, gravel pits, and slow-moving streams and rivers (Harding 1997). Emergent aquatic vegetation or a thick mat of algae near the water's edge is ideal, as shown in Figures 2 and 3. Temporary pools might be inhabited, but only if large permanent bodies of water are nearby (Davis and Menze 2002). Most habitats are canopy free and receive sunlight for most, if not all, of the day (Davis and Menze 2002). In Michigan, the most well-known sites are reported adjacent to body waters that have an alkaline pH (http://web4.sue.msu.edu/mnfi/abstracts/zoology/acris_crepitans_blachardi.pdf).

Permanent water is vital for this species and usually they do not disperse too far away from the surrounding area. During and subsequent to rain periods, dispersion occurs in all directions and the distance of the movements range between 8 m to 100 m or more, with an average between 19 and 25 m. (Burkett 1984). Dispersal is affected by several factors: including rain, humidity, temperature, breeding activity, distance, and habitat conditions (Burkett 1984). Ecological requirements oblige these frogs to remain next to water bodies during drought or dry periods (Ralin and Rogers 1972, http://herpcenter.ipfw.edu). Cricket frogs are diurnal in spring and fall but are active during the day and night in warmer climate (Green and Paul 1987).

Distribution

The historical distribution of Blanchard's cricket frog in The United States has a broad range extending from western Ohio, Southern Michigan, Wisconsin, Minnesota, and southern South Dakota to eastern Colorado through Texas (Figure 4). The current Ohio cricket frog distribution occurs in the west part of the state and appears to be more common in southwestern Ohio than in other parts of the state (Figure 5). During late 1970's and early 1980's, many populations in Michigan and The Great Lakes declined considerably or vanished. Declines in Southern Ohio have not been reported, but there are indications that Blanchard's Cricket Frog is becoming less common in the northwestern corner of the state (Lipps 2000, Davis and Menze 2002).

Status and Conservation

Drastic declines of Blanchard's cricket frogs in the northern portion of its historical range have been reported. This species is listed as an endangered species in Wisconsin (Hay 1998) and Minnesota. In Michigan, Indiana, Ohio and West Virginia it is reported as a species of special concern. In northern Ohio the species appears to be less abundant and declining (Lipps 2000). Possible reasons for these declines include habitat loss, pesticides, and competition with other species. An increasing number of natural wetlands have been converted primarily to aquaculture or agriculture, and as a result, amphibian populations will likely continue to decrease. Habitat modification is caused by the alteration of natural stream channels, through elimination and degradation of riparian vegetation, channelization, other drainage activities, and by stream bank erosion (Environmental Law Institute 1998). Agricultural activities and suburban development are two of the major sources of habitat modification in Ohio (Rankin et al. in Environmental Law Institute 1998).

The decline in amphibian populations is a critical issue because they play an important role in ecosystems. They live on the edge between water and land, have semi-permeable skin, and are very sensitive to pollution and environmental changes. In addition, they can be used as indicator species because they are vulnerable to changes in the atmosphere, the land, or the water.

Geographical Information Systems

Increasingly, Geographic Information Systems (GIS) is a powerful tool used for decision-making and applied land management, allowing land to be selected for management and conservation according to the relative importance of different data. The application of GIS in natural resource management organizations has become commonplace during the past 10 years (Bettinger and Wing 2004). For example, among the multiple uses of GIS, maps are necessary for environmental and conservation agencies to set priorities for forest harvest plans, pesticide plans, human development plans and fertilization projects with limited budget and time. In contrast to conventional maps which require several days to be completed, GIS technology allows map production in large scales in a short period of time. More recently, GIS has been used for collecting, surveying, and analyzing landscape changes that are vital for conservation purposes. Constant advances in GIS software and hardware makes this approach more efficient (Bettinger and Wing 2004). For these reasons, GIS is an excellent tool for examining habitat suitability for cricket frogs and potential environmental factors that may influence it.

The use of models is also becoming an important tool in ecology in order to identify problems, concepts, processes, key elements, and most importantly, to provide predictions. The role of models is crucial in guiding further study or making predictions and decisions concerning complex systems, therefore, they deserve testing that should be viewed as never-ending process or calibration (Garshelis 2000). A wide array of models has been developed to cover aspects as diverse as biogeography, conservation biology, climate change research, and habitat or species management (Guisan and Zimmermann 2000).

Levins (1966) formulated a categorization of models based on their fundamental properties, which illustrates the basic tradeoffs among reality, precision and generality (Figure 6). Most models represent a compromise among these properties that best suits the question of interest. For example, the development of a model that predicts the habitat for a species may be very realistic but not broadly applicable across a variety of areas, or very general but lacking in precision.

One successful approach in ecology combines GIS data and field data to build predictive habitat suitability models that can be readily verified and refined. A suitability model suggests which habitat conditions are required for a species to occur (presence or absence), what conditions are required to sustain high densities of individuals, or to maintain the species viable for a given number of years. Habitat suitability maps are used routinely for making decisions on land management practices, and for guiding decisions in habitat conservation initiatives such as identifying reintroduction sites for endangered species (e.g., Lancia et al. 1982, Breininger et al. 1998, Pereira and Itami 1990).

For these reasons, it is important to study species such as the cricket frog using GIS and models, to learn more about the habitats they use. This research uses GIS technology with available digital data for cricket frog habitat analysis and predictive model development. For this research local variables are defined as the abiotic characteristics within the pond which are critical for distribution and occurrence of frogs (e.g., pH and vegetation). The landscape variables are defined as the characteristics of the pond and its relationship with the surrounding area that are crucial for distribution and occurrence of frogs (e.g., streams and ditches). The use of local and landscape variables are important in order to establish the characteristics that affect occurrence and distribution of cricket frogs in Northwest Ohio. The main objectives of this research were (1) to distinguish where the cricket frogs are currently found, (2) to describe the local and landscape features and potential cricket frog habitat, (3) to develop a model to predict potential habitat suitability for cricket frogs in Wood County, Ohio and (4) suggest recommendations for preserving and restoring suitable areas for cricket frogs.

The findings of this study should aid in the effort to identify suitable areas or those that could be restored for cricket frogs and will give us a better understanding of the ecology of this species. The approach of combining GIS with predictive models of habitat suitability is likely to be useful for other amphibian species.

OBJECTIVES

1. Identify where the cricket frogs are found in Wood County, Ohio.
2. Describe the critical local and landscape features for the cricket frog.
3. Develop a model to predict potential habitat suitability and occurrence for cricket frogs in Wood County, Ohio.
4. Suggest recommendations for managing and restore suitable areas for cricket frogs.

MATERIALS AND METHODS

The methodology employed to test the research objectives was based on the use of GIS tools and habitat features to characterize habitat of cricket frogs. Cricket frogs are found along the shoreline of aquatic habitats with solar exposure and most commonly in water bodies with sparsely emergent vegetation. Streams and ditches are important because they are believed to be used as dispersal corridors. The presence of these features and other habitat characteristics are strongly important for locating possible habitat for this species.

Study Area and Description

All the ponds are located in the Huron-Erie Lake Plain (HELP) ecoregion, characterized by muddy soils and reduced drainage which is a remnant of the former Great Black Swamp (Environmental Law Institute 1998). A total of 13 ponds were selected for this research. The study areas were selected in Wood County, which is located in the northwest corner of Ohio State. Figure 7 shows the location of all selected ponds. The first seven ponds (Seven eagles, Wapakoneta, Wapakoneta 2, Intersection, 6a, 6b, and 6c) are in an area, that is 4,430,578.53 square meters in size, in the northwest part of Wood County in Grand Rapids (Figure 8). The second set of ponds is located in Bowling Green Township and includes four ponds (Tech pond, Rec1, Rec2, and Golf pond) in an area that is 1,136,564.49 square meters in size, located in the central part of Wood County (Figure 9). The third set of ponds is in an area that is 726,295.13 square meters size, in the southern part of Wood County in Henry Township, and includes the last two ponds (Figure 9).

The study ponds were identified between May through August 2003 by a combination of expert opinion (based on their historical known populations from a published report in Lipps 2000), calling surveys, and analyzing aerial photographs from 1998 and 2002 of Wood County for likely habitat sites for cricket frogs. Thirteen ponds were identified in the field and each location was recorded with a Garmin eTrex Vista Global Positioning System (GPS) unit.

The study was conducted from July to September, 2003 with two sampling periods at each site. Each pond was sample twice, the first time at the end of July (29) and the second time at the end of September (30). All of the sites were located on a private property, except for one site in Henry Township, which was purchased recently (2002) by the Ohio Metro parks. In order to survey each site, I had to ask for permission prior to the sampling period. The fact that all the ponds were on private property was an obstacle for increasing in the number of areas to sample. I measured a number of local and landscape variables, shown in Table 1.

Local Variables

Habitat characteristics were estimated using local variables including pH and temperature of the water, slope (i.e. inclination of the shoreline), vegetation cover in water, vegetation cover in ground, and presence/absence of cricket frogs. For this research local variables are defined as the abiotic characteristics within the pond which are critical for distribution and occurrence of frogs (e.g., pH and vegetation). In each pond I marked ten points (sampling points) at equal distance along the shoreline, which was recorded using surveys and a GPS unit. The pH and temperature of the water were measured to the nearest tenth and recorded with a portable Oakton Acorn waterproof meter at every sampling point within a pond as shown in Figure 11. I measured the slope, within one meter of the water's edge, with a fabricated device with two meter sticks, a level, and a piece of string to the nearest half centimeter (Figure 12). Vegetation cover in water and ground was measured as percentage covered, with one meter by one meter grid as shown in Figure 13. In every sampling point I recorded presence/absence of cricket frogs. All the collected data in the field were compiled in Microsoft Excel spreadsheet for subsequent analysis.

Landscape Variables

For the GIS data, landscape variables were measured to characterize habitat of ***Acris crepitans blanchardi***. Streams, rivers, roads, wetlands, vegetation, urban centers, and land use were extracted from TIGER files (Ohio State Plan Coordinate System 1983). The landscape variables are defined as the characteristics of the pond and its relationship with the surrounding area that are crucial for distribution and occurrence of frogs (e.g., streams and ditches).Ohio Wetland Survey data was obtained for this area from http://www.ohiodnr.com.gims/. Landscape variables were selected because their importance for the occurrence of cricket frogs. These were streams and rivers, roads, and presence of a water body. All the ponds were analyzed for seven landscape variables including: distance to the nearest pond with cricket frogs (presence), distance to the nearest pond without cricket frogs (absence), distance to the nearest road, distance to the nearest ditch, and distance to the nearest stream. Measurements were made, to the nearest meter between the nearest edges, using the measurement command in ESRI ArcView GIS 3.3 using the GIS layers overlayed on an aerial photograph of Wood County. All these variables were generated from stream, road, and ponds coverages.

Statistical Analysis

In order to evaluate the variables measured in this study, I applied stepwise regression to the local and landscape variables; logistic regression was selected because the dependent variable, presence of frogs has only two (binomial) possible values. The Wilcoxon signed rank sum test was used to test the statistical difference between presence/absence of frogs for a specific local or landscape variable. Using the PROC logistic and Wilcoxon procedures to determine the statistical difference between presence/absence of frogs for a specific variable (SAS software, version 8.1), each variable was assessed to test for a statistical difference between ponds with and those without cricket frogs. The statistical analysis was intended to determine which and how many characteristics of the habitat were the best predictors for suitable habitat for cricket frogs.

RESULTS

Local Variables

Local variables were sampled at each pond twice from July to September, 2003. Tables 2 and 3 list the results of measurements taken for the 1st and 2nd sampling periods, respectively. The values given in Table 4 are the averages that were derived from the two sampling periods for the local variables in each pond. In total, seven of 13 ponds had cricket frogs present. Six ponds had no cricket frogs.

pH

Mean pH was not significantly associated with presence or absence of frogs in any of the ponds for either sampling date or for the average of the samples. Exact p values for the Wilcoxon test were 0.110, 0.325, and 0.062 for the first sample, second sample and average, respectively. Figure 14 illustrates that there was no clear trend in the values for pH compared to the independent variable (presence or absence of frogs) since the range of values overlapped between the two types of sites. Values ranged from 7.16 to 7.62 and 7.33 to 7.49 for sites with and without frogs, respectively.

Temperature

Figure 15 illustrate the results for water temperature. Water temperatures ranged from 21.56 to 25.36ºC for sites with frogs and 21.12 to 23.55ºC for sites without frogs. As the graph illustrates, the range of values for the two types of sites overlapped. Water temperature was significantly correlated with the presence of cricket frogs only in the first sample ($p=0.0251$, Wilcoxon exact test), but not significantly correlated in the second sample ($p=0.3141$, Wilcoxon exact test) or the average values ($p=0.0903$, Wilcoxon exact test). This difference in correlation between the first and second samplings is assumed to result from the fact that crocket frogs require warmer temperatures; temperatures in the second sampling period were lower than those in the first sampling period.

Slope

Slope, which did not change over the sampling dates, was not significantly correlated with the presence of cricket frogs but it was nearly significant (p=0.0536, Wilcoxon exact test). Figure 16 illustrates the average values for slope in every pond. Values ranged from 16.9 to 34.55 cm for ponds with frogs and 9.1 to 31.2 cm for ponds without frogs.

Vegetation in water

The percentage cover of vegetation in the water near the edge of the ponds was significantly correlated with the presence of cricket frogs for the second sampling date (p=0.036, Wilcoxon exact test) and the average values (p=0.050, Wilcoxon exact test), but not significantly correlated, although nearly significant, for the first sampling date (p=0.054, Wilcoxon exact test). Figure 17 illustrates the average values for the amount of vegetation, which ranged from 2% to 30% for ponds with frogs and 0% to 20% for ponds without frogs.

Vegetation on the ground

The percentage of the cover on the ground along the edge of each pond was significantly correlated with the presence of the frogs for the first sampling date, second sampling date and the average values. Figure 18 illustrates the average amount of vegetation cover found along the edge of each pond, which ranged from 1% to 98% for ponds with frogs and from 25% to 100% for ponds without frogs.

Area

Size of each pond was measured as its area and perimeter. The area of the pond was not significantly correlated with the presence of cricket frogs (p=0.527, Wilcoxon exact test).

However, Figure 19 illustrates the area of the ponds overlapped considerably, with the largest pond containing no frogs and the smallest pond having frogs. Ponds ranged in area 9463 to 32,414 m^2 for ponds with frogs and 12658 to 69097 m^2 for ponds without cricket frogs.

Perimeter

Like area, perimeter of the pond was not significantly correlated with presence of cricket frogs (p=0.473, Wilcoxon exact test). Figure 20 illustrates the perimeter for each pond. The perimeter for ponds with frogs ranged from 413 to 1,742 meters and the perimeter for ponds without frogs ranged from 496 to 3,755 meters.

A number of these local variables were significantly different between ponds with frogs and those without. A predictive model using logistic regression, though, was not possible. Results of the statistical analysis showed that the maximum likelihood estimate does not exist for any combination of the local variables. The estimates and the resulting values for the Chi-Square test are shown in Tables 6, 7 and 8 for the first sampling date, second sampling date, and the average values, respectively, under logistic regression.

Landscape variables

A number of landscape variables were estimated using ArcView 3.3, Table 5.

Nearest pond

I estimated the distance between the edge of the nearest pond with frogs and the edge of the nearest pond without frogs. These distances were significantly correlated with the presence of cricket frogs in the ponds with a p of 0.036 and 0.047 for the distance to the nearest pond with and without frogs, respectively (Wilcoxon exact test). Distances to the closest ponds with frogs ranged from 1,093 to 6,308 meters for ponds with frogs and 5,163 to 16,273 meters for ponds without frogs, Figure 21. Distance to the closest ponds without frogs ranged from 921 to 16,687 meters for ponds with frogs and from 57 to 6,140 meters for ponds without frogs, Figure 22.

Nearest ditch

The distance to the edge of the nearest ditch was not significantly correlated with the presence of cricket frogs (p=0.365, Wilcoxon exact test). Distances to the nearest ditch were very similar and ranged from 36 to 1,199 meters for ponds with frogs and 29 to 686 meters for ponds without frogs, Figure 23.

Nearest road

The distance to the nearest road was not significantly correlated with the presence of cricket frogs (p=0.365, Wilcoxon exact test). Distances to the nearest road were very similar and ranged from 10 to 259 meters for ponds with frogs and 7 to 128 meters for ponds without frogs, Figure 24.

Nearest stream

The distance to the edge of the nearest stream was also not significantly correlated with the presence of cricket frogs (p=0.118, Wilcoxon exact test). Distances to the nearest stream were very similar and ranged from 109 to 2,2922 meters for ponds with frogs and 125 to 3,855 meters for ponds without frogs, Figure 25.

A number of these landscape variables were significantly different between ponds with frogs and those without. A predictive model using logistic regression, though, was not possible. Results of the statistical analysis showed that the maximum likelihood estimate does not exist for any combination of the landscape variables. The estimates and the resulting values for the Chi-Square test, from the logistic regression, are shown in Table 9.

Combining the local and landscape variables did not improve the ability to build a predictive model.

DISCUSSION

The requirement of two kinds of habitats (aquatic and semi-aquatic) for cricket frogs implies that local factors in the habitat may be important for them. Local factors such as pH (reported populations in Michigan, http://web4.sue.msu.edu/mnfi/abstracts/zoology/acris_crepitans_blachardi.pdf), temperature of the water and slope (Greg Lipps, 2003 personal communication) and vegetation (Harding 1997, Davis and Menze 2002) are assumed to be relevant in the presence of some amphibians. However, previous studies for ***Acris crepitans blanchardi*** have focused only on a descriptive analysis of local factors of the habitat (Ralin and Rogers 1972, Burkett 1984, Lannoo 1994, Harding 1997, http://herpcenter.ipfw.edu). In contrast, this study measured and statistically analyzed local variables in cricket frog habitat.

Results from this study revealed that some local factors are statistically significant for presence of frogs in the habitat (temperature, vegetation on water and vegetation on ground), but not all of them (pH, slope). Possible reasons for the significance of temperature, and vegetation would be explained by the requirements of the frogs; activity of this species is higher in warmer climate and vegetation may be used for thermoregulation and mechanism of surviving from predators hidden in the vegetation. In addition, breeding occurs near vegetation or algae mats and females attach their eggs to submerge vegetation. Consequently, vegetation may play an important role in the ecology and habitat requirements of the species. In contrast, pH and slope, exhibited no statistical significance for presence of frogs. Previous studies have indicated pH and slight slope as descriptive characteristics of the habitat for cricket frogs. However, these studies are mostly qualitative not quantitative. In this study, the ranges of pH and slope overlapped for both ponds with frogs and those without frogs, which is not surprising since all of these ponds are artificial, not natural, and based on similar construction characteristics common to the area (e.g., circular, shallow, mowed edge).

In the literature, landscape variables have been mentioned as important characteristics in the habitat for cricket frogs. However, previous studies have focused only on local variables (Burkett 1984, Irwin et al. 1999). The results of this study indicate that the use of statistical analysis on landscape variables might be significant for some of them (distance to nearest pond with presence or absence), as well as, indicates that the use of landscape variables are valuable in the description of the habitat. GIS provides a tool that allows us to “sample” a much larger number of areas with minimal field effort and at much larger scales, which makes planning and conservation across entire regions possible.

Since cricket frogs depend on the availability of permanent water, and this may be important in dispersal issues, and probably explains why the distance to nearest pond with presence or absence was significantly related to the presence of frogs. Distance to nearest stream, ditch and road was not significantly related to the presence of cricket frogs. Even though ditches and streams are also suggested to be important in dispersal issues, they are just temporary habitat for this species and their occurrence and distribution depend more on permanent water nearby. Streams usually have a stronger current than a pond and may be a less desirable choice for movement.

The use of statistical methods in this research was helpful to better understand the role of local and landscape variables. However, the data were not enough powerful to build a model for predicting habitat suitability for these organisms. One explanation for the lack of predictive power is that the sample size was too small. When the sample size was artificially doubled (to 26 ponds), stepwise logistic regression produced a reasonable model that included the distance to the nearest pond with frogs. This is promising and suggests that the approach used in this study is useful for developing a better understanding of habitat needs for the cricket frog. Furthermore, the results of this research suggest that the use of some of these variables may not be important in the characterization of cricket frog habitat.

The results presented in tables and figures illustrated that the statistical methods used in this study are important for improving our understanding about the ecology of the species. The recognition that variables used in this study may not be sufficient to explain important factors in cricket frogs habitat has resulted in some major findings.

This study suggests that we should be cautious in selecting the correct variables for identification of the habitat not only for cricket frogs but also for other amphibians. One of the most important findings in this study was the identification of significant variables, like temperature, vegetation and distance to nearest ponds with or without frogs in the description of the habitat. This is a step forward in the quest for knowledge of the ecology of cricket frogs. The significance of vegetation and temperature for cricket frogs may be related to the use of the vegetation to hide from predators and for thermoregulation purposes. At the same time the distance to nearest pond is also significant because they can disperse to the closest pond for breeding, feeding, and shelter.

Even though it was not possible to build a model ecological insight was gained. A number of potential issues limited the collection of additional data. The fact that all the ponds were on private property represented one of the major problems in this study. Prior to the sampling period I had to ask for permission to access the ponds and sample them. It was difficult to contact the owners during the day or in the summer. Besides the limited access, the short period of available sampling time limited the quantity of ponds and data. I had just one sampling season, summer, because is considered the best since it included more than one age class (juveniles, adults, etc.). For some of the variables the method used to measure them was accurate (pH and temperature) but for others the measurement was less accurate because the device used was an improvised one (slope and vegetation). Most of the ponds were well maintained because they were in private properties. There are very few natural ponds remaining in this area as a result of extensive human impact, such as the clearing of the Great Black Swamp for agriculture. Therefore, we need to consider the impact of humans on the habitat for further study; factors such as the mowed edges may also be important habitat characteristics. Since cricket frogs were found in this research only in human-made ponds, it might be helpful to consider restoring or preserving some artificial ponds. Clearly cricket frogs are using these ponds and they are likely to be important in their long-term viability.

The use of the correct variables (local and landscape) is important not only for the measurement of the habitat but also to improve the management of this species and other amphibians with similar habitat requirements. Overall, the findings identify the significance of local and landscape variables for further study and suggest important conservation strategies for Blanchard's cricket frogs. GIS-derived

In addition to the local and large scale factors, a GIS occurrence-habitat model should be incorporated to help identify populations and suitable areas for conservation and restoration of this species. As the importance of the nearby ponds indicates, important habitat characteristics may be related to the dispersal needs of the species. Little is known dispersal in this species and additional study will be important for its conservation. Genetic analysis should be also included in the research needs, which can be helpful in assessing the actual status of the identified populations and for exploring dispersal issues. This study suggests that cricket frogs is a species that may need some level of disturbance (e.g., mowed edges), therefore it will be important to include humans through education and participation in restoration and management.

Conclusions

One of the major contributions of this thesis is the awareness of the importance of the local and large scale factors in identifying habitat for cricket frogs. My results show the significance of both local and landscape variables. In addition, the increase in the knowledge of the cricket frog's ecology is essential considering that populations of cricket frogs in the north part of their range are declining rapidly.

Recommendations

Based on the increasing declines in the cricket frog's range and the results provided from this thesis, the use of local and large scale variables must be incorporated in any conservation project for cricket frogs to increase the accuracy and success of the strategies. Results from this study clearly documented differences and statistical significance among local and landscape variables. The incorporation of additional variables at large scales should be tested (proximity to adjacent ponds, streams, and rivers that are suggested to be relevant to the habitat of cricket frogs). More information about the habitat variables at local and landscape scale is vital for appropriate and effective management. Since cricket frogs depend on the availability of permanent bodies of water, the protection and restoration of existing areas and their surroundings that incorporate the requirements of the species and be a priority.

Results from this study provide preliminary insights into the potential use of specific local and landscape variables for habitat requirements of cricket frogs. Cricket frogs are a species in decline and without any appropriate management plan and strategies its conservation will be difficult.

APPENDIX A: TABLES

Table 1. Local and Landscape Variables that were measured at each pond.

Variable	Type	Source
Presence/absence of frogs	Local	Survey
pH	Local	Survey with pH meter
Temperature of the water	Local	Survey with temperature meter
Slope	Local	Local measurement
% of local vegetation (Water/ground)	Local	Survey with one meter square grid
Distance to nearest pond with frogs	Landscape	Ohio wetlands survey
Distance to the nearest pond without frogs	Landscape	Ohio wetlands survey
Distance to the nearest ditch	Landscape	Ohio wetlands survey
Distance to the nearest road	Landscape	Ohio wetlands survey
Distance to the nearest stream	Landscape	Ohio wetlands survey

Table 2. Local variables for the first sampling date, including pH, temperature (Temp), slope, percent of vegetation cover in water, percent vegetation cover on ground, and presence/absence for each pond. P indicates a pond with cricket frogs; A indicates a pond without cricket frogs.

Name	Id	PH	Temp (C)	Slope (cm)	Percent cover in water	Percent cover on ground	P/A
Seven Eagles	1	7.66	30.15	34.55	0.530	0.980	P
Freyman	6	7.68	30.15	24.30	0.335	0.515	P
Cygnet	7	7.74	24.31	20.10	0.100	0.010	P
Wapakoneta	8	7.34	29.29	16.90	0.040	0.710	P
Intersection	9	7.13	27.45	27.75	0.290	0.760	P
6b	10	7.85	25.76	31.20	0.020	0.100	P
6a	12	7.66	27.84	28.05	0.085	0.725	P
Tech Pond	2	7.40	24.21	26.10	0.115	0.710	A
Rec 2	3	7.42	26.02	13.45	0.000	1.000	A
Rec 1	4	7.46	25.45	9.10	0.095	1.000	A
Golf Pond	5	7.52	24.29	19.50	0.000	0.900	A
6c	11	7.58	26.95	31.20	0.197	1.000	A
Wapakoneta 2	13	7.46	27.07	16.55	0.000	0.210	A

Table 3. Local variables for the second sampling date, including pH, temperature (Temp), slope, percent of vegetation cover in water, percent vegetation cover on ground, and presence/absence for each pond. P indicates a pond with cricket frogs; A indicates a pond without cricket frogs.

Name	Id	PH	Temp (C)	Slope (cm)	Percent cover in water	Percent cover on ground	P/A
Seven Eagles	1	7.57	20.56	34.55	0.530	0.980	P
Freyman	6	7.33	19.54	24.30	0.335	0.515	P
Cygnet	7	7.67	18.21	20.10	0.100	0.010	P
Wapakoneta	8	7.51	21.72	16.90	0.040	0.710	P
Intersection	9	7.19	18.46	27.75	0.315	0.715	P
6b	10	7.38	20.23	31.20	0.020	0.100	P
6a	12	7.26	19.88	28.05	0.085	0.725	P
Tech Pond	2	7.26	18.95	26.10	0.065	0.735	A
Rec 2	3	7.30	21.07	13.45	0.000	1.000	A
Rec 1	4	7.37	19.24	9.10	0.055	1.000	A
Golf Pond	5	7.41	17.95	19.50	0.000	0.900	A
6c	11	7.39	19.89	31.20	0.197	1.000	A
Wapakoneta 2	13	7.37	19.79	16.55	0.000	0.285	A

Table 4. Average local variables, including pH, temperature (Temp), slope, percent of vegetation cover in water, percent vegetation cover on ground, and presence/absence for each pond. P indicates a pond with cricket frogs; A indicates a pond without cricket frogs.

Name	**Id**	**PH**	**Temp (C)**	**Slope (cm)**	**Percent cover in water**	**Percent cover on ground**	**P/A**
Seven Eagles	1	7.62	25.36	34.55	0.530	0.980	P
Freyman	6	7.51	24.85	24.30	0.335	0.515	P
Cygnet	7	7.71	21.26	20.10	0.100	0.010	P
Wapakoneta	8	7.43	25.51	16.90	0.040	0.710	P
Intersection	9	7.16	22.96	27.75	0.3025	0.7375	P
6b	10	7.62	23.00	31.20	0.020	0.100	P
6a	12	7.46	23.86	28.05	0.085	0.725	P
Tech Pond	2	7.33	21.58	26.10	0.090	0.723	A
Rec 2	3	7.36	23.55	13.45	0.000	1.000	A
Rec 1	4	7.42	22.35	9.10	0.075	1.000	A
Golf Pond	5	7.47	21.12	19.50	0.000	0.900	A
6c	11	7.49	23.42	31.20	0.197	1.000	A
Wapakoneta 2	13	7.42	23.43	16.55	0.000	0.248	A

Table 5. Landscape variables for each pond, including area, perimeter, distance to the nearest pond with frogs, distance to the nearest pond without frogs, distance to the nearest ditch, distance to the nearest road, distance to the nearest stream, and presence/absence. All distances are in meters. P indicates a pond with cricket frogs; A indicates a pond without cricket frogs.

Name	Id	P/A	Area (m^2)	Perimeter	Nearest pond with frogs	Nearest pond without frogs	Nearest ditch	Nearest road	Nearest stream
Seven Eagles	1	P	100298.4	1742.1	6307.52	7220.80	1199.22	39.54	2922.22
Freyman	6	P	32413.5	728.1	1818.22	16686.9	328.25	41.46	620.05
Cygnet	7	P	17297.9	642.0	1818.22	16199.03	65.59	10.01	252.69
Wapakoneta	8	P	16796.9	504.7	1518.95	1518.95	997.46	144.18	786.69
Intersection	9	P	9463.2	413.9	1518.95	1256.12	39.54	60.66	1632.75
6b	10	P	32428.2	800.5	1093.37	1421.05	901.6	259.13	109.35
6a	12	P	32937.3	692.1	1093.37	921.18	143.86	28.77	412.52
Tech Pond	2	A	12658.2	496.4	16226.38	421.67	486.57	127.73	3854.62
Rec 2	3	A	13786.3	497.6	16199.03	56.93	686.09	28.97	3348.30
Rec 1	4	A	69097.2	1273.1	16273.28	56.93	555.48	11.95	3380.78

Table 5. (continued).

Name	Id	P/A	Area (m^2)	Perimeter	Nearest pond with frogs	Nearest pond without frogs	Nearest ditch	Nearest road	Nearest stream
Golf Pond	5	A	562313.5	3755.3	16686.90	1030.36	29.22	6.61	2653.38
6c	11	A	17990.5	749.1	815.23	6140.44	96.39	88.42	316.65
Wapakoneta 2	13	A	18290.6	509.1	5163.40	6140.44	374.54	133.24	124.68

Table 6. Results of the logistic regression analysis in SAS for the local variables on the first sampling date, including pH, temperature, slope, percent vegetation cover in the water (Veg/water) and the percent vegetation cover on the ground (Veg/ground).

Variable	Estimate	Std Error	Chi-square	P
pH	3.3939	3.3921	1.0010	0.3171
Temperature	0.7030	0.4144	2.8757	0.0898
Slope	0.1449	0.0948	2.3343	0.1266
Veg/water	8.0823	6.0141	1.8060	0.1790
Veg/ground	1.9057	3.2125	0.3519	0.5530

Table 7. Results of the logistic regression analysis in SAS for the local variables on the second sampling date, including pH, temperature, slope, percent vegetation cover in the water (Veg/water) and the percent vegetation cover on the ground (Veg/ground).

Variable	Estimate	Std Error	Chi-square	P
pH	- 4.0196	3.9313	1.0454	0.3066
Temperature	$- 5.49 \times 10^{-8}$	4.793×10^{-8}	1.3124	0.2520
Slope	0.2361	0.4611	0.2623	0.6086
Veg/water	- 0.0324	0.0661	0.2400	0.6242
Veg/ground	1.0265	3.0886	0.1105	0.7396

Table 8. Results of the logistic regression analysis in SAS for the average of the local variables, including pH, temperature, slope, percent vegetation cover in the water (Veg/water) and the percent vegetation cover on the ground (Veg/ground).

Variable	Estimate	Std Error	Chi-square	P
pH	$- 6.2 \times 10^{-8}$	3.227×10^{-8}	3.6925	0.0547
Temperature	- 5.6667	3.9534	2.0546	0.1517
Slope	0.0780	0.3510	0.0494	0.8241
Veg/water	- 0.0297	0.0660	0.2029	0.6524
Veg/ground	1.8023	3.1704	0.3232	0.5697

Table 9. Results of the logistic regression analysis in SAS for the landscape variables, including area, perimeter, nearest pond with frogs (Dpondp), nearest pond without frogs (Dponda), nearest ditch (Dditch), nearest road (Droad) and nearest stream (Dstream).

Variable	Estimate	Std Error	Chi-square	P
Area	- 0.0259	0.0169	2.3406	0.1260
Perimeter	0	1.0497	0.0000	1.000
Dpondp	- 1.9496	1.0950	3.1698	0.0750
Dponda	0.000454	0.000585	0.6036	0.4372
Dditch	1.919 E-6	3.488 E-6	0.3027	0.5822
Droad	0.000454	0.000585	0.6036	0.4372
Dstream	0.000143	0.000083	3.0059	0.0830

APPENDIX B: FIGURES

Figure 1. Shown is an adult Blanchard's cricket frog in the hand of Marina Martinez-Ortiz. (Photo by Marina Martinez-Ortiz)

Figure 2. A Blanchard's cricket frog shown in its native habitat in Wood County, Ohio. (Photo by Dr. Karen Root.)

Figure 3. Shown is the typical native habitat for cricket frogs in The Grand Rapids area in Northwest Ohio. (Photo by Dr. Karen Root.)

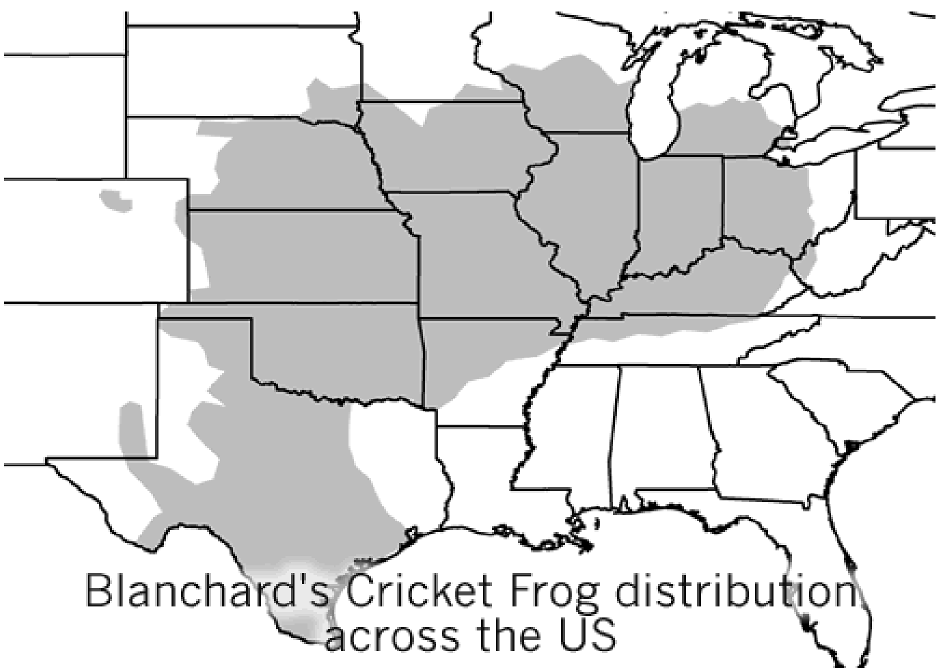


Figure 4. United States distribution of Blanchard's cricket frogs (from http://herpcenter.ipfw.edu).

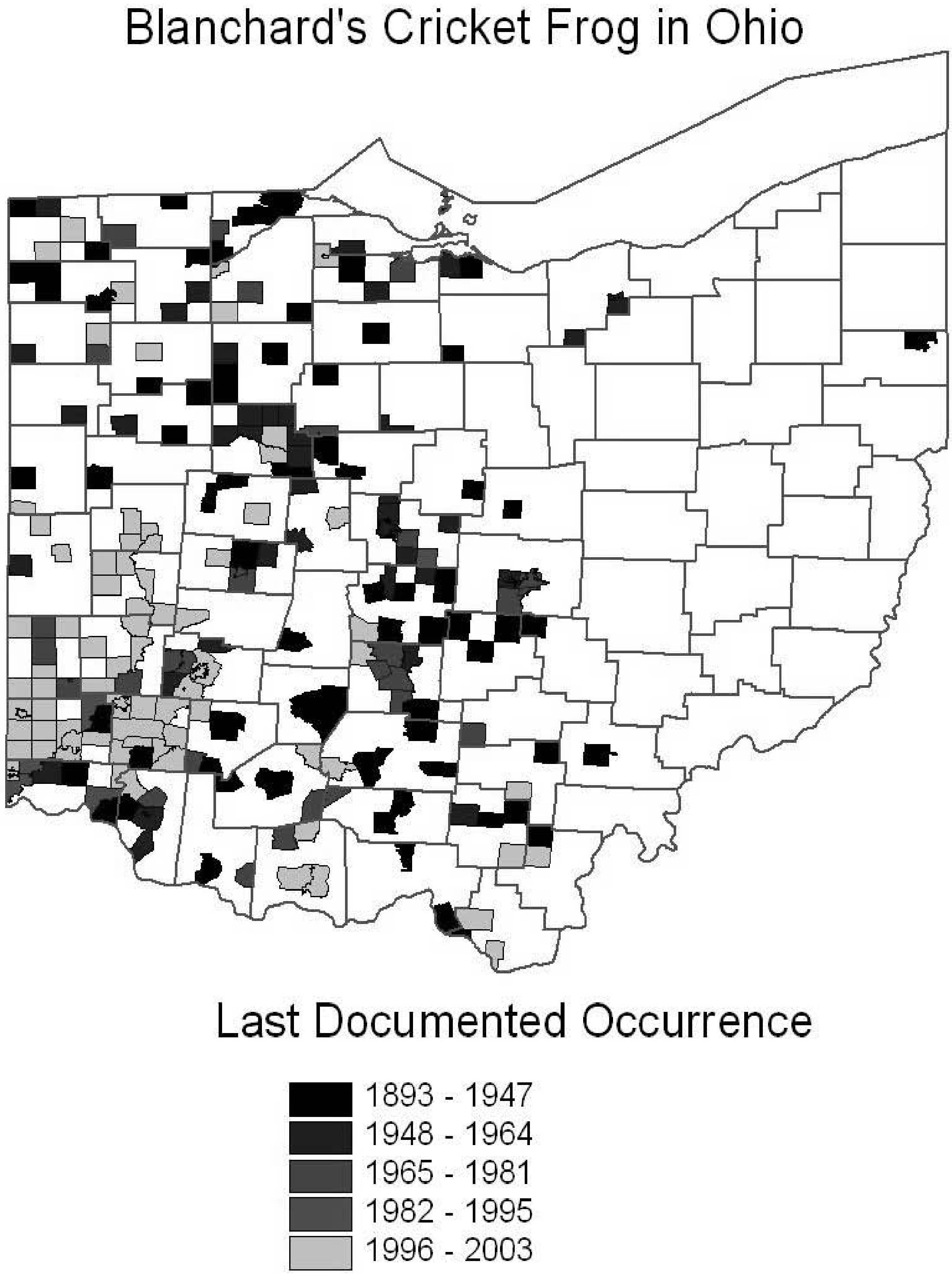


Figure 5. Ohio distribution of Blanchard's cricket frog (Lipps 2003).

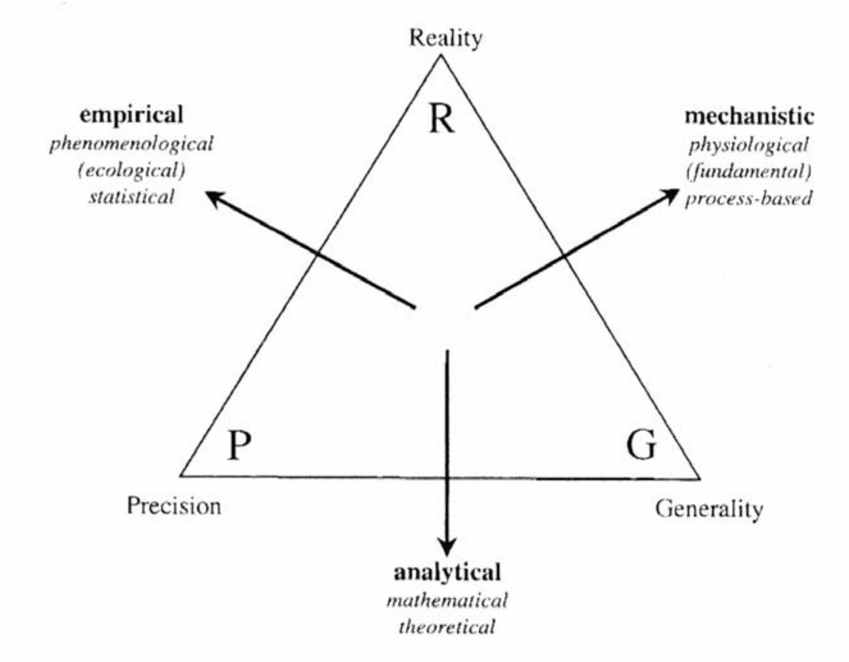


Figure 6. A classification of models based on their intrinsic properties (Guisan and Zimmermann 2000).

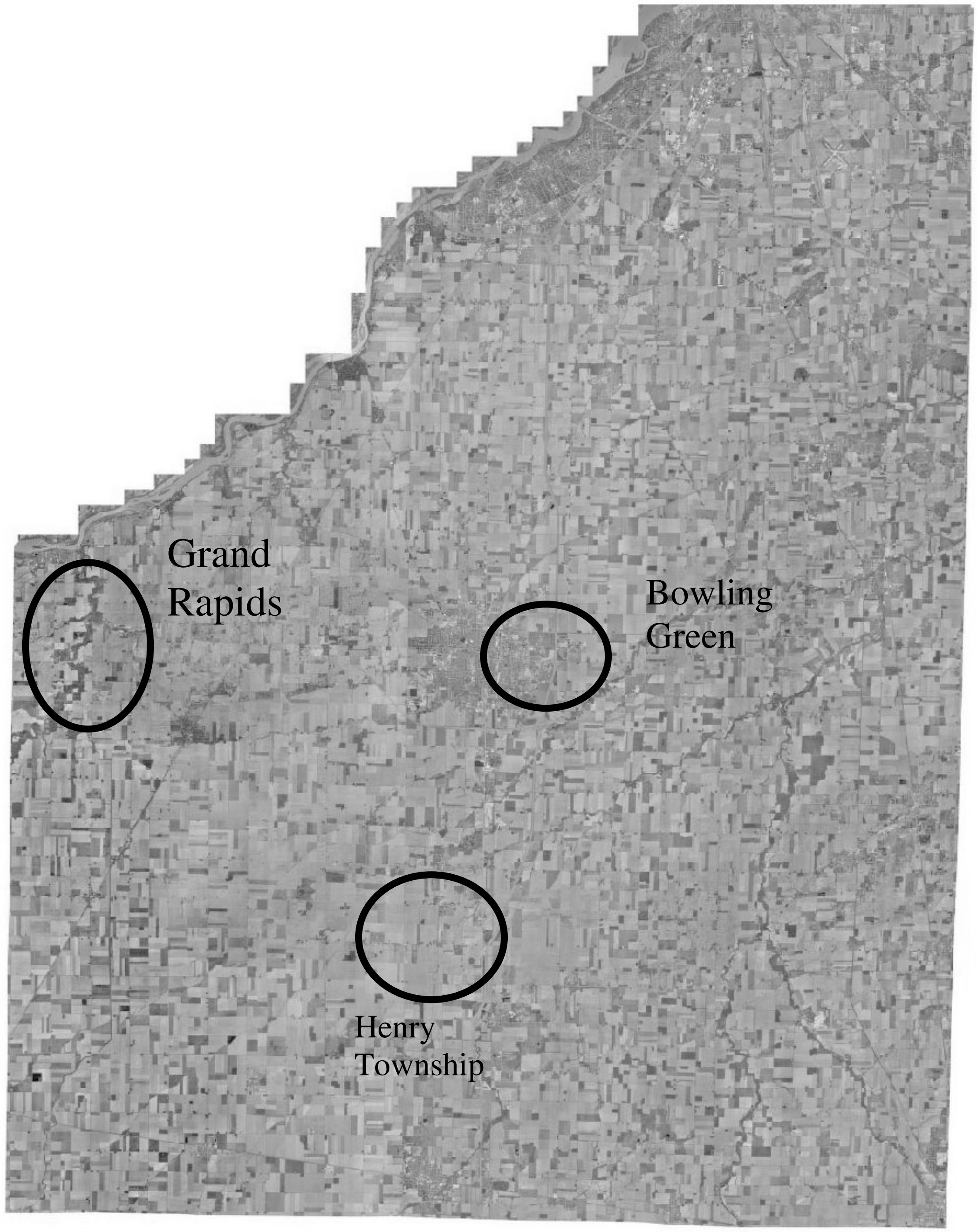


Figure 7. Aerial photo of Wood County, Ohio (1998).

Figure 8. Aerial photo of Grand Rapids Township, Ohio, and the surrounding area (1998).

Figure 9. Aerial photo of Bowling Green Township, Ohio, and the surrounding area (1998).

Figure 10. Aerial photo of Henry Township, Ohio, and the surrounding area (1998).

Figure 11. Temperature and pH measurements taken in the field at each site using a portable meter.

Figure 12. Measuring the slope of the pond bank within 1 meter of its edge.

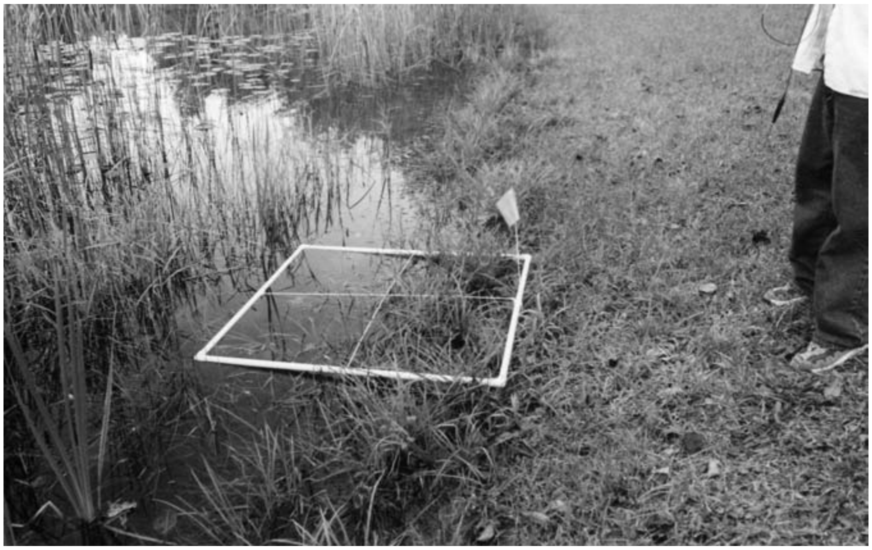
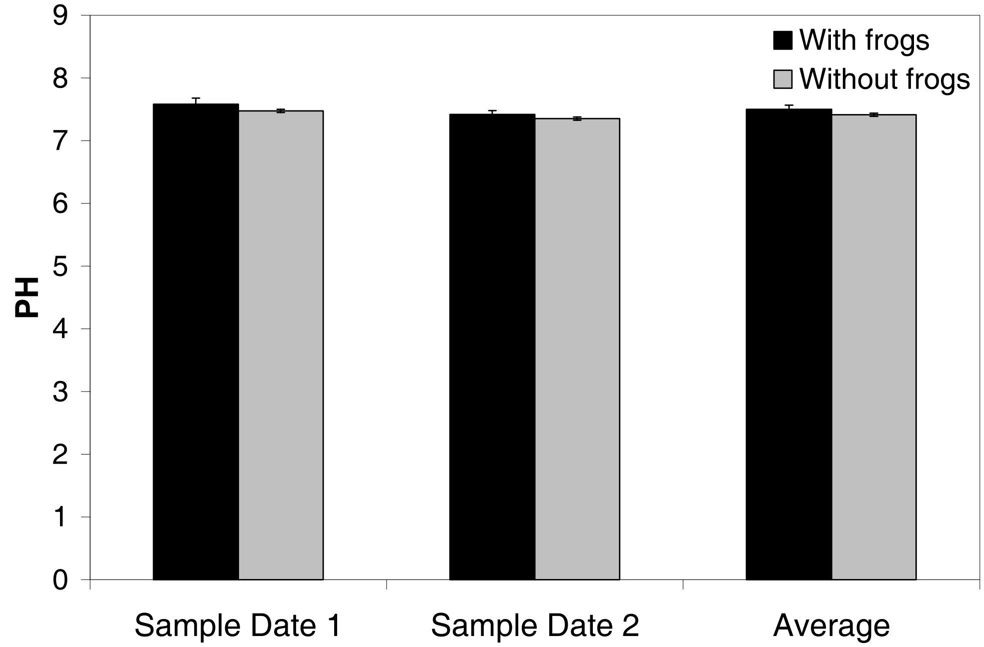


Figure 13. Vegetation cover measurements were taken along the edge of the pond using a one meter by one meter grid.

(a)



(b)

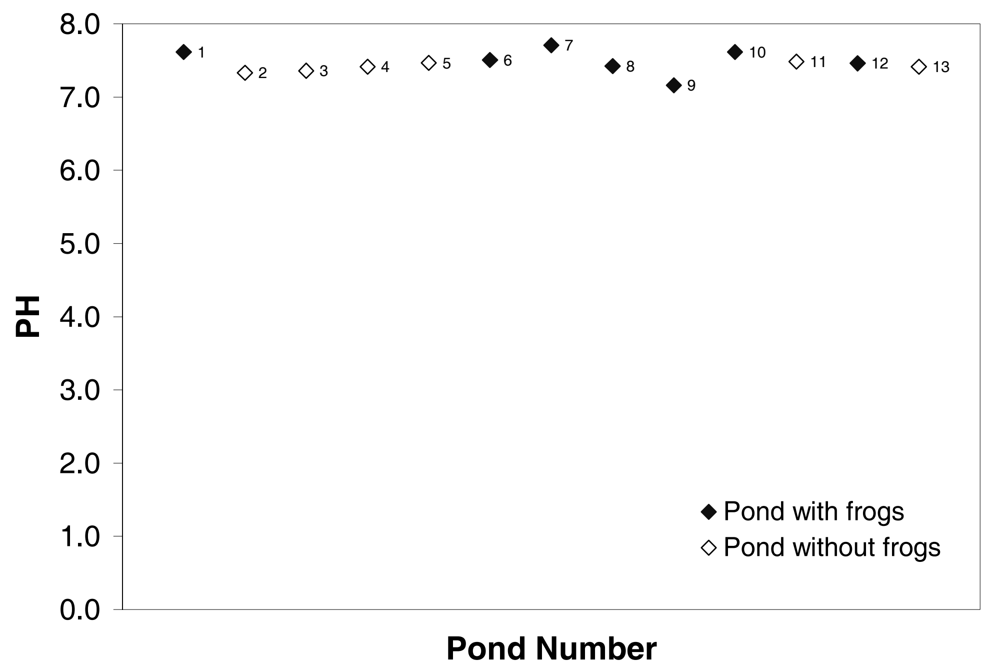


Figure 14. (a) The pH measured for sample date 1, sample date 2 and the average pH for ponds with (dark) and ponds without frogs (light); standard error shown on each bar. (b) The average pH measured for ponds with (filled) and without (open) frogs; pond id is shown next to each symbol.

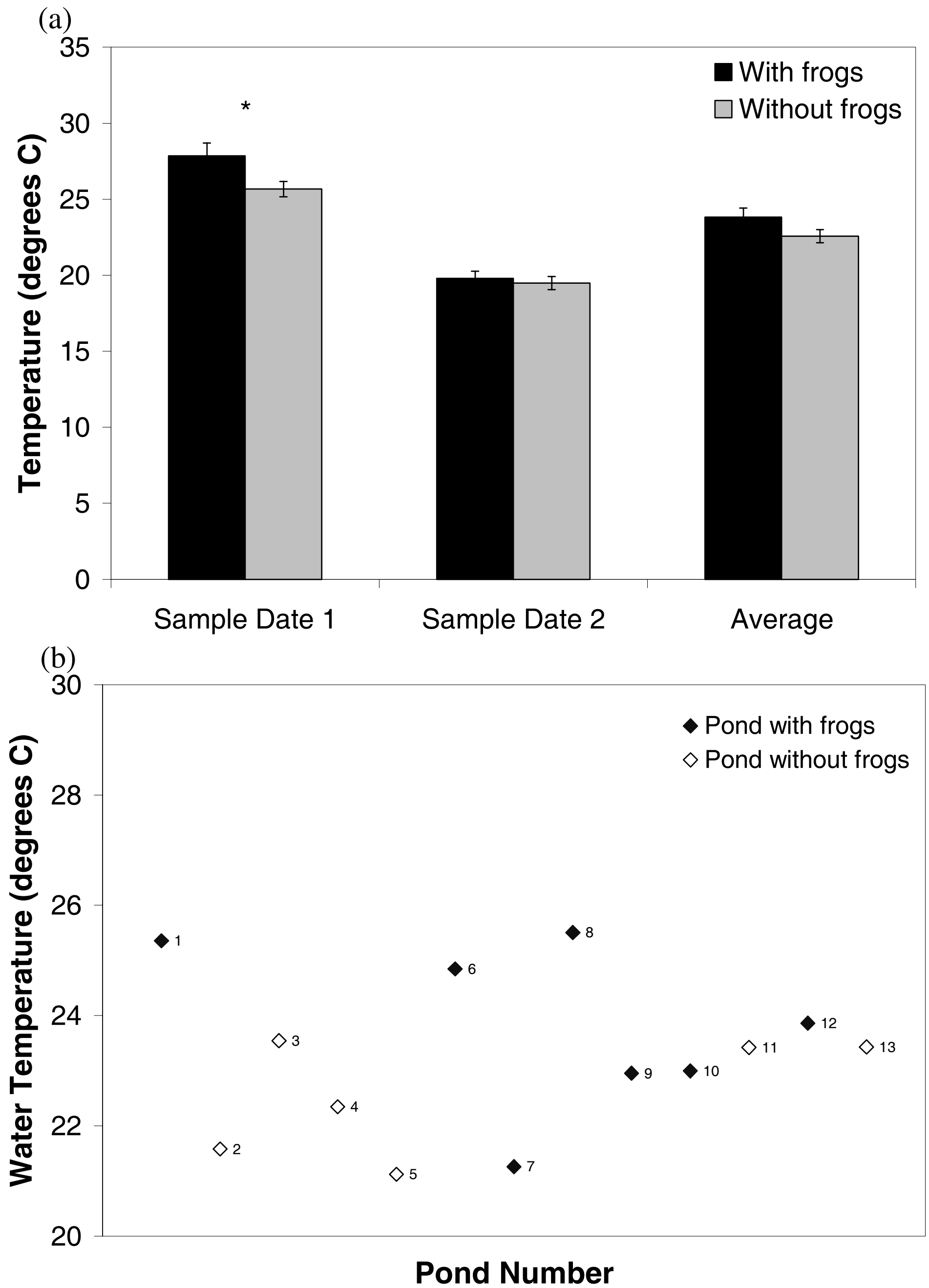


Figure 15. (a) The water temperature measured for sample date 1, sample date 2 and the average pH for ponds with (dark) and ponds without frogs (light); standard error shown on each bar. * indicates significant difference with $p<0.05$, Wilcoxon test. (b) The average water temperature for each pond with (filled) and without (open); pond id is shown next to the symbols.

(a)

(b)

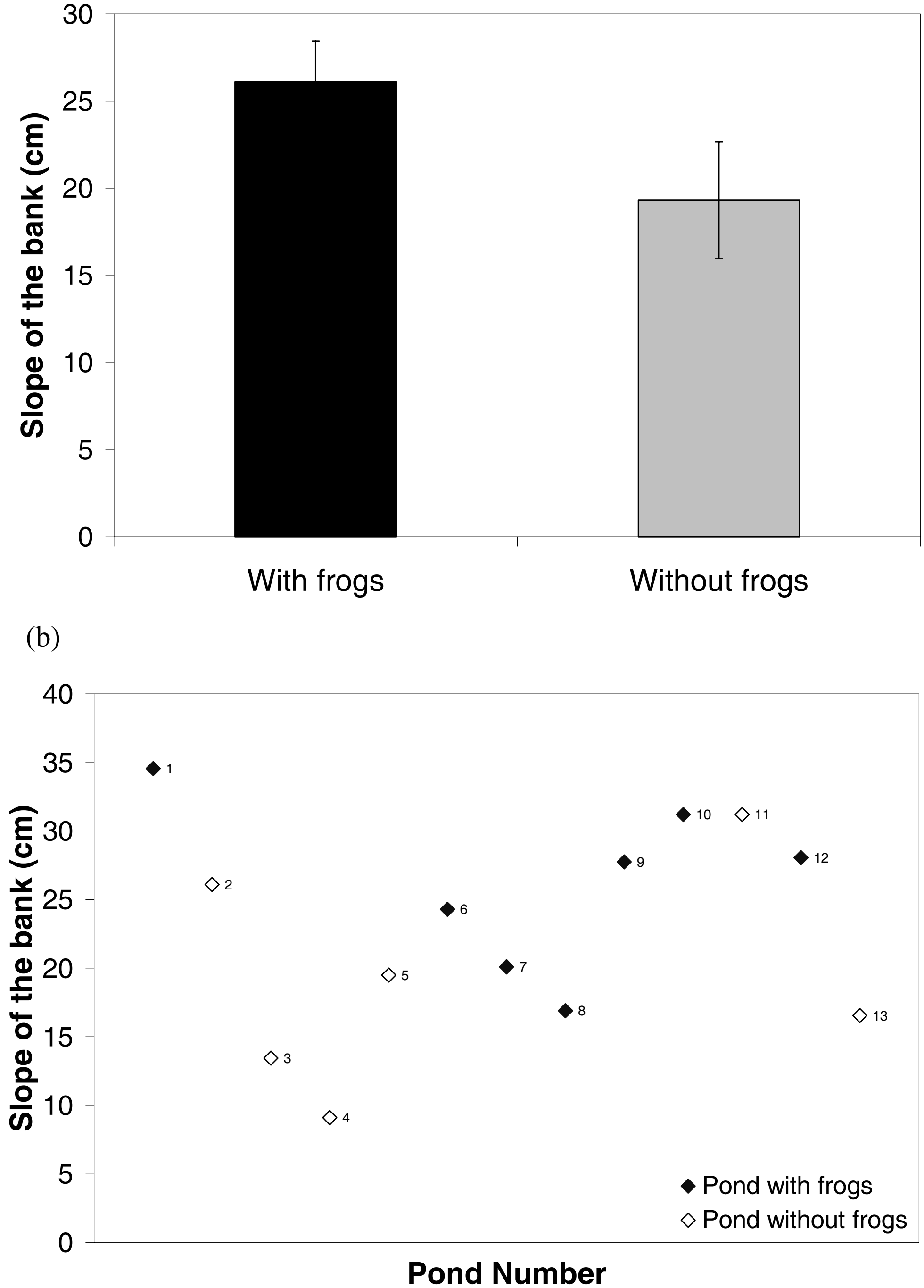


Figure 16. (a) The slope of the bank within the first meter of the edge of ponds with (dark) and without (light) frogs; standard error shown on each bar. (b) The slope for each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

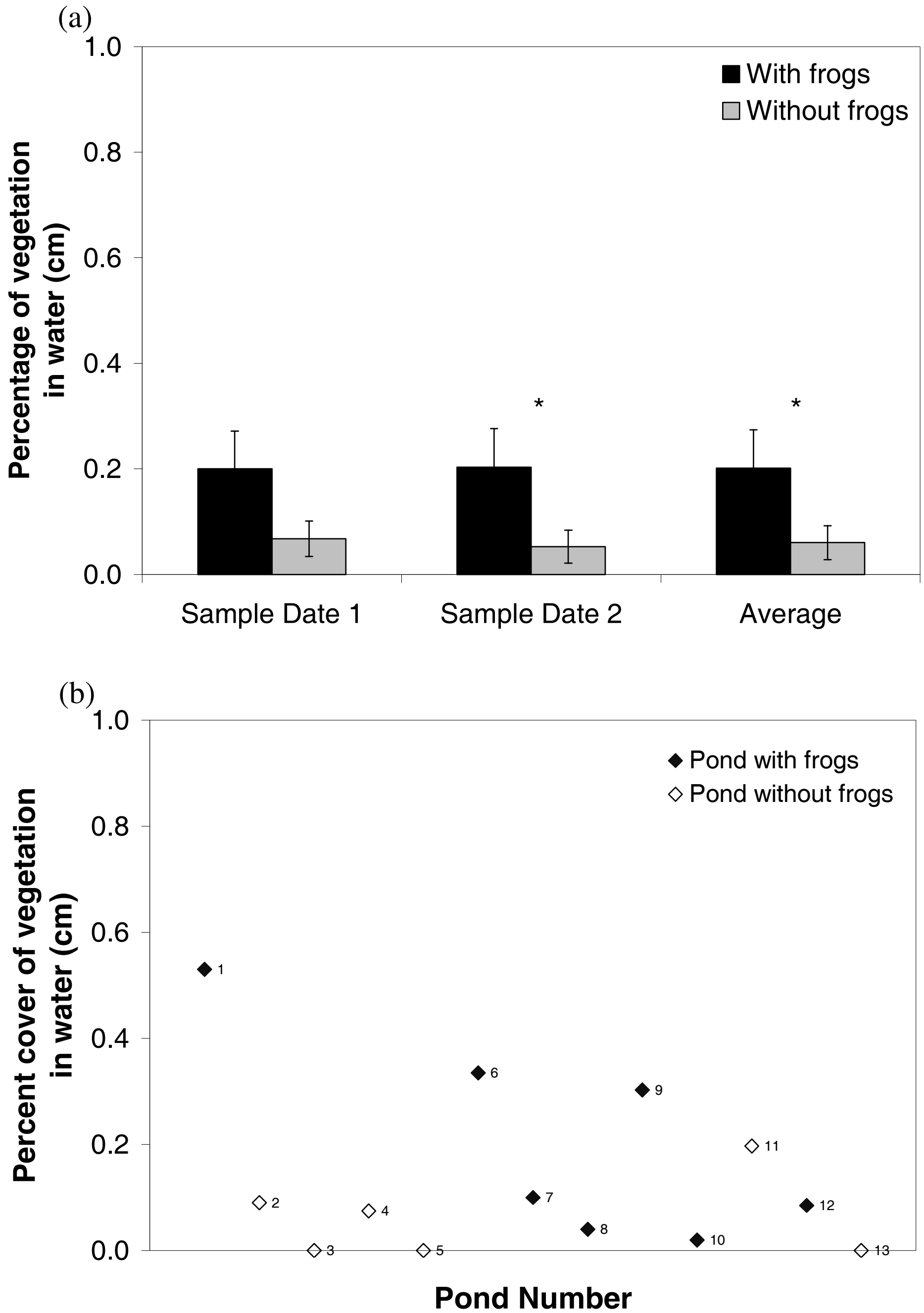


Figure 17. (a) The vegetation cover in the water, as a percent, measured for sample date 1, sample date 2 and on average for ponds with (dark) and ponds without frogs (light); standard error shown on each bar. * indicates significant difference with $p<0.05$, Wilcoxon test. (b) The average amount of vegetation cover for each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

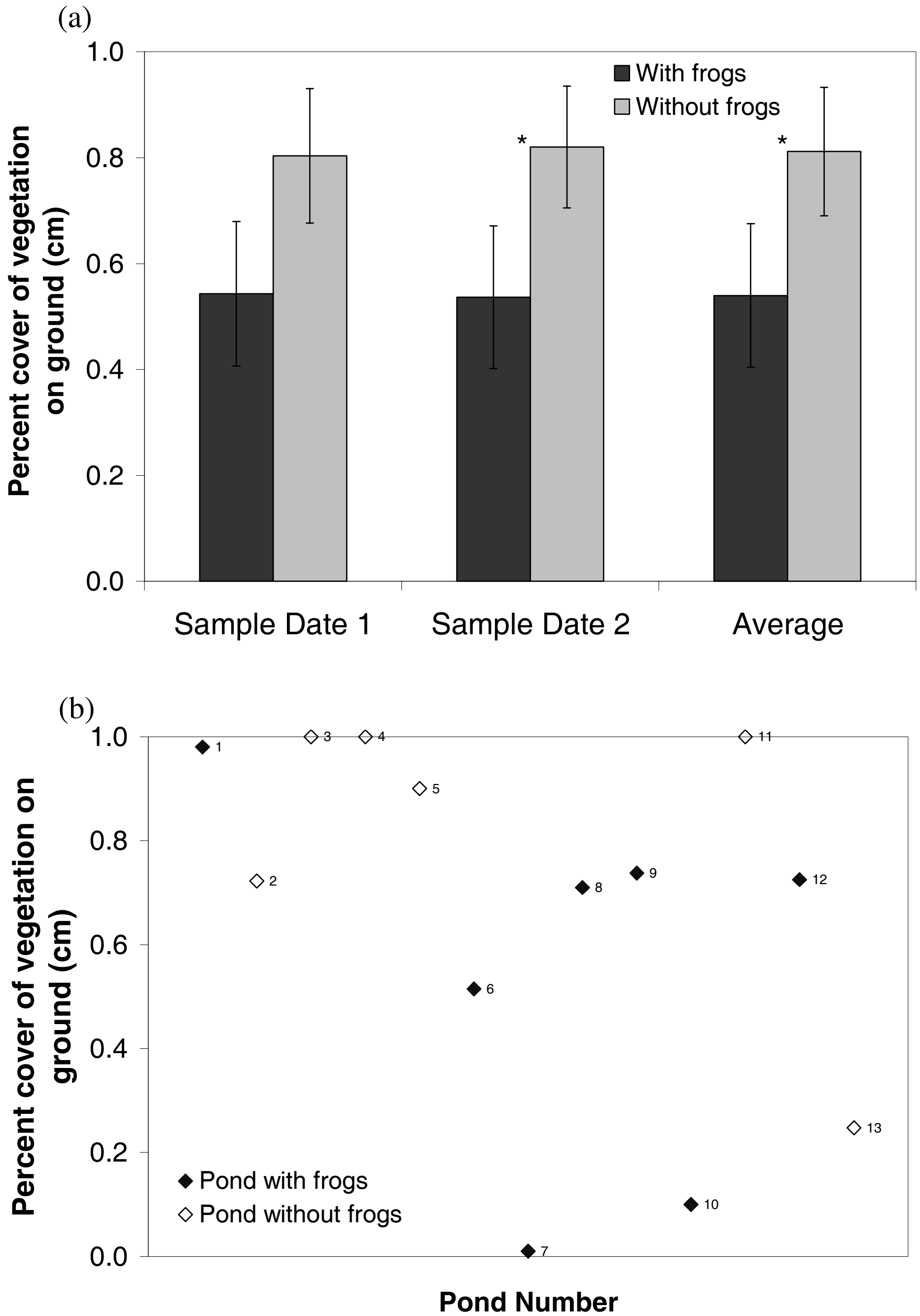


Figure 18. (a) The vegetation cover on the ground along the edge, as a percent, measured for sample date 1, sample date 2 and on average for ponds with (dark) and ponds without frogs (light); standard error shown on each bar. * indicates significant difference with $p<0.05$, Wilcoxon test. (b) The average amount of vegetation cover for each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

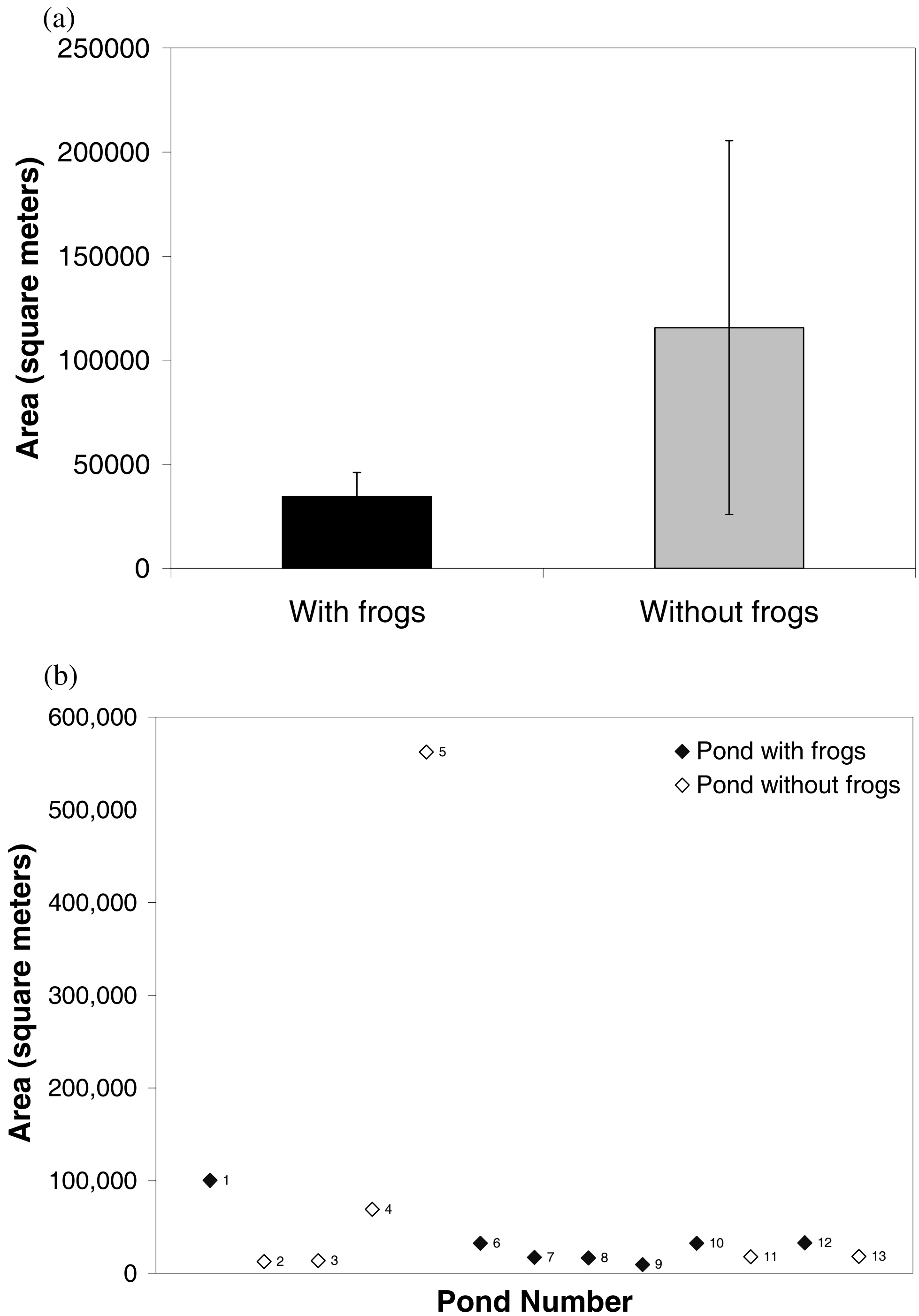


Figure 19. (a) The area, in square meters, of ponds with (dark) and without (light) frogs; standard error is shown above each bar. (b) The area in each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

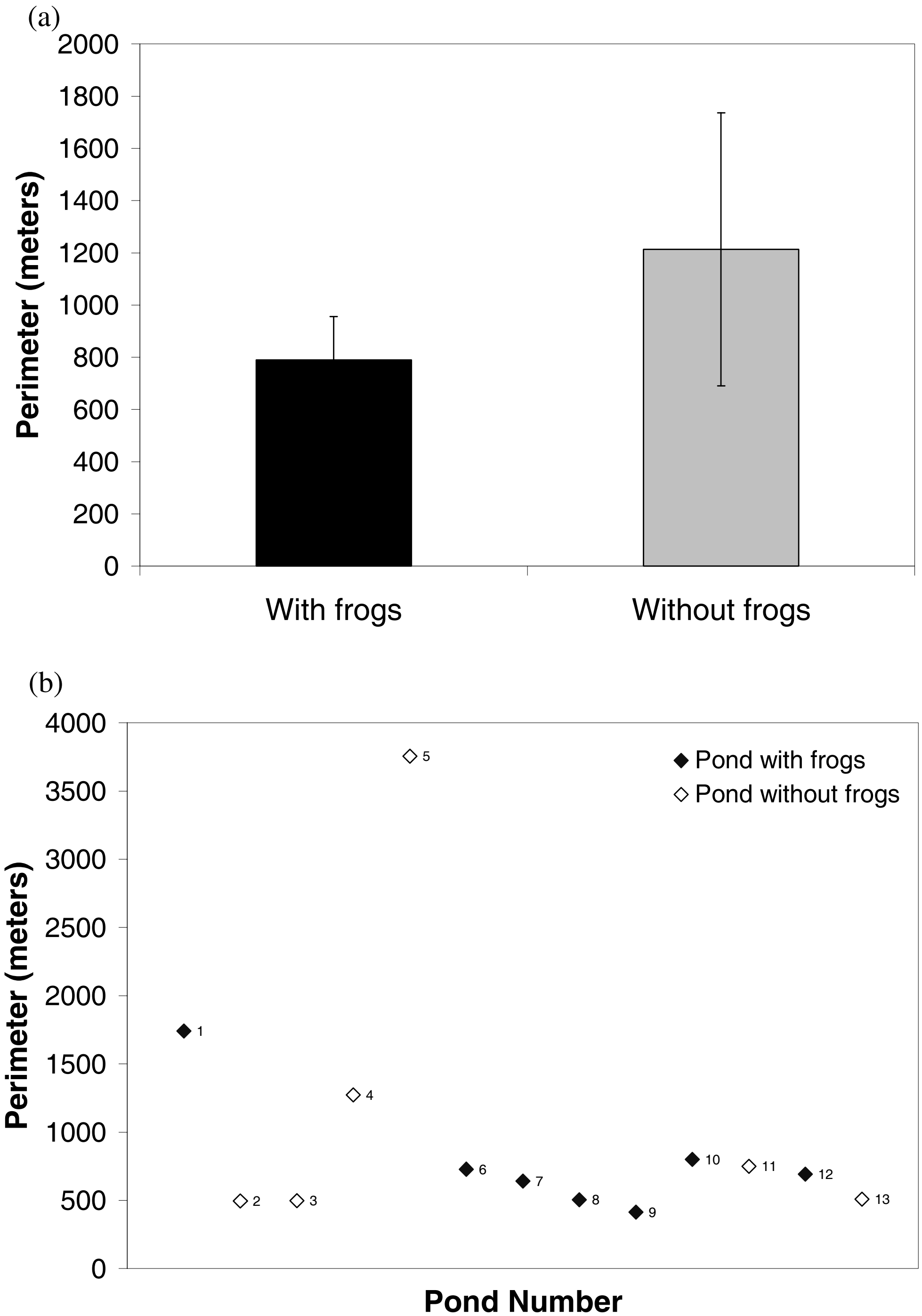
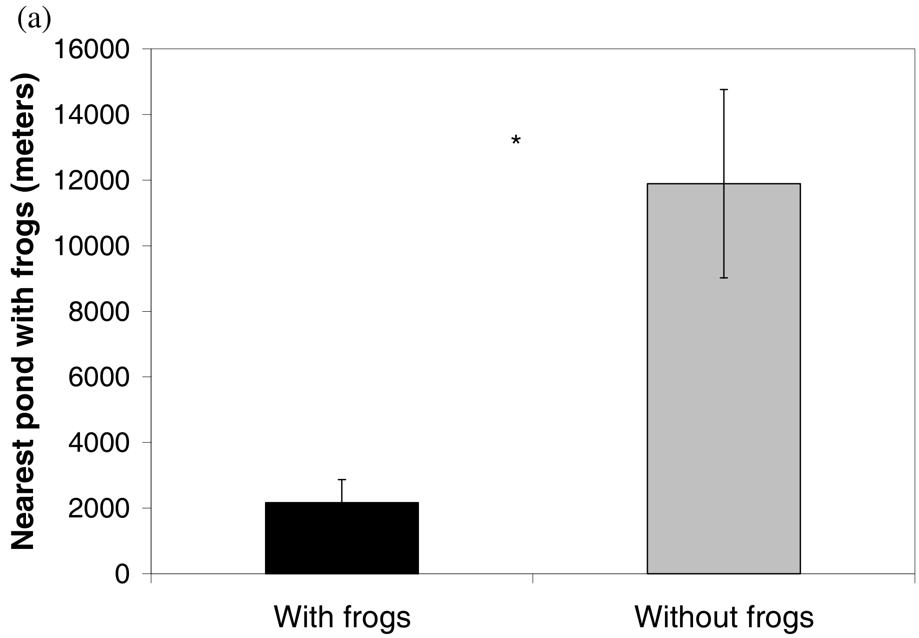


Figure 20. (a) The perimeter, in meters, of ponds with (dark) and without (light) frogs; standard error is shown above each bar. (b) The perimeter in each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.



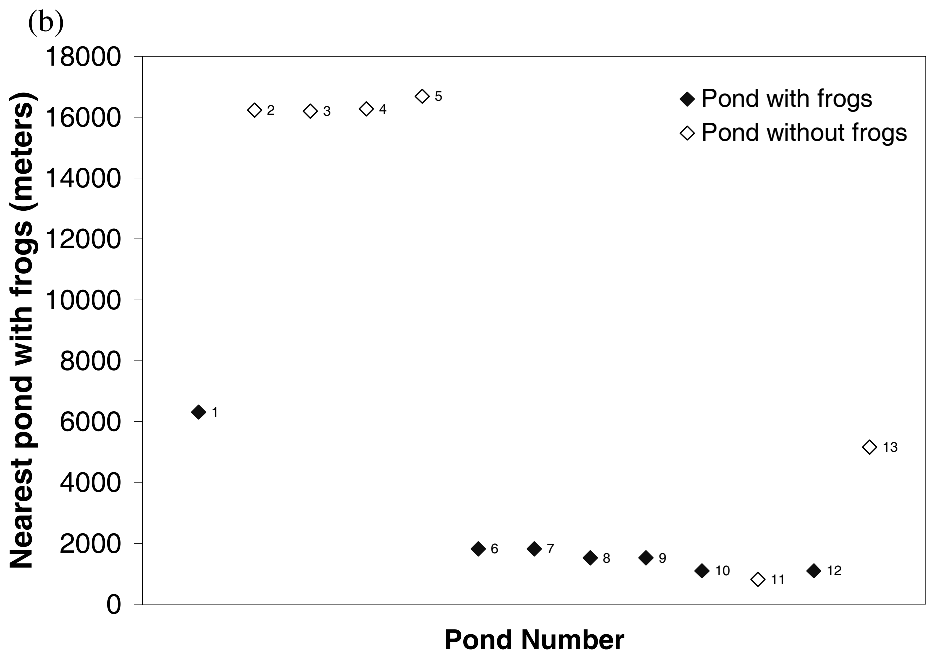


Figure 21. (a) The distance to the nearest pond with frogs, in meters, of ponds with (dark) and without (light) frogs; standard error is shown above each bar. * indicates significant difference with $p<0.05$, Wilcoxon test. (b) Distance, in meters, to the nearest pond with cricket frogs for each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

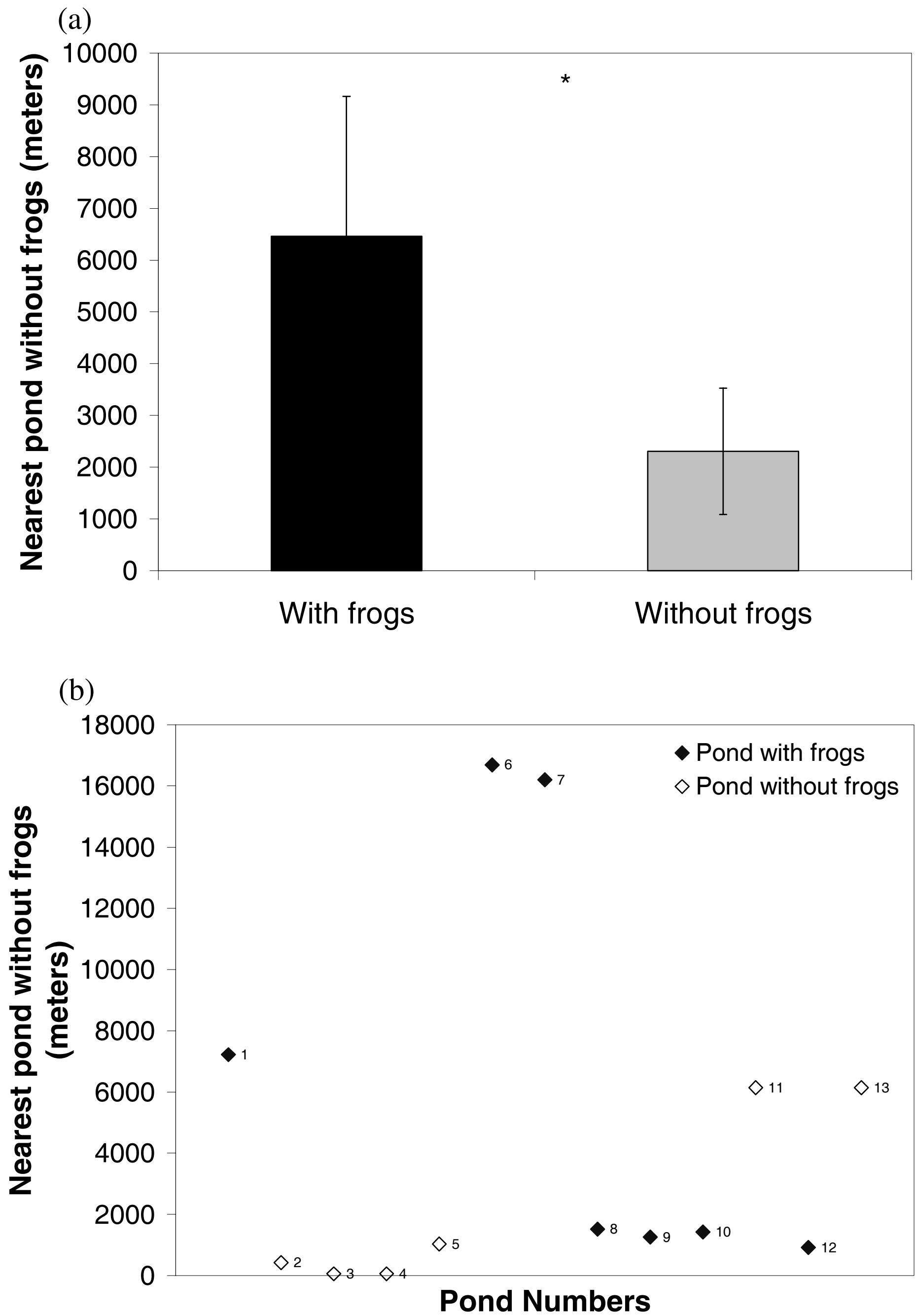


Figure 22. (a) The distance to the nearest pond without frogs, in meters, of ponds with (dark) and without (light) frogs; standard error is shown above each bar. * indicates significant difference with $p<0.05$, Wilcoxon test. (b) Distance, in meters, to the nearest pond without cricket frogs for each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

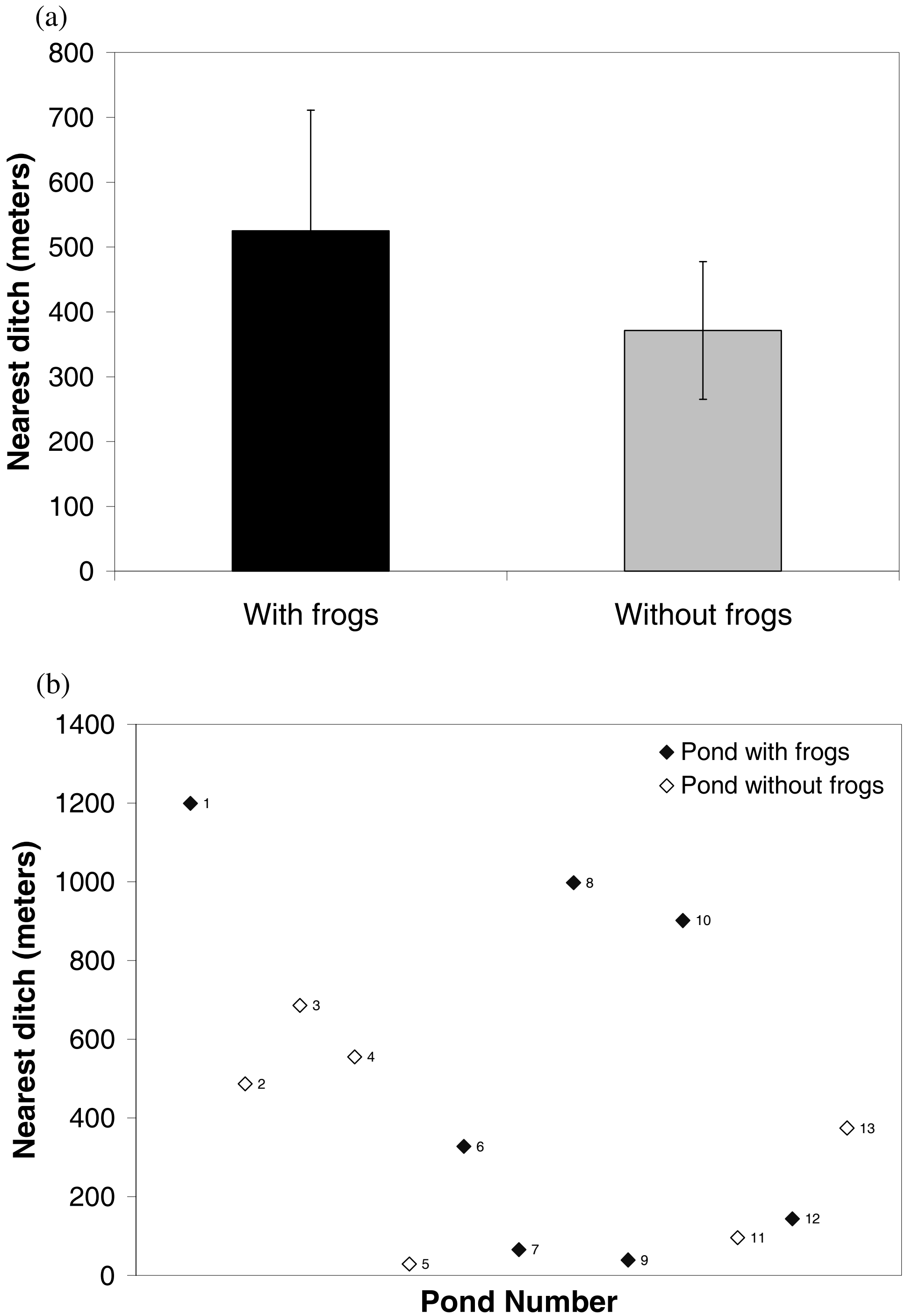
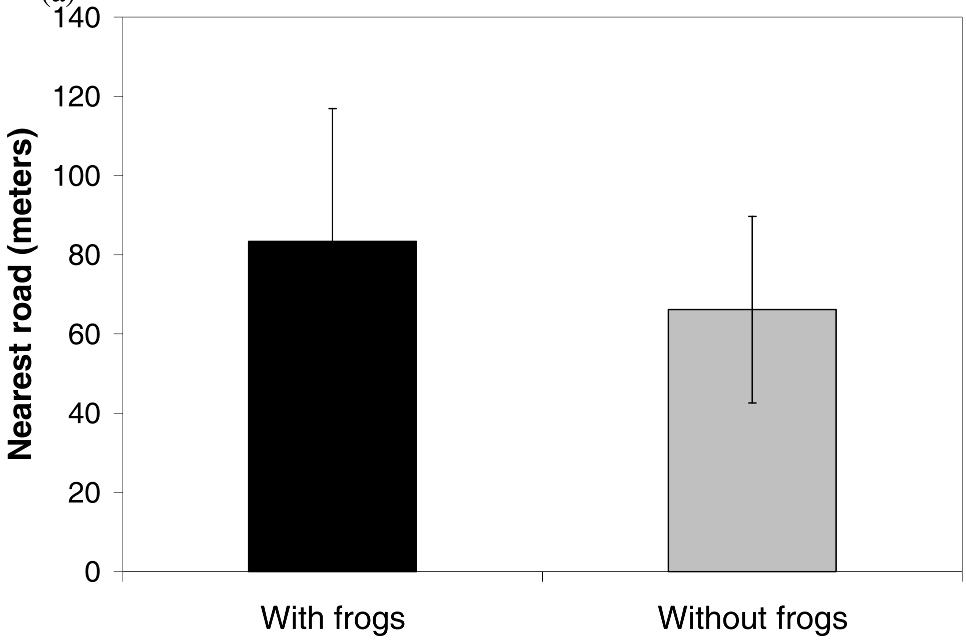


Figure 23. (a) The distance to the nearest ditch, in meters, of ponds with (dark) and without (light) frogs; standard error is shown above each bar. (b) Distance to the nearest ditch for each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

(a)



(b)

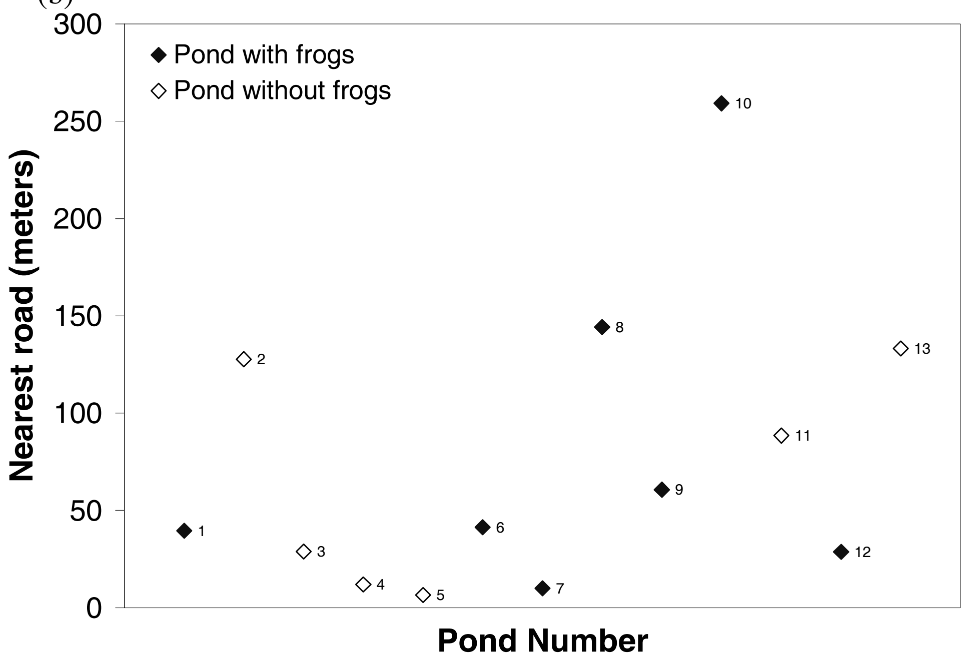


Figure 24. (a) The distance to the nearest road, in meters, of ponds with (dark) and without (light) frogs; standard error is shown above each bar. (b) Distance to the nearest road for each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

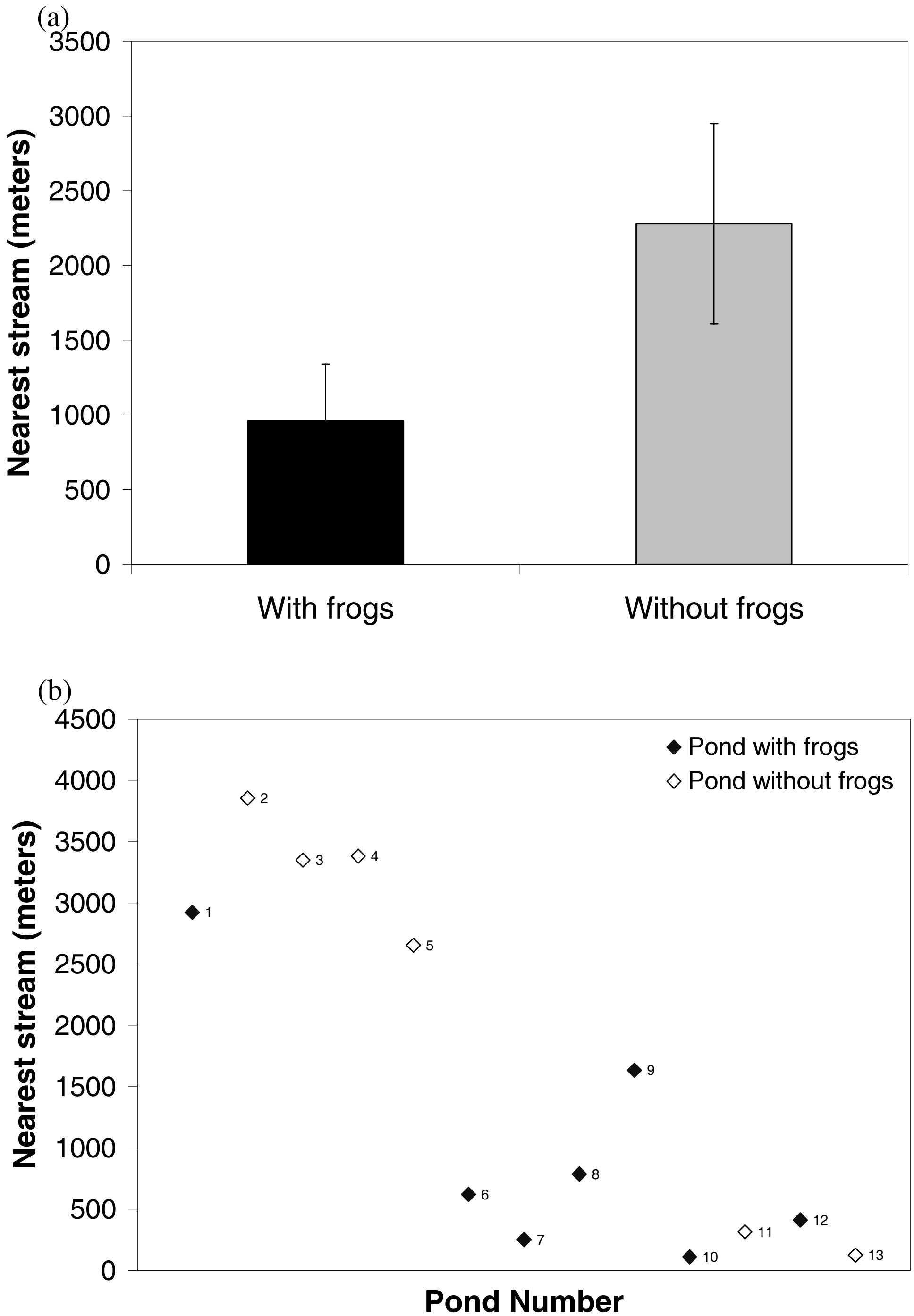


Figure 25. (a) The distance to the nearest stream, in meters, of ponds with (dark) and without (light) frogs; standard error is shown above each bar. (b) Distance to the nearest stream for each pond with (filled) and without (open) frogs; pond id is shown next to the symbols.

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