



Pilot Amphibian Monitoring at Apostle Islands, Pictured Rocks, and Sleeping Bear Dunes National Lakeshores

Analysis and Recommendations

Natural Resource Report NPS/GLKN/NRTR—2010/360



ON THE COVER

A green frog (*Lithobates clamitans*) in the Platte River at Sleeping Bear Dunes National Lakeshore, Michigan.
Photograph by the authors.

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Abstract

We performed pilot monitoring of amphibian populations in Apostle Islands National Lakeshore (APIS) in 2006, Pictured Rocks National Lakeshore (PIRO) in 2007, and Sleeping Bear Dunes National Lakeshore (SLBE) in both 2006 and 2007. Road-based, nighttime calling surveys were performed at SLBE and PIRO, and remote call recorders were used at APIS. We performed daytime surveys (using multiple methods) at a separate set of sites in all three parks. We detected 10 amphibian and two reptile species at APIS, nine amphibian and four reptile species at SLBE, and nine amphibian and one reptile species at PIRO. Temporal and spatial patterns of detection differed among species but were qualitatively similar across parks. Spring peepers, American toads, gray treefrogs, and green frogs tended to be the most commonly detected species, while leopard frogs, mink frogs, and most salamander species were detected less often. Our work resulted in two new species records (gray treefrog and green frog) for Basswood Island at APIS. We found that although daytime surveys allowed us to verify reproduction and resulted in detections that would not have occurred using nighttime surveys, nighttime surveys were faster, easier, more efficient, and generally resulted in more and higher-quality data per unit of time expended. No one daytime survey technique appeared to be superior to any other. We experienced multiple problems with remote recorders, but this technology did result in some detections that otherwise would not have occurred. We believe that future amphibian monitoring efforts in GLKN parks should focus mainly on road-based nighttime calling surveys, and that remote recorders have several problems that need to be overcome before they are useful in wide-scale monitoring; they are time-intensive with current (2006) technologies, which lack a consistently reliable automatic species-detection analysis of digital sound recordings. We suggest that at a minimum, spring peepers, gray treefrogs, American toads, and green frogs be the target species for monitoring. Finally, we advocate the continued use of three sampling seasons.

Introduction

The Great Lakes Inventory and Monitoring Network (hereafter GLKN or the Network) was formed by the National Park Service in 2000 and is one of 32 networks of parks that share common geography and management priorities. The purpose of GLKN is to inventory and monitor natural resources within nine national park units in Indiana, Michigan, Minnesota, and Wisconsin (Route and Elias 2007). In 2000, GLKN began a biological inventory of Network parks (Route 2000), and in 2002 the Network began planning a Vital Signs monitoring program. Vital Signs are defined as a select group of attributes that are particularly rich in the information needed to understand and manage NPS areas (Route 2004). Vital Signs were chosen in part based on how they reflect the health of park ecosystems, and how they respond (or are hypothesized to respond) to natural or anthropogenic stressors. A prioritized list of Vital Signs was finalized in 2004 and amphibian populations were one of the Vital Signs chosen for early development, with full monitoring protocol creation and implementation to be completed by the Network (Route and Elias 2007).

Amphibian populations were chosen as a Vital Sign for several reasons. Many species of amphibians need both aquatic and terrestrial habitats for life cycle completion, and therefore provide a biological link between land and water and the stressors of each (Stebbins and Cohen 1995; Semlitsch 2000). Amphibians often occur at high density and therefore occupy an important position in food webs while potentially dominating energy transfer between terrestrial and aquatic habitats (Stebbins and Cohen 1995; Welsh and Droege 2001; Gibbons et al. 2006). Finally, amphibians are sensitive to a wide variety of natural and anthropogenic stressors (Alford and Richards 1999; Boone et al. 2007; Davidson and Knapp 2007), and the worldwide decline of amphibian species diversity and abundance is well-documented (Wake 1991; Green 1997; Lannoo 2005).

Amphibians have often been suggested for use as indicators of environmental health (Wake 1991; Welsh and Droege 2001). However, the use of amphibians as “bioindicators” has an attendant set of challenges. Recruitment and population size of some species of amphibian are known to vary widely over short time periods (Pechmann et al. 1991), and the population dynamics of many amphibian species are characterized by relatively common extinction and colonization events (Skelly et al. 1999). Long-term monitoring is therefore necessary to reveal true population trends (Droege and Eagle 2005; Whiteman and Wissinger 2005). Amphibians are often secretive, and multiple survey visits using multiple survey methods may be necessary to detect various species (Bridges and Dorcas 2000; Weir et al. 2005; Fellers and Kleeman 2006). This combination of long-term, intensive monitoring and multiple methods means that thorough planning and field-testing are required for an efficient and effective program.

In 2006 and 2007, the GLKN performed pilot work surveying for amphibians within network management units. This pilot work had two primary objectives: 1) to gather information on species distribution and relative abundance for park inventories and as a baseline for future work and 2) to gain insight into the efficiency and effectiveness of various survey and research methods and of surveying different species and life-stages. The overall goal of the pilot work was to aid in the design of a long-term amphibian monitoring protocol that will provide data to test if changes in amphibian species distributions and relative abundances occur over time. The

ideal protocol will provide the maximum amount of information to park managers and staff at minimum cost.

Methods

Study Areas

We performed pilot work at Apostle Islands National Lakeshore (APIS) in 2006, Pictured Rocks National Lakeshore (PIRO) in 2007, and Sleeping Bear Dunes National Lakeshore (SLBE) in both 2006 and 2007. Apostle Islands National Lakeshore is located near Bayfield, Wisconsin, and consists of 21 islands and a 12-mile segment along the mainland shore of Lake Superior (Figure 1). The park is primarily hemlock-hardwood forest (but contains elements of southern boreal forest), and has a wide diversity of coastal features. About 190,000 people visit the park annually. Pictured Rocks National Lakeshore is headquartered in Munising, Michigan, and is located along the south-central shore of Lake Superior within a transition zone between the boreal and eastern deciduous forest (Figure 2). Wetlands are common throughout the park. About 450,000 people visit the park annually. Sleeping Bear Dunes National Lakeshore is headquartered in Empire, Michigan, along the northeastern shore of Lake Michigan (Figure 3). The park includes two large islands in Lake Michigan as well as 65 miles of Lake Michigan shoreline, 26 inland lakes, and four streams. About 1.2 million people visit the park annually (Route and Elias 2007).

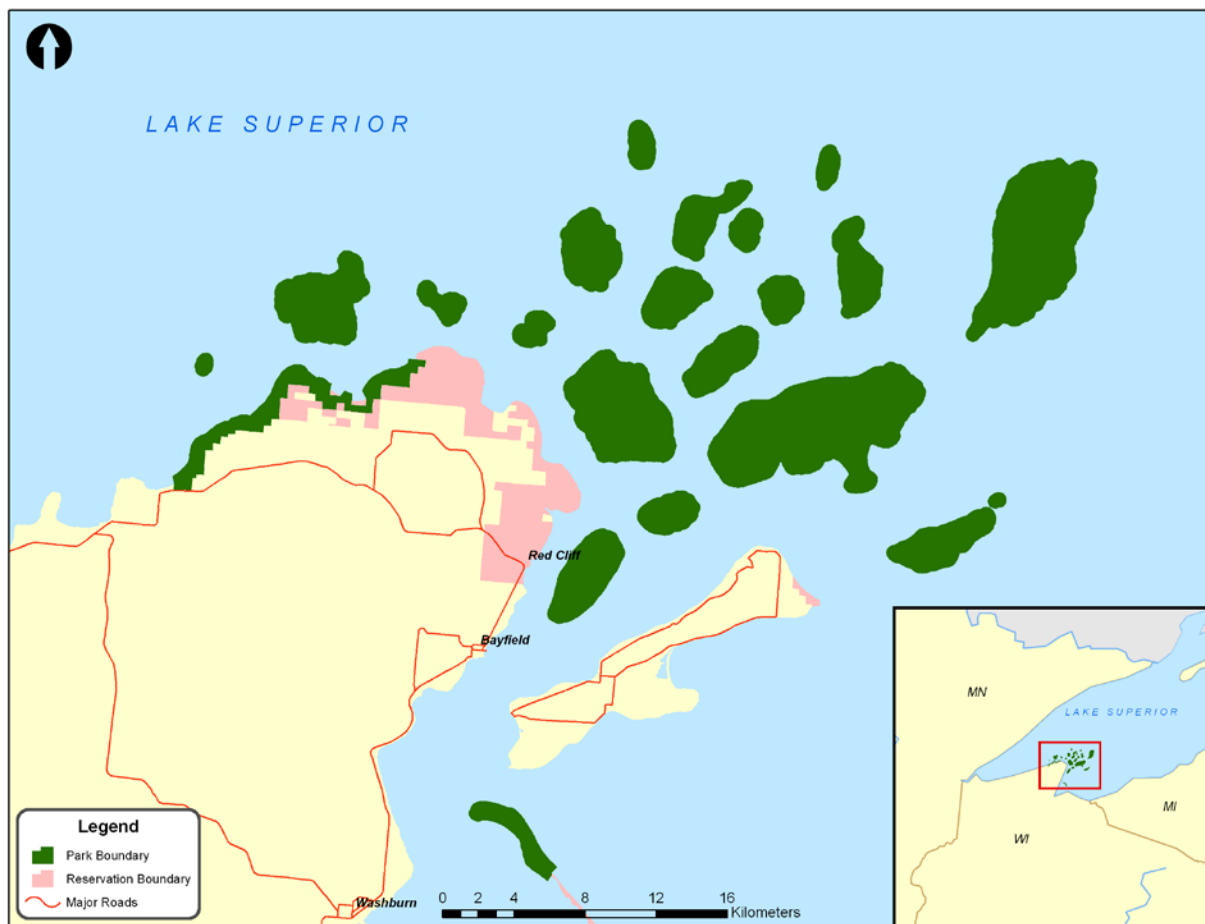


Figure 1. Apostle Islands National Lakeshore, Wisconsin.

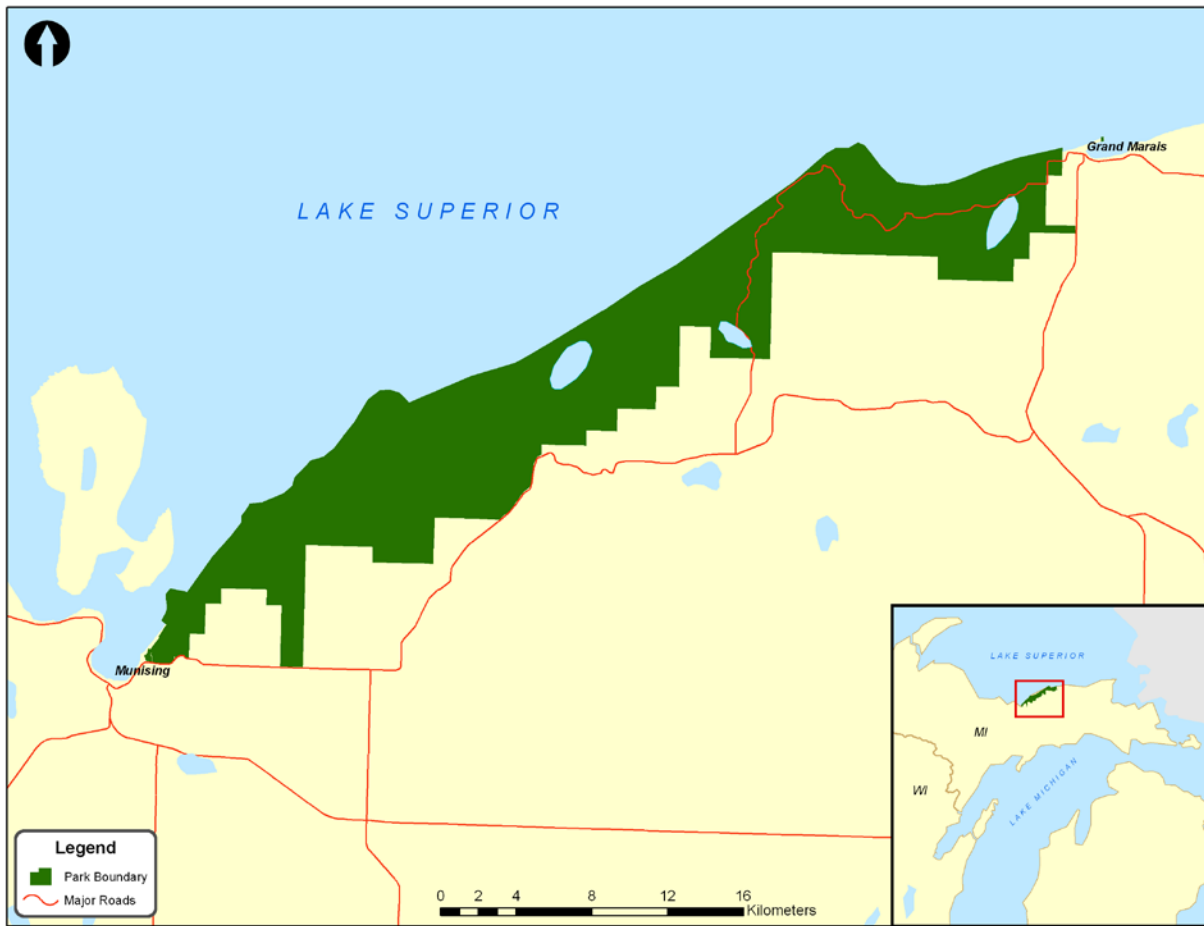


Figure 2. Pictured Rocks National Lakeshore, Michigan.

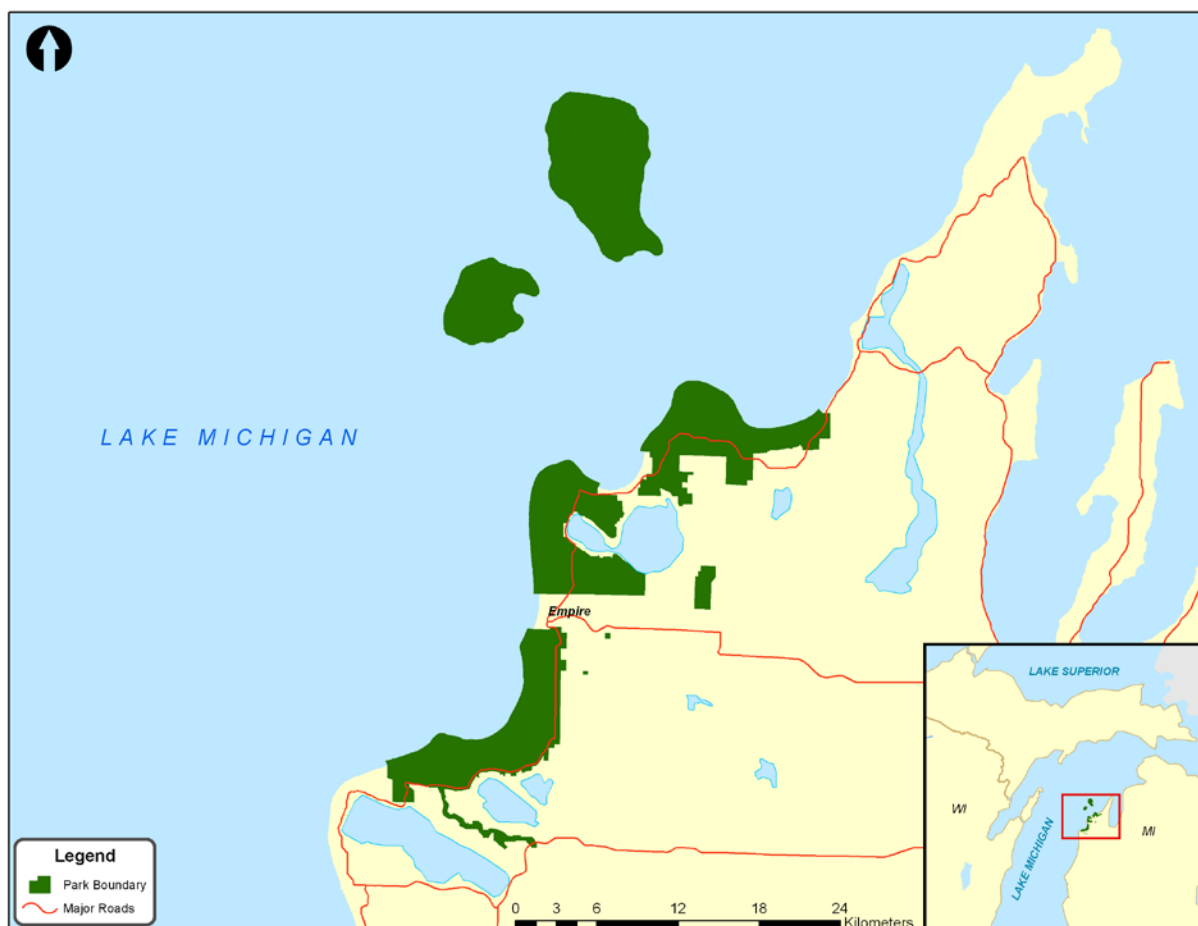


Figure 3. Sleeping Bear Dunes National Lakeshore, Michigan.

Daytime Surveys – Site Selection

Daytime survey sites were chosen by several methods, depending on the logistical difficulties present. At APIS, sampling of wetlands was constrained by numerous logistical factors. These included lake conditions and the availability of watercraft and qualified pilots. The resource management staff at APIS communicated that there were a limited number of permanent wetlands within the island group, and we sampled at all sites that staff identified.

Sampling of wetlands at SLBE was limited by several factors. The largest source of littoral habitats was Lake Michigan. However, much of this was unprotected, and thus too high-energy to be suitable as amphibian habitat. The wave action also created sandy bottoms without submerged or emergent vegetation along much of the coastline. Additionally, many water bodies had private in-holdings within the Lakeshore boundaries, and were thus not available for sampling. Water bodies known to the resource managers and that were not affected by the above constraints were therefore selected for sampling.

Site selection at PIRO was more quantitative. All wetlands from the NHD (National Hydrography Dataset) database with areas between 0.02 and 2.0 ha were assigned random

numbers, and the sites were subsequently sorted by these random numbers. The top 20 of this population of 108 water bodies were selected for possible sampling. The natural-resources staff at PIRO communicated which of these 20 sites they considered reasonable for sampling (i.e., relative accessibility of habitats, specifically whether the site could be travelled to, sampled, and returned from in one day's time).

This process resulted in 10 sites for APIS (Table 1, Figure 4), seven sites for SLBE (Table 1, Figure 5), and seven sites for PIRO (Table 1, Figure 6).

Table 1. Amphibian daytime survey points established for Pictured Rocks National Lakeshore (PIRO), Sleeping Bear Dunes National Lakeshore (SLBE), and Apostle Islands National Lakeshore (APIS). All UTM coordinates are in zone 16, map datum NAD83.

Site Name	Park	UTM	Description
7-Mile Creek	PIRO	5161148N 0555856E	Large Woodland Stream
Beaver Basin West	PIRO	5155510N 0547195E	Small Beaver Ponds
Beaver Basin East	PIRO	5155180N 0550152E	Stream and Beaver Pond
Chapel Road Stream	PIRO	5150238N 543352E	Small Woodland Stream
Chapel Road Beaver Pond	PIRO	5150037N 543446E	Large Beaver Pond
North Country Trail	PIRO	5150516N 0536729E	Ephemeral Beaver Pond Overflow
Chapel Road Alders	PIRO	5148021N 538918E	Large Alder Wetland
Martin Road	SLBE	4952464N 574658E	Small Open Woodland
Aral Lodge	SLBE	4953498N 572332E	Small Ephemeral
Kelderhouse	SLBE	4976506N 586029E	Large Wooded Lake-Bordering
Indian Trail East	SLBE	4951178N 566085E	Small Ridge-Swale Pothole
Indian Trail West	SLBE	4951008N 565270E	Small Ridge-Swale Pothole
Otter Creek	SLBE	4956877N 573285E	Large Stream
Platte River	SLBE	4953012N 567276E	Small River
Little Sand Bay	APIS	5201507N 660817E	Freshwater Lagoon
Basswood Quarry	APIS	5188995N 671152E	Flooded Quarry
Stockton Lagoon South	APIS	5198979N 686711E	Freshwater Lagoon
Stockton Lagoon North	APIS	5200021N 686767E	Freshwater Lagoon
Rocky Island South Swamp	APIS	5210070N 675907E	Lakeside Wetland
Sand River	APIS	5199788N 657097E	Freshwater Estuary
Michigan Lagoon	APIS	5194587N 689592E	Freshwater Lagoon
Outer Island Lagoon	APIS	5208464N 692856E	Freshwater Lagoon
Outer Island Beaver Pond	APIS	5209069N 694257E	Beaver Pond
Outer Lagoon North	APIS	5209328N 693184E	Freshwater Lagoon

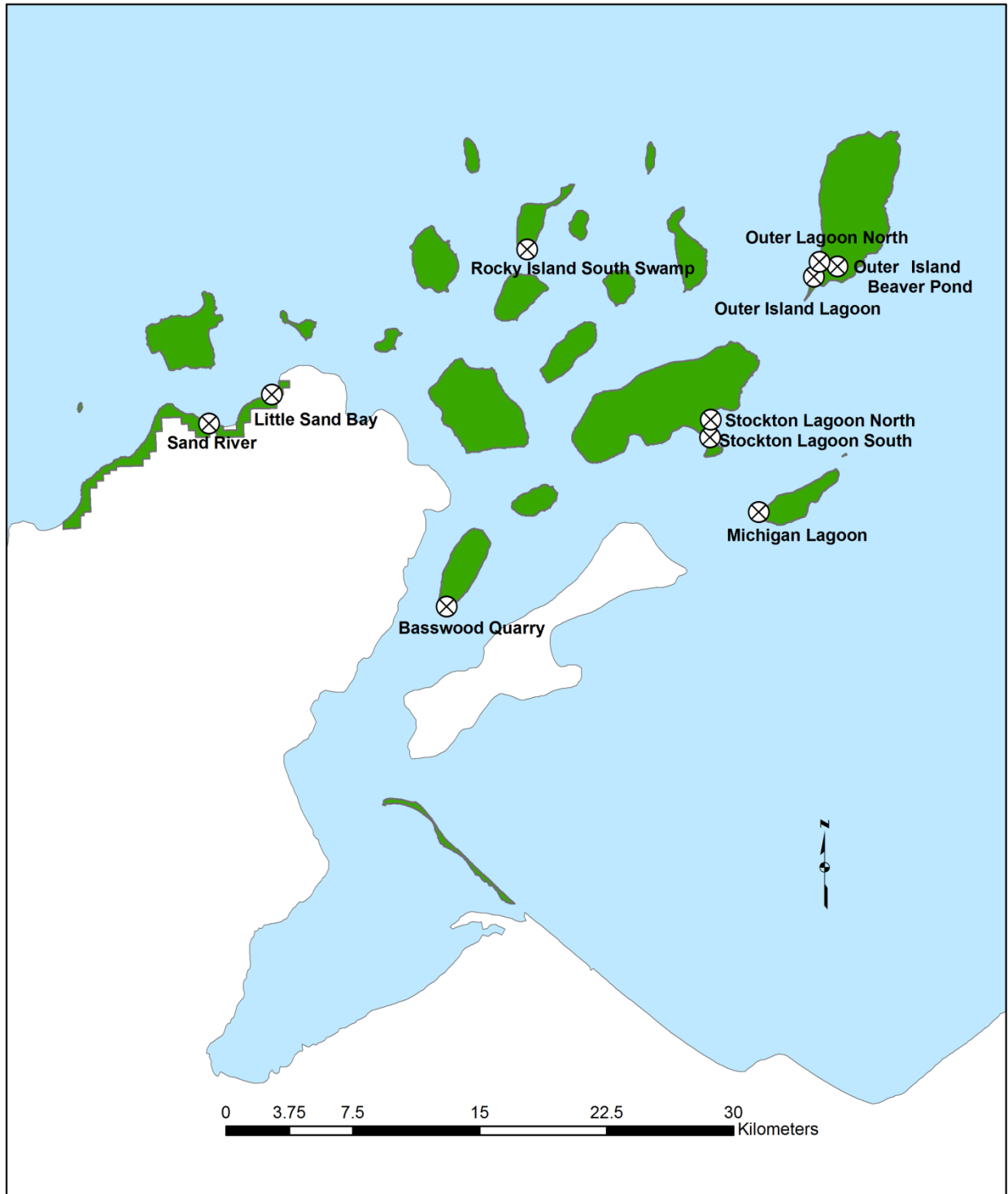


Figure 4. Daytime survey points for 2006 at Apostle Islands National Lakeshore, Wisconsin.

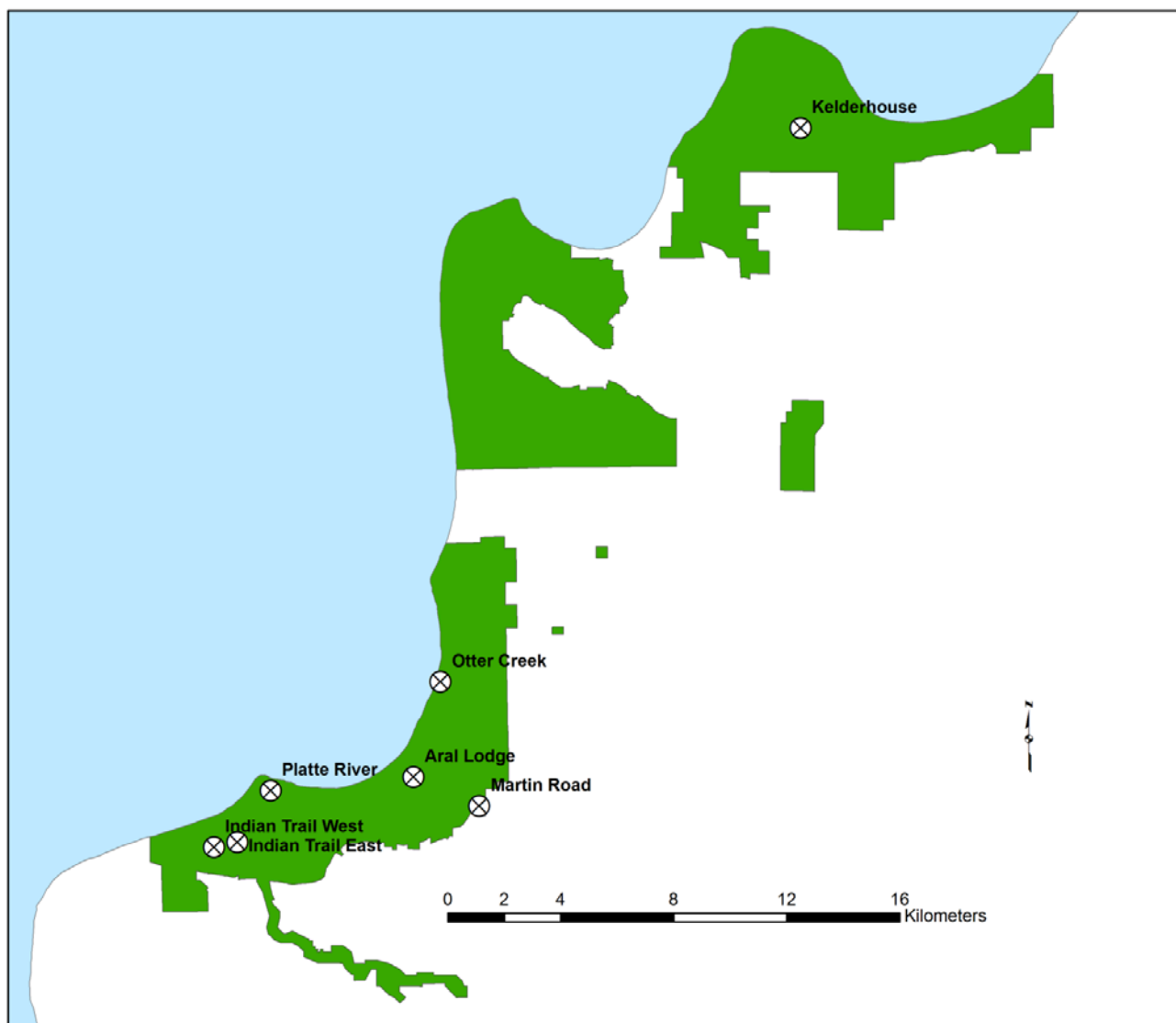


Figure 5. Daytime survey points for 2006 and 2007 at Sleeping Bear Dunes National Lakeshore, Michigan.

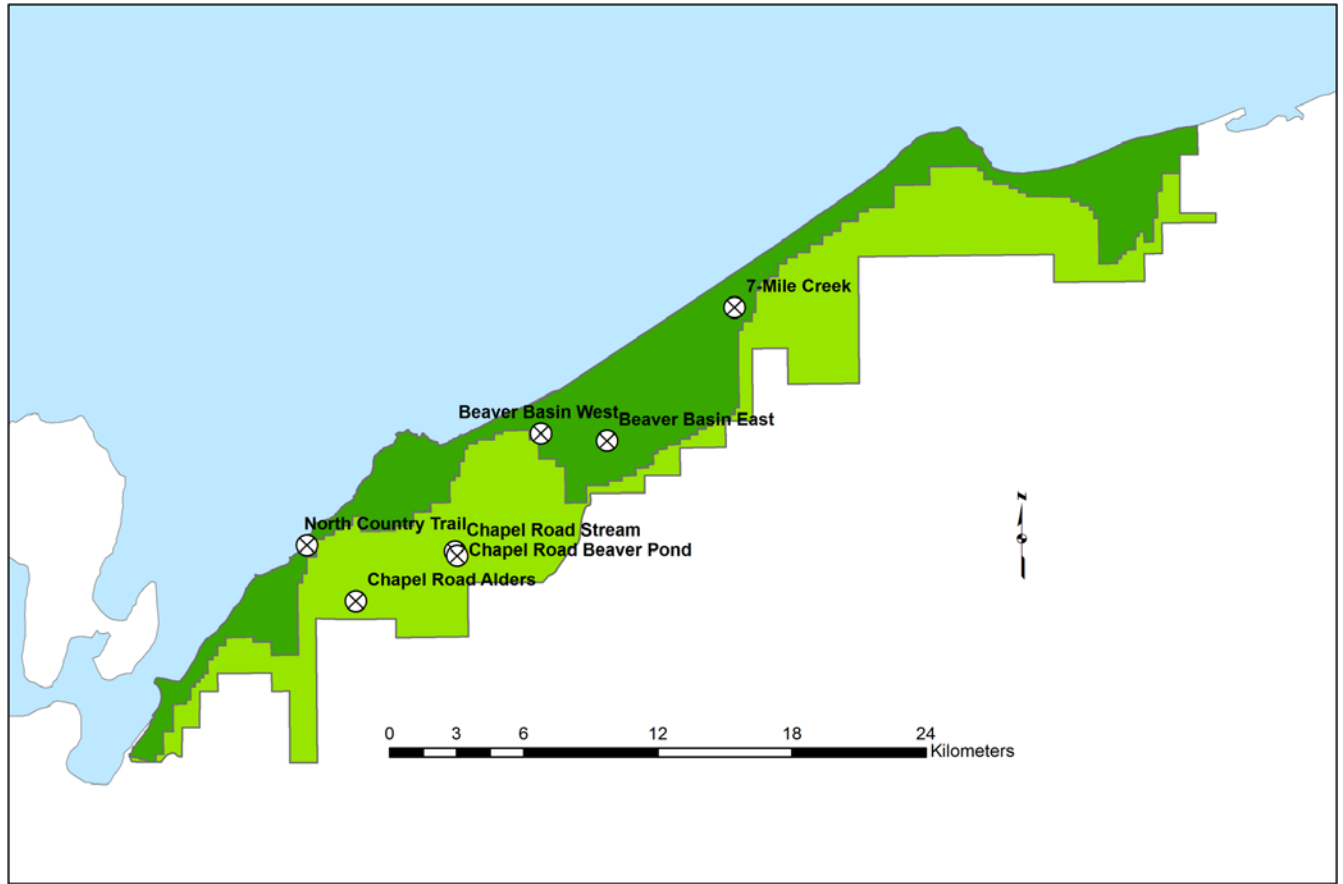


Figure 6. Daytime survey points for 2007 at Pictured Rocks National Lakeshore, Michigan (dark green is park land, light green represents the non-federal Inland Buffer Zone).

Daytime Surveys – Field Methods

Field methods for daytime surveys consisted of four components at each site: call survey, sampling of physical and chemical attributes of wetland, visual encounter survey (Heyer et al. 1994)/dip net sweep (Thoms et al. 1997), and perimeter search. We performed the surveys in that order if we arrived at the site in the AM, but performed call surveys last if we arrived in the PM. Two observers performed one of each type of survey at each site, or one observer performed two of each type of survey if two observers were unavailable. Where possible, daytime survey sites were sampled once each during each of three seasons (Weir and Mossman 2005; Table 2). The “early spring” season roughly corresponded to the period from early April to early May, the “late spring” season to the period from mid-May to early June, and the “summer” period from mid-June to early July (Table 3, Table 4).

Call surveys consisted of standing in an open location on the periphery of the site and listening for calling anurans for a ten-minute period. General methodology for call surveys followed Weir and Mossman (2005). We recorded the species calling, the maximum calling index value for each species (Weir and Mossman 2005), and the time to first detection (TTFD) for each species. We also recorded the ambient temperature (°C), barometric pressure (kPa), relative humidity

(%), and average wind speed (mph) during call surveys with Kestrel[®] 3500 weather meters (Nielsen-Kellerman Co., Boothwyn, PA).

Table 2. Sampling dates for daytime amphibian sampling sites at Apostle Islands National Lakeshore (APIS), Pictured Rocks National Lakeshore (PIRO), and Sleeping Bear Dunes National Lakeshore (SLBE).

Site	Year	Park	Visit 1	Visit 2	Visit 3	Visit 4
Basswood Quarry	2006	APIS	4/24	5/26	7/12	-
Stockton Lagoon South	2006	APIS	4/25	5/25	7/8	-
Stockton Lagoon North	2006	APIS	4/25	5/25	7/9	-
Rocky Island South Swamp	2006	APIS	4/28	5/24	7/6	-
Sand River	2006	APIS	4/29	5/27	7/11	-
Michigan Lagoon	2006	APIS	5/22	7/10	-	-
Outer Island Beaver Pond	2006	APIS	5/23	-	-	-
Little Sand Bay	2006	APIS	4/22	5/27	7/5	-
Outer Island Lagoon	2006	APIS	5/23	-	-	-
Outer Island North	2006	APIS	7/7	-	-	-
Otter Creek	2006	SLBE	5/9	5/14	6/10	6/14
	2007		4/30	5/16	5/18	6/18
Platte River	2006	SLBE	5/12	5/15	6/11	6/15
	2007		4/28	5/16	5/18	6/18
Aral Lodge	2006	SLBE	5/9	5/14	6/9	6/13
	2007		4/28	5/16	5/17	6/17
Kelderhouse	2006	SLBE	6/11	6/14	-	-
	2007		4/29	5/15	5/17	6/16
Indian Trail West	2006	SLBE	6/10	-	-	-
	2007		4/29	5/18	5/22	6/15
Indian Trail East	2006	SLBE	6/10	-	-	-
	2007		4/30	5/17	5/22	6/15
Martin Road	2006	SLBE	6/11	-	-	-
	2007		4/29	5/15	5/17	6/14
7-Mile Creek	2007	PIRO	5/8	6/6	7/2	-
Beaver Basin West	2007	PIRO	7/5	-	-	-
Beaver Basin East	2007	PIRO	7/3	-	-	-
Chapel Road Stream	2007	PIRO	5/9	6/1	6/30	-
Chapel Road Beaver Pond	2007	PIRO	5/9	6/2	7/1	-
North Country Trail	2007	PIRO	5/8	5/30	7/2	-
Chapel Road Alders	2007	PIRO	5/7	5/31	6/29	-

Table 3. Dates of surveys, type of survey, and approximate time spent conducting amphibian surveys at Apostle Islands National Lakeshore (APIS) and Sleeping Bear Dunes National Lakeshore (SLBE) in 2006. Estimates do not include set-up or travel time.

Park	Date	Survey Type	Hours (Night)	Hours (Day)
SLBE	4/9/06	Night	42 minutes	
SLBE	4/11/06	Night	7 hours 22 minutes	
SLBE	4/12/06	Night	10 hours 51 minutes	
SLBE	4/13/06	Night	5 hours 36 minutes	
SLBE	4/14/06	Night	8 hours 27 minutes	
SLBE	4/15/06	Night	5 hours 9 minutes	
APIS	4/22/06	Day		6 hours 11 minutes
APIS	4/24/06	Day		5 hours
APIS	4/25/06	Day		7 hours 32 minutes
APIS	4/28/06	Day		2 hours 10 minutes
APIS	4/29/06	Day		1 hour 21 minutes
SLBE	5/7/06	Night	7 hours 32 minutes	
SLBE	5/8/06	Night	9 hours 10 minutes	
SLBE	5/9/06	Both	7 hours 8 minutes	6 hours 22 minutes
SLBE	5/10/06	Night	5 hours 45 minutes	
SLBE	5/12/06	Day		2 hours 54 minutes
SLBE	5/14/06	Both	5 hours 26 minutes	5 hours 42 minutes
SLBE	5/15/06	Both	2 hours 34 minutes	3 hours 35 minutes
SLBE	5/16/06	Night	10 minutes	
APIS	5/22/06	Both	11 minutes	5 hours 12 minutes
APIS	5/23/06	Day		3 hours 11 minutes
APIS	5/24/06	Day		3 hours 32 minutes
APIS	5/25/06	Both	10 minutes	6 hours 13 minutes
APIS	5/26/06	Day		2 hours 7 minutes
APIS	5/27/06	Day		6 hours 17 minutes
SLBE	5/25/06	Night	1 hour 19 minutes	
SLBE	5/26/06	Night	1 hour 39 minutes	
SLBE	6/7/06	Night	8 hours 32 minutes	
SLBE	6/8/06	Night	8 hours 15 minutes	
SLBE	6/9/06	Day		3 hours 15 minutes
SLBE	6/10/06	Day		9 hours 41 minutes
SLBE	6/11/06	Day		8 hours 32 minutes
SLBE	6/13/06	Both	4 hours 27 minutes	3 hours 21 minutes
SLBE	6/14/06	Both	4 hours 24 minutes	5 hours 17 minutes
SLBE	6/15/06	Both	40 minutes	2 hours 40 minutes
APIS	7/5/06	Day		3 hours 54 minutes
APIS	7/6/06	Day		1 hour 14 minutes
APIS	7/7/06	Day		2 hours 29 minutes
APIS	7/8/06	Day		3 hours 15 minutes
APIS	7/9/06	Day		3 hours 1 minute
APIS	7/10/06	Day		2 hours 54 minutes
APIS	7/11/06	Day		3 hours 19 minutes
APIS	7/12/06	Day		3 hours

Table 4. Dates of surveys, type of survey, and approximate time spent conducting amphibian surveys at Pictured Rocks National Lakeshore (PIRO) and Sleeping Bear Dunes National Lakeshore (SLBE) in 2007. Estimates do not include set-up or travel time.

Park	Date	Survey Type	Hours (Night)	Hours (Day)
SLBE	4/22/07	Night	12 hours 4 minutes	
SLBE	4/23/07	Night	4 hours 13 minutes	
SLBE	4/24/07	Night	2 hours 20 minutes	
SLBE	4/27/07	Both	7 hours 37 minutes	2 hours 39 minutes
SLBE	4/28/07	Both	6 hours 39 minutes	3 hours 56 minutes
SLBE	4/29/07	Both	9 hours 48 minutes	8 hours 14 minutes
SLBE	4/30/07	Both	2 hours 32 minutes	5 hours 34 minutes
PIRO	5/4/07	Night	10 hours 18 minutes	
PIRO	5/5/07	Night	8 hours 38 minutes	
PIRO	5/6/07	Night	10 hours 11 minutes	
PIRO	5/7/07	Both	9 hours 48 minutes	2 hours 20 minutes
PIRO	5/8/07	Both	6 hours 37 minutes	4 hours 39 minutes
PIRO	5/9/07	Day		2 hours 25 minutes
SLBE	5/14/07	Night	3 hours 15 minutes	
SLBE	5/15/07	Day		6 hours 18 minutes
SLBE	5/16/07	Day		7 hours 12 minutes
SLBE	5/17/07	Day		9 hours 28 minutes
SLBE	5/18/07	Both	11 hours 22 minutes	7 hours 17 minutes
SLBE	5/21/07	Night	12 hours 51 minutes	
SLBE	5/22/07	Both	5 hours 32 minutes	5 hours 20 minutes
SLBE	5/23/07	Night	5 hours 34 minutes	
PIRO	5/30/07	Both	5 hours 50 minutes	2 hours 32 minutes
PIRO	5/31/07	Both	5 hours 28 minutes	1 hour 40 minutes
PIRO	6/1/07	Both	5 hours 4 minutes	1 hour 1 minute
PIRO	6/2/07	Both	5 hours 50 minutes	1 hour 58 minutes
PIRO	6/3/07	Night	5 hours 32 minutes	
PIRO	6/6/07	Day		2 hours 1 minute
PIRO	6/7/07	Night	2 hours 47 minutes	
PIRO	6/11/07	Night	1 hour 39 minutes	
PIRO	6/13/07	Night	2 hours 47 minutes	
PIRO	6/22/07	Night	1 hour 47 minutes	
SLBE	6/13/07	Night	8 hours 5 minutes	
SLBE	6/14/07	Both	8 hours 19 minutes	2 hours 18 minutes
SLBE	6/15/07	Both	8 hours 28 minutes	6 hours 40 minutes
SLBE	6/16/07	Both	7 hours 29 minutes	2 hours 30 minutes
SLBE	6/17/07	Both	5 hours	1 hour 30 minutes
SLBE	6/18/07	Day		4 hours 4 minutes
SLBE	6/21/07	Night	1 hour 47 minutes	
PIRO	6/29/07	Both	1 hour 10 minutes	1 hour 58 minutes
PIRO	6/30/07	Day		1 hour 20 minutes
PIRO	7/1/07	Day		2 hours 42 minutes
PIRO	7/2/07	Both	7 hours 58 minutes	4 hours 21 minutes
PIRO	7/3/07	Both	8 hours 46 minutes	2 hours 20 minutes
PIRO	7/4/07	Night	7 hours 48 minutes	
PIRO	7/5/07	Both	7 hours 45 minutes	1 hour 20 minutes

At each site, we recorded the water temperature ca. 1 m from the shoreline at a depth of ca. 2.5 cm. We also recorded the conductivity (mS) and pH at the same location using an Exstik (Extech

Instruments, Waltham, MA). We then measured the length and width of the wetland basin with a laser rangefinder, estimated the percentage of the wetland basin that contained surface water and the percentage of surface water that contained emergent vegetation, and estimated the percentage of the wetland basin that had canopy cover (these data are not provided in this report but are available from GLKN upon request).

For dip-net surveys, the observer walked a transect through the wetland while wearing polarized glasses. Transects were located arbitrarily (but far enough apart so that observers did not disturb each other) along the edge of open water and consisted of ten nodes, with each node being two-minutes in duration. At the end of each two-minute node, the observer performed a dip-net sweep (ca. 1 m in length). We recorded the species observed, the approximate number of individuals of each species, and the TTFD of each species for each two-minute node. We also recorded the species observed and the approximate number of each species for each dip-net sweep. Any ensnared animals were immediately released at the point of capture.

Perimeter surveys consisted of the observer walking along the land-water interface of the site or, alternatively, along the edge of the wetland basin if it was clearly defined. Starting points were located arbitrarily, but were far enough apart so that observers did not disturb each other while searching. Perimeter surveys were terminated after 20 minutes or when the site had been circumnavigated, whichever came first. We scrutinized the land/water interface for adult amphibians, larvae, and egg masses, and also looked under logs and other potential cover objects adjacent to the wetland. We recorded the species observed, the approximate number of individuals of each species, and the TTFD for each species.

Daytime Surveys – Analytical Methods

To analyze daytime survey data, we first organized species detections by year, park, site, method, and season. Detections were defined as an observation of a species at a given site, on a given day, using a given method. For example, if 20 green frogs (*Lithobates clamitans*) were detected by a dip-net survey at a given site on a given day, it was considered to be one detection of that species. If green frogs were also detected during the call survey at the same site on the same day, it was considered to be a separate detection. This approach allowed us to determine the species composition at each park and site, and to determine which species were most common (and most commonly detected) among sites without biasing our results toward species that are locally abundant or toward a particular survey technique. Accordingly, we also calculated the percentage of survey sites at which each detected species was found (naïve occupancy; Mackenzie et al. 2002).

We analyzed TTFD by first organizing species observations by year, park, season, method, and species. Observations were defined as any time that a species was observed during a perimeter survey, call survey, or any two-minute node of a dip-net survey. For example, if green frogs were observed during the perimeter survey and 4 dip-net nodes at a site on a given day, it was considered to be five observations. If a given species had at least 10 observations for which TTFD was recorded at a park using a particular method in a given season, we calculated the mean and standard deviation (mean $\pm$ 1 SD) of those observations. We then plotted the results for different species and seasons to determine if species differed in the amount of time that it

took observers to find them, or if the amount of time needed to find a species changed with season. All life stages for a given species were combined in this analysis.

Occasionally, we observed species at sites outside of the proscribed survey periods, and thus these species will not appear in the above analyses. We therefore compiled a separate list of species found outside of the survey periods at each site in each park, in order to provide a more complete accounting of the species present. We included any observed reptile species in this list. We also created a species-by-island matrix for Apostle Islands National Lakeshore. For all analyses, common and scientific names of species follow Crother (2008).

Nighttime Call Surveys – Site Selection

We performed standardized nighttime call surveys at SLBE in 2006 and at SLBE and PIRO in 2007. Due to the extensiveness and the legacy of road-based call surveys in the ecoregion and nationally (Weir and Mossman 2005), our initial effort for calling surveys involved limiting nighttime call surveys to roads. Thus, the area of inference for the nighttime call surveys is limited to a buffer around roads equal to the maximum distance at which species can effectively be heard. Nighttime surveys putatively allow for a greater number of sites to be sampled for a given budget, and should thus provide greater precision on estimates of site occupancy for understanding inter-annual trend within a given park unit. We recognize, however, that surveys conducted along roads are inherently biased because: a) the roads themselves are not randomly located (i.e., they are often routed around the wetland habitats preferred by many amphibians); b) road-associated stressors (e.g., road salts, noise and dust generated by vehicular traffic, discarded trash, vectors of non-native species) disproportionately affect wetlands at different distances from roads; and c) the road geometry itself creates unequal probabilities of including different sites (e.g., a site might be accessible from portions of two different roads) (D. Stevens, pers. comm.).

The National Wetlands Inventory (NWI) and National Hydrological Dataset (NHD) were not used directly in the site selection process because they contain many omissions of small or ephemeral wetlands (Peterson et al. 2005). Rather, Natural Resource Conservation Service Soil Survey Geographic Database information (NRCS SSURGO; <http://soildatamart.nrcs.usda.gov>) was used because the map unit design includes polygons where hydric soils may be a small component of the mapped unit, and includes areas of wetland that may be very small. This represents an intermediate approach between choosing only road areas immediately adjacent to large wetlands and choosing a random group of sites selected from the entire road network within a park unit. The former approach results in tracking only the highest-quality habitats within an area, which biases the program toward negative trends (i.e., loss of wetlands or species is the most likely outcome; Weir and Mossman 2005). In contrast, the latter approach may provide a large number of zero counts, making parameters more difficult to estimate and trends more difficult to detect (MacKenzie and Royle 2005; Weir and Mossman 2005).

To select sample sites, we created a 100-m buffer around the park boundary, and the roads and soil layers were clipped to this composite area (using the `_BUFFER` and `_CLIP` processes/commands/algorithms, respectively, in ArcGIS v9.x). Of this set of roads within the buffered park area, road segments were clipped to the hydric soils layer, meaning that only portions of roads occurring over SSURGO soil polygons that contained entirely or partially

hydric soils were retained. Next, we overlaid an 800-meter grid on the buffered park area. This 800-meter buffer represents the minimum distance that sampling locations must be separated by, according to NAAMP protocols (Weir and Mossman 2005). This threshold is intended to eliminate the possibility of aurally sampling the same wetland(s) from adjacent listening locations, and thus to ensure statistical independence of adjacent (i.e., closest) locations. Of all the 800-m grid cells within the park, we systematically removed every other cell to ensure further separation of adjacent listening locations, because roads rarely traveled through the centroid of each cell. From the remaining cells, we selected all cells that contained road segments that intersected hydric soil polygons. Thirty cells were randomly selected from this set. A point layer was then created by building centroids for each of the selected cells. Within each cell, the sampling location was chosen by identifying with an on-screen measuring tool (if necessary) the road segment closest to the centroid of each cell and then visually selecting a point approximately in the middle of that road segment. Given that roads are digitized using a series of vertices, each segment represents the longest straight distance that can be traveled before a new vertex is required to closely track the shape of the road (Figure 7). We selected a point in the middle of the segment to avoid points being selected at the edge of a wetland, where suitable habitat might be marginal. Typical lengths of selected road segments were much shorter than distances that frog calls can carry, so visually selecting the approximate center should not alter our results.

After initial ground-truthing, some selected sites could not be included because of accessibility problems (i.e., locked gates, private property), safety (i.e., at the base of a steep hill or around a sharp curve), or noise (usually due to high traffic). More points were selected using the same methods to ensure that the total number of sampling locations would meet the number of sites (30; suggested by *a priori* power analyses) necessary to robustly examine occupancy within a park unit. This method resulted in 30 sites for SLBE and 31 sites for PIRO (Table 5; Figure 8; Figure 9). Points were then divided up into three routes of 10 to 11 points based on geographic proximity, with each route to be completed by one or two observers on one night of sampling.

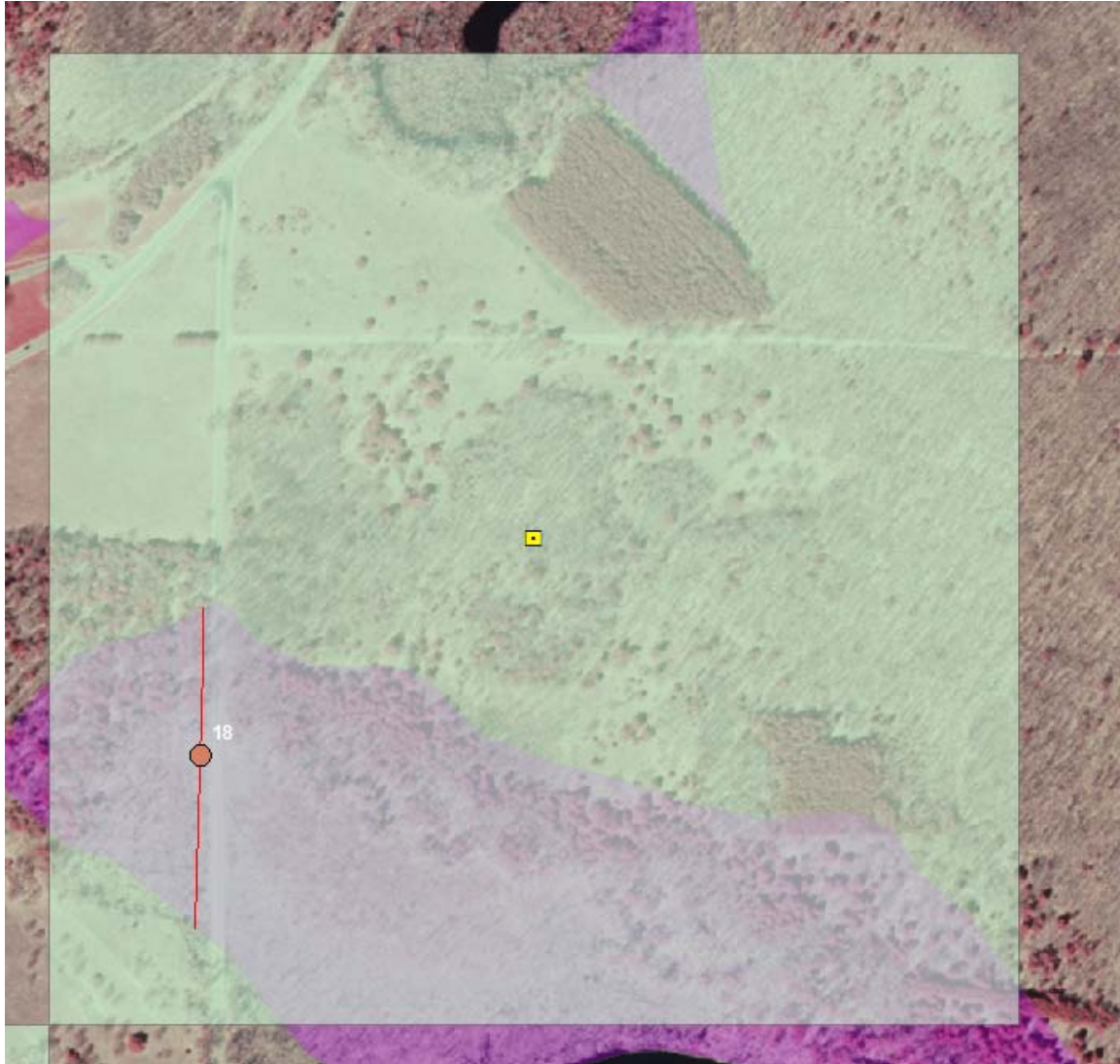


Figure 7. Example of grid cell (green square), centroid (yellow square), road segment (red line), and selected sampling point (18) for amphibian nighttime call surveys in Sleeping Bear Dunes National Lakeshore (Michigan) and Pictured Rocks National Lakeshore (Michigan).

Table 5. Amphibian nighttime call survey points established for Pictured Rocks National Lakeshore (PIRO) and Sleeping Bear Dunes National Lakeshore (SLBE). Points were divided into three nightly routes of 10-11 points each. All UTM coordinates are in zone 16, map datum NAD83.

Point	Route	UTM	Point	Route	UTM
PIRO P61	North	5167977N 576479E	SLBE A45	North	4975865N 593350E
PIRO P36	North	5166745N 575424E	SLBE A23	North	4977508N 588037E
PIRO P72	North	5165791N 574356E	SLBE A27	North	4979201N 586870E
PIRO P94	North	5163565N 569297E	SLBE A36	North	4978555N 587127E
PIRO P9	North	5164848N 567450E	SLBE A22	North	4974889N 588327E
PIRO P32	North	5165872N 565221E	SLBE A21	North	4976307N 585568E
PIRO P59	North	5167141N 564962E	SLBE A26	North	4978847N 584953E
PIRO P7	North	5168052N 564219E	SLBE A25	North	4979018N 583806E
PIRO P87	North	5166691N 561783E	SLBE A24	North	4978205N 584340E
PIRO P84	North	5165007N 561252E	SLBE A19	North	4976043N 583080E
PIRO P18	Central	5162595N 560149E	SLBE A18	Central	4973183N 582244E
PIRO P8	Central	5161765N 560136E	SLBE A17	Central	4972704N 581722E
PIRO P80	Central	5161668N 561078E	SLBE A16	Central	4971873N 577849E
PIRO P58	Central	5161091N 559558E	SLBE A43	Central	4970939N 577065E
PIRO P20	Central	5159373N 559327E	SLBE A14	Central	4966979N 577943E
PIRO P77	Central	5157820N 560481E	SLBE A13	Central	4965305N 578563E
PIRO P71	Central	5153810N 549623E	SLBE A11	Central	4960421N 575861E
PIRO P11	Central	5155164N 548719E	SLBE A10	Central	4960377N 574823E
PIRO P29	Central	5150312N 547734E	SLBE A9	Central	4958962N 574603E
PIRO P44	Central	5148881N 547223E	SLBE A31	Central	4957036N 573299E
PIRO P3	South	5149142N 545220E	SLBE A8	South	4954150N 574519E
PIRO P12	South	5147347N 543461E	SLBE A30	South	4952448N 572858E
PIRO P41	South	5148568N 542798E	SLBE A7	South	4953365N 572093E
PIRO P53	South	5149562N 541539E	SLBE A6	South	4953118N 567199E
PIRO P68	South	5151317N 541690E	SLBE A3	South	4950163N 569037E
PIRO P52	South	5147516N 539250E	SLBE A0	South	4946413N 573034E
PIRO P17	South	5142136N 535991E	SLBE A2	South	4950044N 567299E
PIRO P39	South	5141173N 535965E	SLBE A39	South	4951752N 566938E
PIRO P33	South	5146513N 534320E	SLBE A37	South	4948637N 567418E
PIRO P38	South	5141841N 530326E	SLBE A1	South	4949465N 564981E
PIRO P34	South	5143511N 530260E			

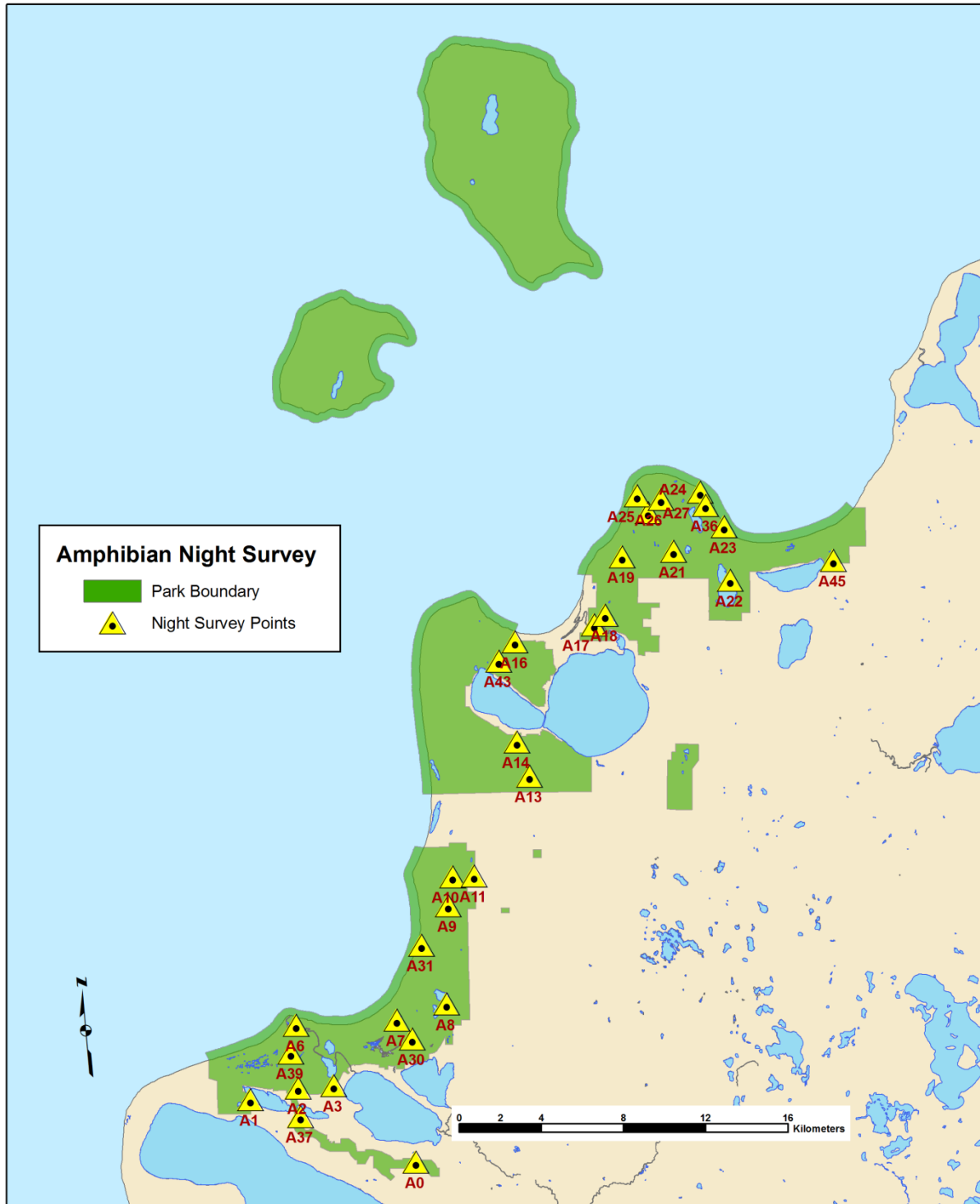


Figure 8. Nighttime call survey points for 2006 and 2007 at Sleeping Bear Dunes National Lakeshore, Michigan.

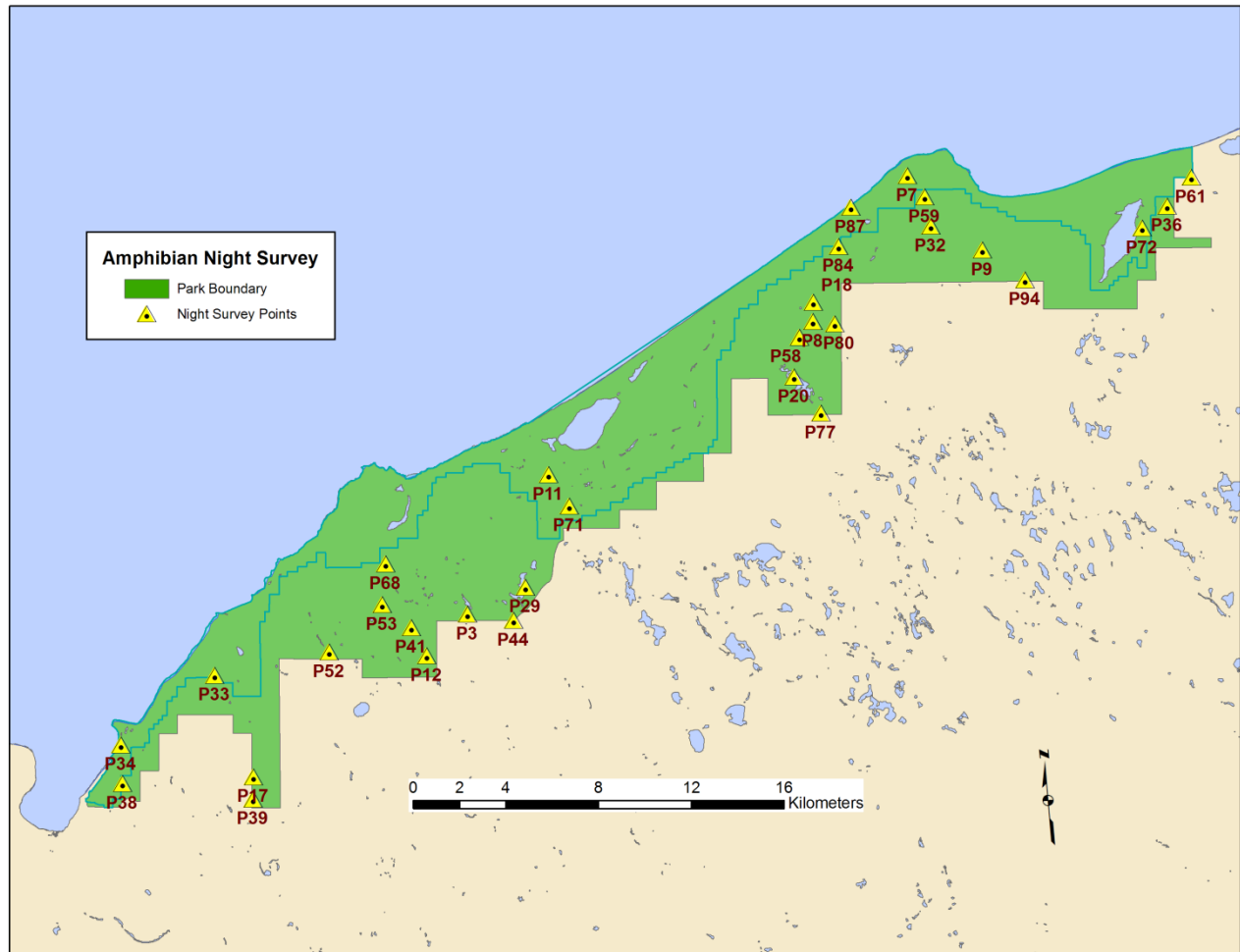


Figure 9. Nighttime call survey points for 2007 at Pictured Rocks National Lakeshore, Michigan.

Nighttime Call Surveys – Field Methods

In 2007, nighttime call surveys were conducted at a given park until each route had been surveyed at least four times in a season (Table 3; Table 4). The third and fourth surveys were conducted together by two independent observers, one with and one without a parabolic microphone and recorder, to compare the effectiveness of surveys with and without the microphone (the results of this comparison will be detailed in a separate publication). 2006 surveys were more sporadic, and fewer surveys were done during the summer season. However, each route was surveyed at least twice in each season, and at least two of the three routes were surveyed with a parabolic microphone in each season. In both years, we ran routes in different directions on different nights. For example, the “North” route at SLBE might first be run in a north to south direction, then in a south to north direction, and finally with all of the points alternated from north to south or south to north. The purpose of this was to avoid sampling points at the same time every night, and therefore maximize the probability of hearing species such as mink frogs (*Lithobates septentrionalis*; Lannoo 2005) that tend to vocalize at specific times. Where possible, routes were run by different observers on different nights to minimize observer bias.

We patterned our criteria for performing call surveys (i.e. whether or not we performed surveys on a given night) after the North American Amphibian Monitoring Protocol (Weir and Mossman 2005). We did not conduct surveys if there was heavy rain or lightning, if winds were consistently above 12 mph (ca. 19 kph), or if the ambient temperature was below the accepted level for a particular season (5.6 °C for early spring, 10 °C for late spring, 12.8 °C for summer). Surveys were begun one half hour after sunset and completed by 0100 hours. If a route was not completed by 0100 hours the remaining points were surveyed on the next available night.

At each site, we parked our vehicle at walked at least 5 m away from it. Using a tree branch or other available structure, we then hung a Kestrel[®] 3500 weather meter (Nielsen-Kellerman Co., Boothwyn, PA) at least 1 m off of the ground. We listened for 5 minutes at each site and for an additional 5 minutes at each third site to compare the efficacy of differing survey lengths (the results of this comparison will be detailed in a separate publication). Table 6 lists the variables that were recorded at each site. We recorded the amount of time that we were interrupted, if any, and added this amount of time to the end of the survey. We attempted to listen in each cardinal direction for an equal amount of time in order to maximize species detections.

Table 6. Variables and units (if applicable) that were recorded during amphibian nighttime call surveys at Pictured Rocks National Lakeshore (Michigan) in 2007 and Sleeping Bear Dunes National Lakeshore (Michigan) in 2006 and 2007. Water temperature was recorded only if there was standing water within 15 m of the listener.

Variable	Units
Species calling	-
Species calling index (Weir and Mossman 2005)	-
Number of cars passing	-
Elapsed time of interruption	minutes
Moon visibility (yes/no)	-
Precipitation (none/mist/light rain)	-
Sky code (Weir and Mossman 2005)	-
Average wind speed	miles per hour
Air temperature	degrees Celsius
Relative humidity	-
Barometric pressure	kilopascals
Water temperature	degrees Celsius
Azimuth of calling anurans	degrees
Time to first detection for each species	seconds

Nighttime Call Surveys – Analytical Methods

We compiled the species detected at each site and the number of sites at which each species was detected (naïve occupancy; MacKenzie et al. 2002) for each park and year. We also determined which species were heard in which seasons, both by constructing a species by season matrix and by plotting the proportion of total detections that a given species represented on a given night (standardized day of year) throughout the field season (Johnson and Batie 2001). In addition to this analysis, we summed the hours spent performing both daytime and nighttime surveys. We estimated occupancy and detectability by species and park using multi-model inference

(Mackenzie et al. 2002), and the results of these analyses will be detailed in a separate publication.

Nighttime Call Surveys – Wetland Route

Because our method of site selection for nighttime call surveys is unique, we created a separate route at SLBE with which to compare our results. This route was created by driving the roads of the park and identifying all wetlands (i.e., areas containing water) within visual range of the road. This effort resulted in 74 potential wetland survey sites. We arbitrarily selected 10 of these sites in the south region of the park to create a “wetland” route similar to those run by some state programs (Weir and Mossman 2005). We surveyed this wetland route twice in 2006 (both times in the late spring season) and three times in 2007 (once in each of the three sampling seasons). We analyzed the data collected from these routes by calculating naïve occupancy. We also included wetland routes in our calculations of hours spent performing surveys.

Nighttime Call Surveys – Remote Surveys

Apostle Islands National Lakeshore presented a challenge with regard to nighttime surveys because island sites are not easily reached after dark. Furthermore, staying overnight on an island means that only one site can be surveyed per evening. While we occasionally were able to stay overnight on islands to perform standard nighttime surveys at daytime sites, we also experimented with remote call recorders (Bridges and Dorcas 2000) to overcome the aforementioned logistical challenges.

We used Diasonic Voice Bank Digital recorders (Diasonic Co. Ltd., Anyang City, South Korea; Figure 10) programmed to record for one minute at one-hour intervals, beginning at 20:00 h and ending at 03:00 h. We placed recorders at Little Sand Bay (late spring; drop off 27 May 2006, pick up unknown), Basswood Quarry (early spring; drop off 24 April 2006, pick up 21 May 2006), and Stockton Lagoon (late spring; drop off 25 May 2006; pick up unknown). Pick up dates for two of the sites are unknown because these recorders were removed by park staff. We also placed a recorder at Little Sand Bay and Stockton Lagoon in early spring (22 April and 25 April, respectively) and at Basswood Quarry in late spring (26 May). Unfortunately, equipment malfunction prevented us from collecting any data from these three recorders.

Among the sample of daytime-sampling sites at APIS, macro-scale locations for call recorders were largely determined by the desire of APIS resource management staff to have recorders be easily accessible (for sustained logistical feasibility of retrieval and deployment of recorders). Thus, a recorder was placed on the most-accessible mainland location and on two islands (Basswood, Stockton) closest to the APIS boat-launch site just north of Bayfield. Micro-scale location of recorders reflected compromise between several objectives: a) location accessible on foot by GLKN monitoring staff and APIS resource management staff, once on the island (i.e., without a skiff); b) location within the aural-shed of portions of the wetland known or suspected (by virtue of habitat present) to contain amphibians; c) be sympatric with the area searched during the daytime surveys at the site; d) be sufficiently camouflaged that park visitors would not detect the recorder and thus remove, damage, or impair the recording device out of curiosity.

Once the units had been removed from the islands, we listened to the recordings using AKG Acoustics K240 Monitoring headphones (AKG Acoustics, Vienna, Austria). We logged the date,



Figure 10. The Diasonic Voice Bank remote call recorder (Diasonic Co. Ltd., Anyang City, South Korea) at Stockton Island Lagoon, Apostle Islands National Lakeshore, Wisconsin. This unit was placed on-site on 25 May 2006.

time, species, and calling index of each recorded call. We were careful to log only those recordings which were obviously anuran calls, thus eliminating the potential for false positives resulting from disturbance to the recorder, inadequate volume (i.e., quiet, indistinct, or distant calls), or interference.

Results

Daytime Surveys

We were unable to determine the number of detections or most common species with regard to season because not all sites were visited in all three seasons, and some sites were visited multiple times in one season (see Table 2). Furthermore, we were unable to quantitatively determine the utility of various methods based on detections because we were unable to perform all surveys during every visit at all sites. For these same reasons, naïve occupancy estimates and species and detections per site should be viewed with caution. Qualitatively, however, there appeared to be little difference in the quantity or diversity of detections among methods or seasons, with the possible exception of summer season surveys resulting in lower species diversity.

We detected a total of 10 amphibian species at APIS. Outer Island and Michigan Island had the most diverse herpetofaunas with five amphibian and two reptile species and six amphibian and one reptile species, respectively (Table 7). With regard to individual sampling sites (daytime sampling only), Michigan Lagoon and Rocky Island South Swamp had the most amphibian species (six). Basswood Quarry produced the largest number of amphibian detections (13), followed by Michigan Lagoon (11; Table 8). Naïve occupancy ranged from 90% of sites for the spring peeper (*Pseudacris crucifer*) to only one of ten sites for gray treefrogs (*Hyla versicolor*), mink frogs, blue-spotted salamanders (*Ambystoma laterale*), and four-toed salamanders (*Hemidactylium scutatum*; Table 9).

Table 7. Amphibian and reptile species detections by island at Apostle Islands National Lakeshore (Wisconsin) in 2006. This table includes data from both daytime and nighttime surveys.

Species	Basswood	Michigan	Outer	Rocky	Stockton
<i>Anaxyrus americanus</i>	X	X	X	X	X
<i>Pseudacris crucifer</i>	X	X	X	X	X
<i>Hyla versicolor</i>	X				X
<i>Lithobates clamitans</i>	X	X	X		X
<i>Lithobates sylvaticus</i>	X	X		X	
<i>Notophthalmus viridescens</i>		X	X		
<i>Hemidactylium scutatum</i>				X	
<i>Ambystoma laterale</i>				X	
<i>Ambystoma maculatum</i>	X	X	X	X	X
<i>Chrysemys picta</i>			X		X
<i>Thamnophis sirtalis</i>		X	X		

Table 8. Amphibian species detections by site, method, and season at Apostle Islands National Lakeshore (Wisconsin) in 2006. Results should be interpreted with caution because sites were not visited an equal number of times.

Species	Site	Method	Season ¹
<i>Anaxyrus americanus</i>	Rocky Island South Swamp	Dip Net Survey	LS
	Michigan Lagoon	Dip Net Survey	S
	Outer Island Lagoon	Perimeter Survey	LS
<i>Hyla versicolor</i>	Little Sand Bay	Dip Net Survey	LS
<i>Pseudacris crucifer</i>	Little Sand Bay	Call Survey	ES
	Basswood Quarry	Call Survey	ES, LS
		Dip Net Survey	ES, S
	Stockton Lagoon South	Call Survey	ES, LS
		Dip Net Survey	LS
	Stockton Lagoon North	Call Survey	LS
	Rocky Island South Swamp	Call Survey	LS
	Sand River	Call Survey	LS
		Perimeter Survey	LS
	Michigan Lagoon	Call Survey	LS
		Dip Net Survey	LS, S
	Outer Island Lagoon	Perimeter Survey	LS
	Outer Island Beaver Pond	Call Survey	LS
		Dip Net	LS
		Perimeter Survey	LS
<i>Lithobates clamitans</i>	Little Sand Bay	Call Survey	S
		Dip Net Survey	LS, S
		Perimeter Survey	S
	Basswood Quarry	Call Survey	S
		Dip Net Survey	LS, S
		Perimeter Survey	S
	Stockton Lagoon North	Dip Net Survey	S
	Sand River	Dip Net Survey	LS, S
		Perimeter Survey	LS, S
	Michigan Lagoon	Dip Net Survey	LS, S
		Perimeter Survey	S
	Outer Island Beaver Pond	Dip Net Survey	LS
		Perimeter Survey	LS
	Outer Lagoon North	Dip Net Survey	S
		Perimeter Survey	S
<i>Lithobates septentrionalis</i>	Sand River	Dip Net Survey	LS
<i>Lithobates sylvaticus</i>	Basswood Quarry	Dip Net Survey	LS, S
		Perimeter Survey	LS
	Rocky Island South Swamp	Dip Net Survey	LS
		Perimeter Survey	ES, LS
	Michigan Lagoon	Perimeter Survey	LS
<i>Ambystoma maculatum</i>	Basswood Quarry	Dip Net Survey	ES, LS
	Rocky Island South Swamp	Dip Net Survey	ES, LS
	Michigan Lagoon	Dip Net Survey	LS, S
	Stockton Lagoon South	Dip Net Survey	S
		Perimeter Survey	S
	Sand River	Dip Net Survey	S
		Dip Net Survey	LS
	Outer Island Beaver Pond	Perimeter Survey	LS
		Perimeter Survey	LS
	Outer Lagoon North	Perimeter Survey	S
<i>Notophthalmus viridescens</i>	Michigan Lagoon	Dip Net Survey	LS
	Outer Island Beaver Pond	Dip Net Survey	LS
<i>Ambystoma laterale</i>	Rocky Island South Swamp	Perimeter Survey	LS
<i>Hemidactylium scutatum</i>	Rocky Island South Swamp	Perimeter Survey	LS

¹ES = early spring, LS = late spring, S = summer

Table 9. Number of daytime sampling sites at which amphibian species were detected and naïve occupancy (percent of sites occupied by amphibian species) for Apostle Islands National Lakeshore in 2006 (APIS), Pictured Rocks National Lakeshore in 2007 (PIRO), and Sleeping Bear Dunes National Lakeshore in 2006 and 2007 (SLBE). Results should be interpreted with caution because sites were not visited an equal number of times, and nighttime surveys are not included.

Species	Park	Year	Number of Sites	Naïve Occupancy (%)
<i>Anaxyrus americanus</i>	APIS	2006	3	30
	SLBE	2006	2	28.6
	SLBE	2007	1	14.3
	PIRO	2007	3	42.9
<i>Hyla versicolor</i>	APIS	2006	1	10
	SLBE	2006	1	14.3
	SLBE	2007	5	71.4
	PIRO	2007	2	28.6
<i>Pseudacris crucifer</i>	APIS	2006	9	90
	SLBE	2006	5	71.4
	SLBE	2007	5	71.4
	PIRO	2007	5	71.4
<i>Lithobates clamitans</i>	APIS	2006	7	70
	SLBE	2006	6	85.7
	SLBE	2007	6	85.7
	PIRO	2007	7	100
<i>Lithobates pipiens</i>	SLBE	2007	2	28.6
	PIRO	2007	1	14.3
<i>Lithobates septentrionalis</i>	APIS	2006	1	10
	PIRO	2007	1	14.3
<i>Lithobates sylvaticus</i>	APIS	2006	3	30
	SLBE	2006	2	28.6
	SLBE	2007	2	28.6
	PIRO	2007	2	28.6
<i>Notophthalmus viridescens</i>	APIS	2006	2	20
	SLBE	2006	1	14.3
	SLBE	2007	1	14.3
	PIRO	2007	1	14.3
<i>Plethodon cinereus</i>	SLBE	2006	2	28.6
	SLBE	2007	3	42.9
	PIRO	2007	1	14.3
<i>Hemidactylium scutatum</i>	APIS	2006	1	10
<i>Ambystoma laterale</i>	APIS	2006	1	10
<i>Ambystoma maculatum</i>	APIS	2006	7	70
	SLBE	2007	1	14.3

We detected a total of nine amphibian species and four reptile species at SLBE over two years (Table 10, Table 11). In 2006, Aral Lodge and Indian Trail West had the most amphibian species (five). Aral Lodge produced the largest number of amphibian detections (seven), followed by Indian Trail West (six; Table 10). Naïve occupancy ranged from 85.7% of sites for the green frog to only one of seven sites for gray treefrogs and central newts (*Notophthalmus viridescens*; see Table 9). Outside of the survey periods, we observed green frogs at Aral Lodge and northern leopard frogs (*Lithobates pipiens*) at Indian Trail West. If combined with survey data, this results in an occupancy of 100% at daytime sites for green frogs in 2006. The only reptile species that

we observed in 2006 were the eastern gartersnake (*Thamnophis sirtalis*) at Otter Creek and the northern ribbonsnake (*Thamnophis sauritus*) at Aral Lodge and Indian Trail East.

In 2007, Indian Trail West had the most amphibian species (five), followed by Platte River, Kelderhouse, and Indian Trail East (four each). Martin Road produced the largest number of amphibian detections (14), followed by Indian Trail West and Platte River (12 each; Table 11). However, detections at Martin Road were dominated by green frogs and spring peepers. Naïve occupancy ranged from 85.7% of sites for the green frog to only one of seven sites for American toads (*Anaxyrus americanus*), spotted salamanders (*Ambystoma maculatum*), and central newts (see Table 9). We observed eastern gartersnakes at Platte River, Indian Trail East and Indian Trail West and northern ribbonsnakes at Aral Lodge, Indian Trail East, and Indian Trail West. We also observed painted turtles (*Chrysemys picta*) at Indian Trail East and Martin Road and snapping turtles (*Chelydra serpentina*) at Platte River, Indian Trail West, and Martin Road.

Table 10. Amphibian species detections by site, method, and season at Sleeping Bear Dunes National Lakeshore (Michigan) in 2006. Results should be interpreted with caution because sites were not visited an equal number of times.

Species	Site	Method	Season ¹
<i>Anaxyrus americanus</i>	Aral Lodge	Call Survey	LS
		Dip Net Survey	S
<i>Hyla versicolor</i>	Indian Trail West	Dip Net Survey	S
<i>Pseudacris crucifer</i>	Aral Lodge	Call Survey	LS
		Dip Net Survey	LS
<i>Lithobates clamitans</i>	Platte River	Call Survey	LS
	Aral Lodge	Dip Net Survey	S
	Indian Trail West	Dip Net Survey	S
	Indian Trail East	Dip Net Survey	S
	Kelderhouse	Dip Net Survey	S
<i>Lithobates sylvaticus</i>	Otter Creek	Call Survey	S
		Dip Net Survey	LS, S
		Perimeter Survey	LS, S
	Platte River	Dip Net Survey	LS, S
		Perimeter Survey	LS, S
	Indian Trail West	Call Survey	S
		Perimeter Survey	S
	Indian Trail East	Call Survey	S
		Perimeter Survey	S
	Kelderhouse	Call Survey	S
		Dip Net Survey	S
		Perimeter Survey	S
<i>Notophthalmus viridescens</i>	Martin Road	Call Survey	S
		Perimeter Survey	S
<i>Plethodon cinereus</i>	Aral Lodge	Dip Net Survey	S
	Indian Trail East	Dip Net Survey	S
<i>Notophthalmus viridescens</i>	Indian Trail West	Dip Net Survey	S
<i>Plethodon cinereus</i>	Aral Lodge	Perimeter Survey	LS
	Indian Trail West	Perimeter Survey	S

¹ LS = late spring, S = summer

Table 11. Amphibian species detections by site, method, and season at Sleeping Bear Dunes National Lakeshore (Michigan) in 2007. Results should be interpreted with caution because sites were not visited an equal number of times.

Species	Site	Method	Season ¹
<i>Anaxyrus americanus</i> <i>Hyla versicolor</i>	Kelderhouse	Call Survey	LS
	Platte River	Call Survey	LS
		Perimeter Survey	LS
	Aral Lodge	Perimeter Survey	LS
	Indian Trail West	Call Survey	LS
		Dip Net Survey	LS
		Perimeter Survey	LS
	Indian Trail East	Call Survey	ES, LS
		Dip Net Survey	LS
		Perimeter Survey	LS
	Martin Road	Call Survey	LS
		Dip Net Survey	ES
		Perimeter Survey	LS
	Otter Creek	Call Survey	ES
	Aral Lodge	Call Survey	LS
		Dip Net Survey	LS
<i>Pseudacris crucifer</i>	Indian Trail West	Dip Net Survey	LS
	Kelderhouse	Call Survey	ES, LS
	Martin Road	Call Survey	ES, LS
		Dip Net Survey	LS
		Perimeter Survey	LS
	Otter Creek	Dip Net Survey	ES, LS, S
<i>Lithobates clamitans</i>	Platte River	Perimeter Survey	ES, LS, S
		Call Survey	S
	Indian Trail West	Dip Net Survey	ES, LS, S
		Perimeter Survey	ES, LS, S
		Call Survey	S
	Indian Trail East	Dip Net Survey	LS, S
		Perimeter Survey	LS, S
		Call Survey	LS, S
	Kelderhouse	Dip Net Survey	LS, S
		Perimeter Survey	LS, S
		Call Survey	S
	Martin Road	Dip Net Survey	ES, LS, S
		Perimeter Survey	LS, S
		Call Survey	LS, S
<i>Lithobates pipiens</i>	Platte River	Perimeter Survey	LS, S
	Indian Trail East	Call Survey	ES
<i>Lithobates sylvaticus</i>	Platte River	Perimeter Survey	LS
	Kelderhouse	Perimeter Survey	ES
<i>Ambystoma maculatum</i>	Martin Road	Perimeter Survey	LS
<i>Notophthalmus viridescens</i>	Indian Trail West	Dip Net Survey	LS
<i>Plethodon cinereus</i>	Aral Lodge	Perimeter Survey	LS
	Indian Trail West	Perimeter Survey	ES, LS
	Indian Trail East	Perimeter Survey	LS

¹ ES = early spring, LS = late spring, S = summer

We detected a total of nine amphibian species and one reptile species at PIRO (Table 12). North Country Trail had the most amphibian species (six), followed by Chapel Road Alders and Chapel Road Beaver Pond (four each). North Country Trail produced the largest number of amphibian detections (11), followed by Chapel Road Beaver Pond (eight; Table 12). Naïve occupancy ranged from 100% of sites for the green frog to only one of seven sites for northern leopard frogs, mink frogs, central newts, and eastern red-backed salamanders (*Plethodon cinereus*; see Table 9). Outside of the survey periods, we observed American toads at Beaver Basin West and Chapel Road Alders. The only reptile species that we observed at PIRO was the eastern gartersnake (*Thamnophis sirtalis*) at North Country Trail.

At APIS, four species (spotted salamanders, spring peepers, green frogs, and wood frogs [*Lithobates sylvaticus*]) provided enough data to analyze TTFD for dip-net surveys. The results suggested that TTFD does not differ between species for this method, at least within the summer sampling season (Figure 11). There were insufficient data to compare individual species among seasons. One species, spring peepers, provided enough data to analyze call survey TTFD ($N = 11$, mean ± 1 SD = 255.27 s $\pm$ 182.16 s). This result suggests that time to first detection is longer for call surveys than for dip-net surveys. No species provided sufficient data to analyze TTFD for perimeter surveys.

Table 12. Amphibian species detections by site, method, and season at Pictured Rocks National Lakeshore (Michigan) in 2007. Results should be interpreted with caution because sites were not visited an equal number of times.

Species	Site	Method	Season ¹
<i>Anaxyrus americanus</i>	Chapel Road Stream	Perimeter Survey	LS
	Chapel Road Beaver Pond	Call Survey	ES
	North Country Trail	Call Survey	ES
		Dip Net Survey	ES
<i>Hyla versicolor</i>	North Country Trail	Call Survey	ES
		Dip Net Survey	LS
	Chapel Road Alders	Call Survey	ES
<i>Pseudacris crucifer</i>	7-Mile Creek	Call Survey	ES
	Chapel Road Stream	Call Survey	ES
	Chapel Road Beaver Pond	Call Survey	ES
	North Country Trail	Call Survey	ES
	Chapel Road Alders	Call Survey	ES
		Dip Net Survey	LS
		Perimeter Survey	ES
<i>Lithobates clamitans</i>	7-Mile Creek	Perimeter Survey	S
	Beaver Basin West	Call Survey	S
		Perimeter Survey	S
	Beaver Basin East	Dip Net Survey	S
		Perimeter Survey	S
	Chapel Road Stream	Call Survey	S
		Perimeter Survey	ES, LS
	Chapel Road Beaver Pond	Call Survey	LS
		Dip Net Survey	ES, LS
		Perimeter Survey	LS, S
	North Country Trail	Dip Net Survey	LS, S
		Perimeter Survey	LS
	Chapel Road Alders	Dip Net Survey	LS, S
	North Country Trail	Dip Net Survey	LS
<i>Lithobates pipiens</i>	Chapel Road Beaver Pond	Call Survey	S
<i>Lithobates septentrionalis</i>	North Country Trail	Dip Net Survey	ES
<i>Lithobates sylvaticus</i>		Perimeter Survey	LS
	Chapel Road Alders	Call Survey	ES
<i>Notophthalmus viridescens</i>	Beaver Basin West	Perimeter Survey	S
<i>Plethodon cinereus</i>	Beaver Basin West	Perimeter Survey	S

¹ ES = early spring, LS = late spring, S = summer

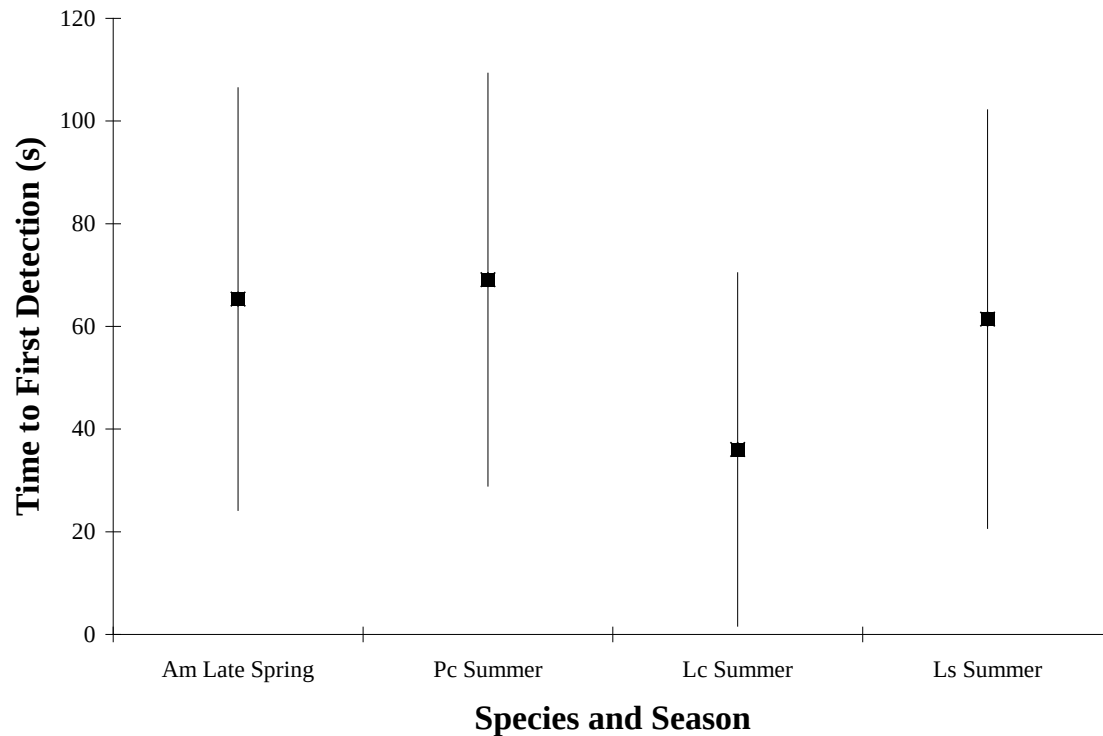


Figure 11. Time to first detection (mean $\pm$ 1 SD) for *Ambystoma maculatum* (Am; N = 28), *Pseudacris crucifer* (Pc; N = 10), *Lithobates clamitans* (Lc; N = 53), and *Lithobates sylvaticus* (Ls; N = 12) adults, metamorphs, larvae, and eggs during two-minute nodes of dip net surveys at Apostle Islands National Lakeshore (Wisconsin) in 2006.

At SLBE in 2006, three species (American toads, spring peepers, and green frogs) provided enough data to analyze TTFD for dip-net surveys. The results suggested that TTFD does not differ between species for this method, at least within the summer sampling season. In addition, TTFD does not appear to differ between the late spring and summer sampling seasons for green frogs (Figure 12). One species, green frogs, provided enough data to analyze perimeter survey TTFD (N = 13, mean $\pm$ 1 SD = 206 s $\pm$ 308.33 s). This result suggests that time to first detection is longer for perimeter surveys than for dip-net surveys. However, dip-net surveys have a shorter time period for measurement so this result is expected. No species provided sufficient data to analyze TTFD for call surveys.

At SLBE in 2007, one species (green frogs) provided enough data to analyze TTFD for dip-net surveys. The results suggest that TTFD does differ between sampling seasons for this species (Figure 13). There were insufficient data to compare TTFD among species. No species provided sufficient data to analyze TTFD for call surveys or perimeter surveys.

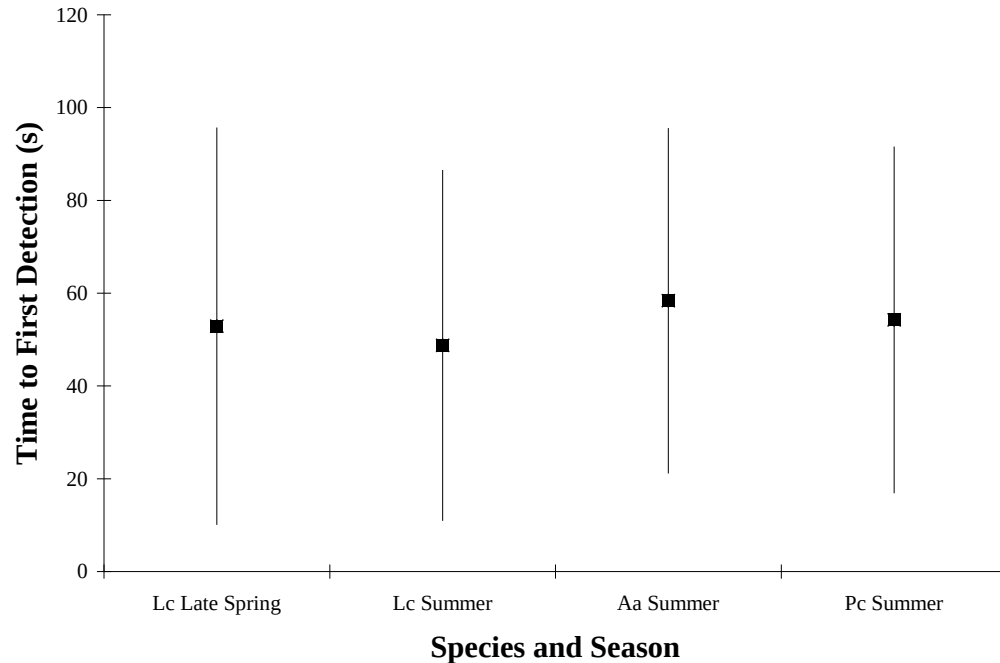


Figure 12. Time to first detection (mean $\pm$ 1 SD) for *Lithobates clamitans* (Lc; N = 19 for Early Spring and 40 for Summer), *Anaxyrus americanus* (Aa; N = 19), and *Pseudacris crucifer* (Pc; N = 24) adults, metamorphs, and larvae during two-minute nodes of dip net surveys at Sleeping Bear Dunes National Lakeshore (Michigan) in 2006.

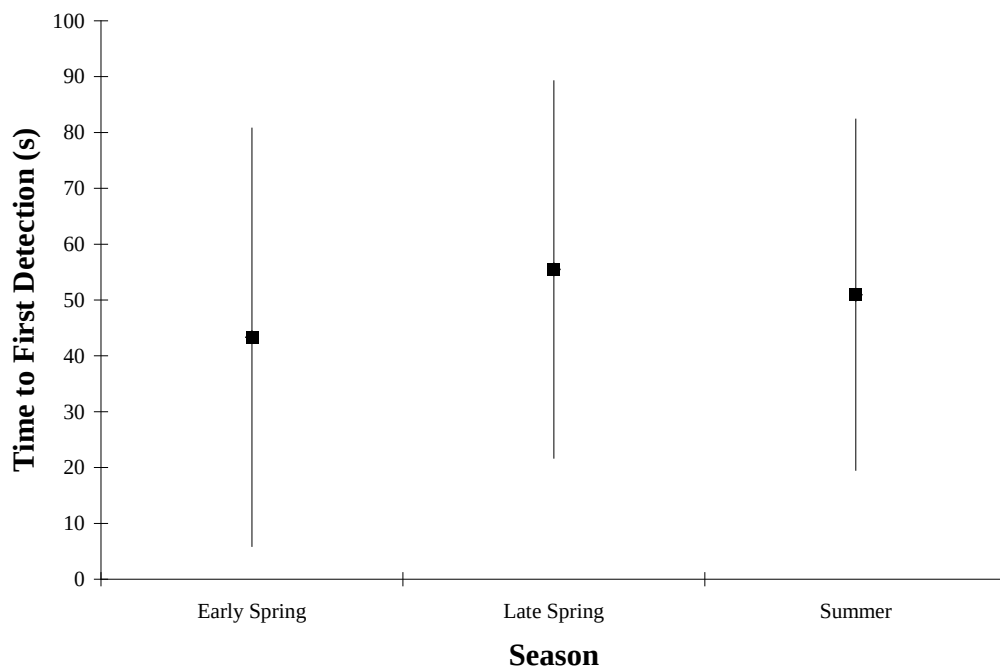


Figure 13. Time to first detection (mean $\pm$ 1 SD) for green frog adults, metamorphs, and larvae during two-minute nodes of dip-net surveys at Sleeping Bear Dunes National Lakeshore (Michigan) in 2007. Samples sizes are 15 for Early Spring, 38 for Late Spring, and 22 for Summer.

Nighttime Call Surveys

Naïve occupancy was similar among parks and years for most species, but differed greatly among species within parks. At SLBE in 2006, the spring peeper had the highest naïve occupancy and the northern leopard frog had the lowest among detected species (Table 13). This was also true for 2007 (Table 14). Wood frogs and green frogs showed the largest change in occupancy between years with a decline for wood frogs and an increase for green frogs between 2006 and 2007. The decline for wood frogs suggests that we missed the brief calling period of this species (Weir and Mossman 2005) in 2007. The increase for green frogs may reflect the fact that we performed more surveys during the summer season in 2007. At PIRO in 2007, spring peepers also had the highest naïve occupancy and mink frogs had the lowest naïve occupancy among detected species. Northern leopard frogs were not detected during nighttime surveys. American toad naïve occupancy at PIRO was nearly double that for SLBE in either year (Table 15).

Analysis of naïve occupancy for SLBE wetland routes suggested that naïve occupancy was similar to that of standard routes for gray treefrogs and spring peepers in 2006. In 2006, no wood frogs were detected on the wetland routes. This could reflect the fact that no early spring surveys were conducted on the wetland route in this year. A similar result was obtained for American toads, and the likely cause is the same as that for wood frogs. Few green frogs were detected on the wetland route in 2006, which is likely a result of no surveys of this route in the summer season (Table 16). No wood frogs were detected on the wetland route in 2007. However, few wood frogs were detected on the standard routes and it is likely that we missed the calling period for this species in 2007. Naïve occupancy for spring peepers, gray treefrogs, and green frogs was similar for both types of routes in 2007. However, naïve occupancy for American toads was substantially higher on the wetland route, which could suggest that wetland-oriented routes are better for detection of this species (Table 17). No northern leopard frogs were detected on wetland routes in either year. This could reflect poor timing of surveys or the wetland chosen.

Spring peepers were heard in all three seasons at SLBE in both 2006 and 2007. The gray treefrog, American toad, and green frog were heard in two seasons each. However, in 2006 the American toad was heard in late spring and summer, and in 2007 it was heard in early spring and late spring. The northern leopard frog and wood frog were heard only in the early spring season (Table 18). We combined data from 2006 and 2007 to plot proportion of detections. Spring peepers reached a peak early in the field season and gradually tapered off. The gray treefrog held a relatively constant proportion in the middle to late portions of the field season. Green frogs slowly increased during the later portion of the field season until they accounted for most of the detections. American toads were sporadic callers and never attained a large proportion of detections, while wood frogs reached an early peak and then quickly dropped off (Figure 14).

Table 13. Detection by nighttime call survey site and naïve occupancy (ψ) for six amphibian species at Sleeping Bear Dunes National Lakeshore (Michigan) in 2006.

Site	<i>Lithobates sylvaticus</i>	<i>Hyla versicolor</i>	<i>Pseudacris crucifer</i>	<i>Lithobates pipiens</i>	<i>Lithobates clamitans</i>	<i>Anaxyrus americanus</i>
A0	1	1	1			1
A1	1	1	1	1	1	1
A10		1	1			
A11	1	1	1		1	
A13						
A14		1	1			
A16		1	1			
A17	1	1	1		1	1
A18	1	1	1		1	1
A19	1	1	1			1
A2	1	1	1		1	
A21	1	1	1		1	1
A22	1	1	1		1	1
A23			1			
A24	1	1	1		1	1
A25	1	1	1			1
A26			1			
A27			1			
A3	1	1	1			1
A30	1	1	1		1	1
A31			1			1
A36			1			
A37	1	1	1	1	1	
A39	1	1	1	1	1	
A43	1	1	1		1	1
A45		1	1			
A6		1	1		1	1
A7		1	1		1	1
A8		1	1		1	
A9	1	1	1			
# sites at which detected	17	24	29	3	15	15
$\psi \geq$	0.567	0.8	0.967	0.100	0.5	0.5

Table 14. Detection by nighttime call survey site and naïve occupancy (ψ) for six amphibian species at Sleeping Bear Dunes National Lakeshore (Michigan) in 2007.

Site	<i>Lithobates sylvaticus</i>	<i>Hyla versicolor</i>	<i>Pseudacris crucifer</i>	<i>Lithobates pipiens</i>	<i>Lithobates clamitans</i>	<i>Anaxyrus americanus</i>
A0			1		1	1
A1		1	1		1	1
A10		1	1		1	
A11		1	1		1	1
A13			1			
A14			1			
A16						
A17	1	1	1		1	1
A18	1	1	1		1	
A19	1		1		1	
A2	1	1	1		1	
A21			1		1	1
A22		1	1		1	1
A23			1			
A24		1	1			1
A25		1	1			1
A26						1
A27			1			
A3		1	1		1	
A30		1	1		1	
A31		1	1		1	1
A36		1	1		1	1
A37		1	1	1	1	1
A39	1	1	1		1	
A43		1	1		1	
A45		1	1		1	
A6		1	1		1	1
A7		1	1		1	
A8			1		1	
A9		1	1		1	
# sites at which detected	5	20	28	1	22	13
$\psi \geq$	0.167	0.667	0.933	0.033	0.733	0.433

Table 15. Detection by nighttime call survey site and naïve occupancy (ψ) for six amphibian species at Pictured Rocks National Lakeshore (Michigan) in 2007.

Site	<i>Lithobates sylvaticus</i>	<i>Hyla versicolor</i>	<i>Pseudacris crucifer</i>	<i>Lithobates septentrionalis</i>	<i>Lithobates clamitans</i>	<i>Anaxyrus americanus</i>
P11		1	1		1	1
P12		1	1		1	1
P17		1	1			
P18			1			
P20		1	1		1	1
P29		1	1			1
P3		1	1			1
P32		1	1		1	1
P33	1	1	1			
P34			1		1	1
P36			1		1	1
P38		1	1		1	1
P39	1	1	1	1	1	1
P41	1	1	1			1
P44		1	1			1
P52	1		1		1	1
P53	1	1	1		1	1
P58		1	1			1
P59		1	1			1
P61			1			1
P68			1		1	
P7	1		1			1
P71			1		1	1
P72			1		1	
P77		1	1		1	1
P8		1	1			1
P80		1	1			1
P84		1	1		1	1
P87			1			1
P9		1	1			1
P94		1	1		1	1
# sites at which detected	6	21	31	1	16	26
$\psi \geq$	0.194	0.677	1.0	0.032	0.516	0.839

Table 16. Detection by nighttime call survey site and naïve occupancy (ψ) on a wetland route for six amphibian species at Sleeping Bear Dunes National Lakeshore (Michigan) in 2006.

Site	<i>Lithobates sylvaticus</i>	<i>Hyla versicolor</i>	<i>Pseudacris crucifer</i>	<i>Lithobates pipiens</i>	<i>Lithobates clamitans</i>	<i>Anaxyrus americanus</i>
WB22		1	1			
WB17		1	1			
WB14		1	1			
WB11		1	1			
WB23		1	1			
WB8			1			
WB5		1	1			1
WB1		1	1		1	
WA5		1	1			
WA2		1	1			1
# sites at which detected	0	9	10	0	1	2
$\psi \geq$	0	0.9	1.0	0	0.1	0.2

Table 17. Detection by nighttime call survey site and naïve occupancy (ψ) on a wetland route for six amphibian species at Sleeping Bear Dunes National Lakeshore (Michigan) in 2007.

Site	<i>Lithobates sylvaticus</i>	<i>Hyla versicolor</i>	<i>Pseudacris crucifer</i>	<i>Lithobates pipiens</i>	<i>Lithobates clamitans</i>	<i>Anaxyrus americanus</i>
WB22		1	1			1
WB17		1	1		1	1
WB14		1	1			
WB11		1	1			
WB23		1	1		1	1
WB8		1	1		1	1
WB5		1	1		1	1
WB1			1		1	1
WA5		1	1		1	1
WA2		1	1		1	1
# sites at which detected	0	9	10	0	7	8
$\psi \geq$	0	0.9	1.0	0	0.7	0.8

Table 18. Detection by season for six amphibian species at Sleeping Bear Dunes National Lakeshore (Michigan) in 2006 and 2007.

Season	<i>Anaxyrus americanus</i>	<i>Hyla versicolor</i>	<i>Pseudacris crucifer</i>	<i>Lithobates clamitans</i>	<i>Lithobates pipiens</i>	<i>Lithobates sylvaticus</i>
Early Spring 2006			X		X	X
Late Spring 2006	X	X	X	X		
Summer 2006	X	X	X	X		
Early Spring 2007	X		X		X	X
Late Spring 2007	X	X	X	X		
Summer 2007		X	X	X		

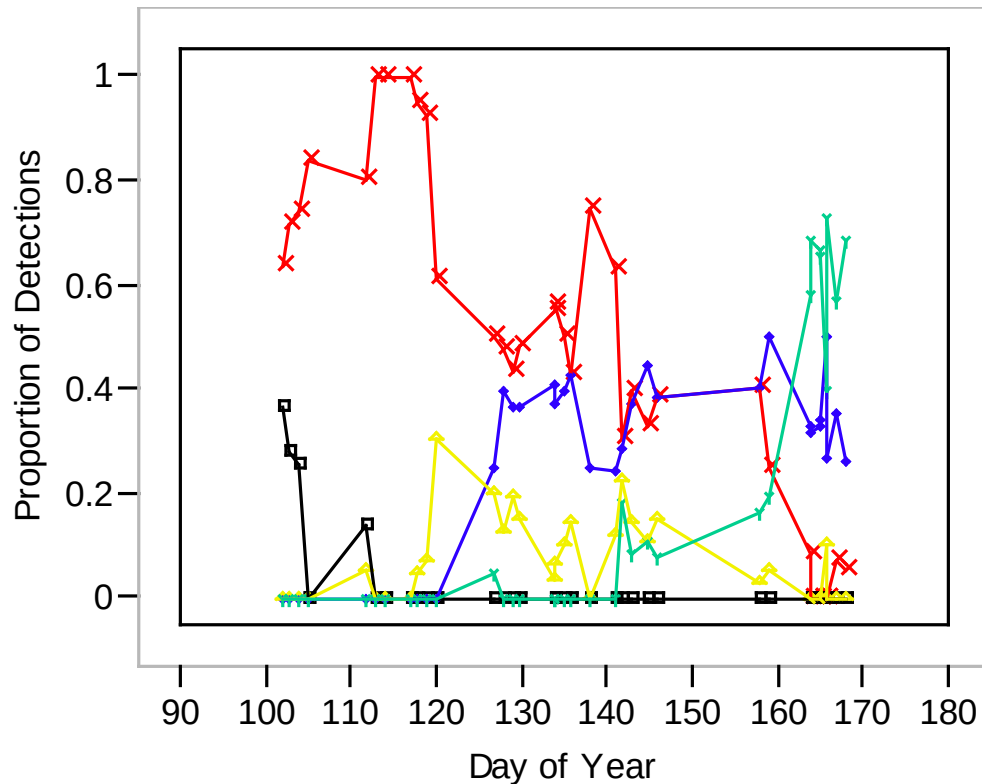


Figure 14. Proportion of all detections for each of five anuran species on days when nighttime call surveys were conducted at Sleeping Bear Dunes National Lakeshore (Michigan) in 2006 and 2007. Red = *Pseudacris crucifer*, Black = *Lithobates sylvaticus*, Yellow = *Anaxyrus americanus*, Blue = *Hyla versicolor*, and Green = *Lithobates clamitans*.

At PIRO in 2007, American toads were heard in the early spring and late spring. The gray treefrog and spring peeper were heard in all three seasons. Green frogs were heard in the late spring and summer seasons. Wood frogs and mink frogs were heard rarely and only in the early spring and summer seasons, respectively (Table 19). Patterns for proportion of detections were not as clear as those for SLBE, and this can likely be attributed to possessing only one year of calling data. However, calling was similar to SLBE in that spring peepers reached an early peak and then declined, gray treefrogs were most common toward the middle portion of the field season, green frogs reached a late peak, and wood frogs had a brief early peak. American toads made up a larger proportion of calling species for a longer period of time at PIRO (Figure 15).

Table 19. Detection by season for six amphibian species at Pictured Rocks National Lakeshore (Michigan) in 2007.

Season	<i>Anaxyrus americanus</i>	<i>Hyla versicolor</i>	<i>Pseudacris crucifer</i>	<i>Lithobates clamitans</i>	<i>Lithobates septentrionalis</i>	<i>Lithobates sylvaticus</i>
Early Spring	X	X	X			X
Late Spring	X	X	X	X		
Summer		X	X	X	X	

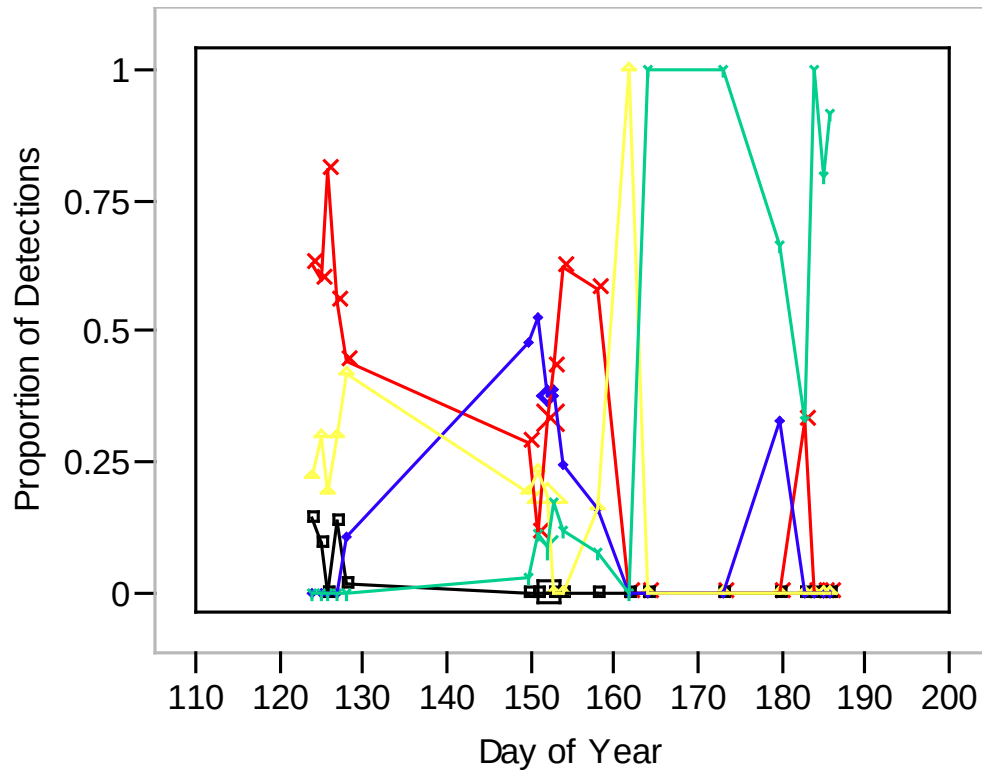


Figure 15. Proportion of all detections for each of 5 anuran species on days when nighttime call surveys were conducted at Pictured Rocks National Lakeshore (Michigan) in 2007. Red = *Pseudacris crucifer*, Black = *Lithobates sylvaticus*, Yellow = *Anaxyrus americanus*, Blue = *Hyla versicolor*, and Green = *Lithobates clamitans*.

We stayed overnight and performed standard nighttime surveys on two islands at APIS in 2006. Surveys at Stockton Lagoon North and Stockton Lagoon South (25 April 2006; Early Spring) detected spring peepers at a maximum calling index of three. A survey at Michigan Lagoon (22 May 2006; Late Spring) detected spring peepers at a maximum calling index of three. A second survey at Stockton Lagoon North (25 May 2006; Late Spring) detected spring peepers at a maximum calling index of three and American toads at a maximum calling index of one.

At APIS, remote call recorders detected one species at Little Sand Bay (Table 20), three species at Stockton Lagoon (Table 21), and four species at Basswood Quarry (Table 22). We would not have detected gray treefrogs on Stockton Island or gray treefrogs and American toads on Basswood Island without remote recordings. Spring peepers called throughout the recording period. American toads also called throughout the recording period, but seemed to call more often after 22:00 h. Gray treefrogs and wood frogs were not recorded often enough for us to characterize the calling period. Although we logged the calling indices, these were often difficult to determine from the recordings.

In 2006, we spent 105 hours-8 minutes and 51 hours-19 minutes (153 hours-12 minutes total) performing SLBE nighttime and daytime surveys, respectively. At APIS, we spent 71 hours-52 minutes performing daytime surveys and 21 minutes on nighttime surveys (72 hours-13 minutes

total; see Table 3). In 2007, we spent 122 hours-55 minutes and 73 hours (195 hours-55 minutes total) performing SLBE nighttime and daytime surveys, respectively. At PIRO, we spent 115 hours-43 minutes performing nighttime surveys and 32 hours-37 minutes performing daytime surveys (148 hours-20 minutes total; see Table 4). It is important to note that these numbers are for surveying only and do not include set-up or travel times. Early spring was the sampling season most likely to contain unfinished routes and extra nights spent sampling. This was usually caused by low ambient temperatures in the latter half of the allowed survey period. However, nights where ambient temperature, wind, or rain precluded surveys altogether were often a problem during the late spring 2007 sampling season at PIRO.

Table 20. Results from remote call recordings at Little Sand Bay, Apostle Islands National Lakeshore (Wisconsin) in 2006. The nightly recording period was from 20:00 to 03:00 h.

Dates	Species	Maximum Calling Index
5/27 to 5/28	-	
5/28 to 5/29	-	
5/29 to 5/30	-	
5/30 to 5/31	<i>Pseudacris crucifer</i>	2
5/31 to 6/1	<i>Pseudacris crucifer</i>	2
6/1 to 6/2	<i>Pseudacris crucifer</i>	1
6/2 to 6/3	<i>Pseudacris crucifer</i>	2
6/3 to 6/4	-	
6/4 to 6/5	-	
6/5 to 6/6	<i>Pseudacris crucifer</i>	2
6/6 to 6/7	<i>Pseudacris crucifer</i>	1
6/7 to 6/8	<i>Pseudacris crucifer</i>	1
6/8 to 6/9	-	
6/9 to 6/10	-	
6/10 to 6/11	-	
6/11 to 6/12	-	
6/12 to 6/13	-	
6/13 to 6/14	-	
6/14 to 6/15	-	
6/15 to 6/16	-	
6/16 to 6/17	-	
6/17 to 6/18	-	
6/18 to 6/19	-	
6/19 to 6/20	-	
6/20 to 6/21	-	
6/21 to 6/22	-	
6/22 to 6/23	-	
6/23 to 6/24	-	

Table 21. Results from remote call recordings at Stockton Island Lagoon, Apostle Islands National Lakeshore (Wisconsin) in 2006. The nightly recording period was from 20:00 to 03:00 h.

Dates	Species	Maximum Calling Index
5/27 to 5/28	<i>Hyla versicolor</i>	1
5/28 to 5/29	<i>Pseudacris crucifer</i>	1
	<i>Anaxyrus americanus</i>	1
5/29 to 5/30	<i>Pseudacris crucifer</i>	1
	<i>Anaxyrus americanus</i>	1
5/30 to 5/31	<i>Pseudacris crucifer</i>	1
	<i>Anaxyrus americanus</i>	2
5/31 to 6/1	<i>Pseudacris crucifer</i>	1
	<i>Anaxyrus americanus</i>	2
6/1 to 6/2	<i>Anaxyrus americanus</i>	2
6/2 to 6/3	<i>Pseudacris crucifer</i>	1
	<i>Anaxyrus americanus</i>	2
6/3 to 6/4	<i>Anaxyrus americanus</i>	1
6/4 to 6/5	<i>Pseudacris crucifer</i>	1
	<i>Anaxyrus americanus</i>	1
6/5 to 6/6	<i>Anaxyrus americanus</i>	2
6/6 to 6/7	-	
6/7 to 6/8	<i>Pseudacris crucifer</i>	2
	<i>Anaxyrus americanus</i>	1
6/8 to 6/9	-	
6/9 to 6/10	-	
6/10 to 6/11	<i>Pseudacris crucifer</i>	1
6/11 to 6/12	<i>Pseudacris crucifer</i>	1
6/12 to 6/13	-	
6/13 to 6/14	-	
6/14 to 6/15	<i>Pseudacris crucifer</i>	1
6/15 to 6/16	<i>Pseudacris crucifer</i>	1
6/16 to 6/17	-	
6/17 to 6/18	-	
6/18 to 6/19	-	
6/19 to 6/20	-	
6/20 to 6/21	-	
6/21 to 6/22	-	
6/22 to 6/23	-	
6/23 to 6/24	-	
6/24 to 6/25	-	

Table 22. Results from remote call recordings at Basswood Quarry, Apostle Islands National Lakeshore (Wisconsin) in 2006. The nightly recording period was from 20:00 to 03:00 h.

Dates	Species	Maximum Calling Index
4/28 to 4/29	<i>Pseudacris crucifer</i>	3
4/29 to 4/30	<i>Pseudacris crucifer</i>	3
4/30 to 5/1	<i>Hyla versicolor</i>	2
5/1 to 5/2	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	1
	<i>Hyla versicolor</i>	1
	<i>Lithobates sylvaticus</i>	1
5/2 to 5/3	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	2
	<i>Lithobates sylvaticus</i>	1
5/3 to 5/4	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	3
	<i>Hyla versicolor</i>	2
5/4 to 5/5	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	2
	<i>Hyla versicolor</i>	1
5/8 to 5/9	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	1
5/9 to 5/10	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	2
	<i>Lithobates sylvaticus</i>	1
5/13 to 5/14	<i>Pseudacris crucifer</i>	3
5/15 to 5/16	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	2
5/16 to 5/17	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	3
5/17 to 5/18	<i>Pseudacris crucifer</i>	3
	<i>Anaxyrus americanus</i>	3
5/18 to 5/19	<i>Hyla versicolor</i>	1
5/19 to 5/20	-	
5/20 to 5/21	-	

Discussion

Daytime Surveys

With regard to overall number of species detected, daytime surveys were an effective way to monitor amphibians. More species were detected collectively using the various daytime survey methods than by using nighttime call surveys alone. In particular, daytime surveys resulted in detections of species that do not call, such as salamanders. Daytime surveys also allowed us to determine if reproduction was actually occurring via egg mass and larvae detections, whereas calling males do not necessarily equate to successful reproduction (Heyer et al. 1994). At this time, we cannot recommend one of the three daytime sampling methods over the others. Dip-net surveys tended to produce more detections, but call surveys and perimeter surveys allowed us to detect species that would not have been noted using dip-net surveys alone. Within dip-net surveys, our data suggest that this method is equally effective for detecting different species and for detecting green frogs (the only species with enough detections for a comparison) in different seasons.

Based on our sampling, SLBE was the most diverse park in terms of reptile and amphibian species, followed by APIS and PIRO. This is sensible given the fact that SLBE is the southernmost park that we sampled. However, more amphibian species were detected at APIS than at either of the other parks. There are a number of species at all three parks that should have been present but were not detected, such as Fowler's toads (*Anaxyrus fowleri*) at SLBE, four-toed salamanders at PIRO and eastern red-backed salamanders at APIS (Harding 1997; Casper 2001; Casper 2005). In some cases we know that these species are present based on past surveys. Regardless, we cannot state with confidence that these species are absent without more surveying effort (Kery 2002; Mackenzie 2005). Notable species detections include two new records for Basswood Island at APIS (gray treefrogs and green frogs; Casper 2001).

Nighttime Call Surveys

With the possible exception of American toads, our survey site selection procedure provided a similar or larger number of detections for calling species when compared to choosing individual wetlands to construct a survey route. Our site selection method has the added advantage of providing more potential surveys sites. Furthermore, it provides an intermediate course between selecting sites in a completely random manner (and thus creating many sites with no calling amphibians) and selecting only the best or most obvious wetland sites (which will bias the monitoring program toward a negative trend; Weir and Mossman 2005). For these reasons, we suggest that this method of selecting nighttime call survey sites be used in the future.

We heard six species calling at both SLBE and PIRO. This suite of species was the same across parks with the exception that the northern leopard frog was heard only at SLBE and the mink frog was heard only at PIRO. Spring peepers were the most commonly detected species at both parks, followed by gray treefrogs, green frogs, and American toads in varying order depending on park and year. While the calls of all species should be noted in any survey, we suggest for several reasons that these latter four species be targeted in future monitoring efforts. First, they represent three different families of anurans (Lannoo 2005). In addition, they form a rough spectrum of species that breed in seasonal or semi-permanent wetlands (spring peepers), to either temporary or permanent wetlands (American toads and gray treefrogs), to permanent wetlands

(green frogs; Lannoo 2005). Finally, because they appear to be common and will likely provide consistently large amounts of calling data, they should provide the best opportunity to detect subtle, long-term trends in species/wetland distribution and abundance.

Because these species have peak calling times in each of the three seasons (Mossman et al 1998; Weir et al. 2005; this report), we recommend that surveys continue to be done in all seasons. However, if removing a season were necessary for logistical or cost-associated reasons, the summer season may be the best option. Only green frogs call frequently during this season, while removing the early spring season would eliminate a great deal of data on spring peepers and American toads and removing the late spring season would eliminate most of the data collected on gray treefrogs and a considerable amount of data on American toads. Removal of the early spring season would also completely eliminate detections of wood frogs and northern leopard frogs.

Additional Recommendations for Future Monitoring

We recommend that future efforts focus on nighttime call surveys for two reasons. First, based on our experience, nighttime call surveys result in more and higher quality data. This stems from the fact that eggs, larvae, and often adults are difficult to identify during daytime surveys. We often had to label adults and larvae as “unidentified” during our data collection, usually because they escaped too quickly to be correctly identified. In contrast, the calls of male anurans are often (but not always, see Droege and Eagle 2005) easy to identify and distinguish from one another. Nighttime call surveys provide more data because, given a fixed budget, more sites can be surveyed in a more efficient manner with this method.

In addition, compared to nighttime call surveys, daytime surveys are more expensive and more difficult to complete. The amount of time spent performing the different types of surveys is deceiving when one considers the fact that our calculations of time spent surveying with the different methods do not include set-up and travel time. Daytime sites are often isolated and require “hiking in” or other transportation such as a boat to reach, while nighttime sites are located along roads and can be reached with an automobile (this could be remedied by choosing more accessible daytime sites, however). Including set-up and travel time, it generally took 3-4 hours for one person to complete one nighttime survey route of ten sites. In some cases, it took 3-4 hours (or longer) for a two-person team to survey one daytime site. In several instances we were unable to perform daytime surveys, often because the location of sites precluded us from completing them in the time that we had available. Furthermore, because eggs and larvae are generally more difficult to identify than calls, more time would be necessary to train field crews to perform daytime surveys than nighttime surveys.

Despite these challenges, however, we believe that daytime sampling should continue in some form if staff and resources allow. Daytime sampling does result in the detection of species that would be missed by nighttime call surveys. Such information could be useful to park staff for conservation and management planning, and to the general public to better foster a sense of stewardship and understanding of their parks. Furthermore, amphibian surveys are most effective when a combination of daytime searches and nighttime call surveys is used (Kline 1998; Fellers and Kleeman 2006), and terrestrial species may be good indicators of forest ecosystem health (Welsh and Droege 2001). Finally, the area of inference for road-based nighttime sampling is

limited to the area around roads. A bias in observed population trends could result from focusing only on sites along roads because such areas may be subject to different human use and stressors than more remote areas (Weir and Mossman 2005).

Remote call recorders allowed us to detect species that otherwise would have gone unnoticed, and resulted in a new species record for Basswood Island at APIS. Unfortunately, we experienced multiple problems with this technology including battery failure (despite backups), unexplained resetting of time and date, and even complete loss of data when initial batteries switched to backups. Furthermore, disturbances such as wind, rain, branches, or animal interference commonly obscured anuran calls, and we were often unable to determine the calling index even when recordings were relatively clear. It is difficult for us to recommend the widespread use of this technology in monitoring efforts. However, it may be suitable in cases where recorders can be regularly maintained and research questions are limited (i.e. attempting to determine the presence of a particular species), or if advances in technology eliminate some or all of the aforementioned issues.

In summary, we believe that future amphibian monitoring efforts in GLKN parks should focus on road-based nighttime call surveys for calling anurans, and that remote recorders should be avoided barring improvements in technology. We recommend that the site selection methods detailed here be used to select future sites. We suggest that spring peepers, gray treefrogs, American toads, and green frogs be the target species for monitoring. Finally, we advocate the continued use of three sampling seasons.

Literature Cited

- Alford, R. A., and S. J. Richards. 1999. Global amphibian declines: A problem in applied ecology. *Annual Review of Ecology and Systematics* 30:133-165.
- Boone, M. D., R. D. Semlitsch, E. E. Little, and M. C. Doyle. 2007. Multiple stressors in amphibian communities: Effects of chemical contamination, bullfrogs, and fish. *Ecological Applications* 17:291-301.
- Bridges, A. S., and M. E. Dorcas. 2000. Temporal variation in anuran calling behavior: Implications for calling surveys and monitoring programs. *Copeia* 2000:587-592.
- Burnham, K. P., and D. R. Anderson. 2002. *Model Selection and Multimodel Inference: A Practical Information-theoretic Approach*, 2nd edition. Springer-Verlag, New York, USA.
- Casper, G. S. 2001. Reptile surveys of Long, Michigan, and Stockton islands, and Little Sand Bay, in the Apostle Islands National Lakeshore, with notes on amphibians. Unpublished technical report to Apostle Islands National Lakeshore, Bayfield, WI, USA.
- Casper, G. S. 2005. An amphibian and reptile inventory of Pictured Rocks National Lakeshore. Great Lakes Inventory and Monitoring Network. Technical Report GLKN/2005/05. National Park Service, Ashland, WI, USA.
- Crother, B. I., editor. 2008. *Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico*. SSAR Herpetological Circular 37.
- Davidson, C., and R. A. Knapp. 2007. Multiple stressors and amphibian declines: Dual impacts of pesticides and fish on yellow-legged frogs. *Ecological Applications* 17:587-597.
- Droege, S., and P. Eagle. 2005. Evaluating calling surveys. Pages 314-319 *in* M. J. Lannoo, editor. *Amphibian declines: The conservation of United States species*. University of California Press, Berkeley, USA.
- Fellers, G. M., and P. M. Kleeman. 2006. Diurnal versus nocturnal surveys for California red-legged frogs. *Journal of Wildlife Management* 70:1805-1808.
- Gibbons, J. W., C. T. Winne, D. E. Scott, J. D. Willson, X. Glaudas, K. M. Andrews, B. D. Todd, L. A. Fedewa, L. Wilkinson, R. N. Tsaliagos, and others. 2006. Remarkable amphibian biomass and abundance in an isolated wetland: Implications for wetland conservation. *Conservation Biology* 20:1457-1465.
- Green, D. M. Perspectives on amphibian population declines: Defining the problem and searching for answers. Pages 291-308 *in* D. M. Green, editor. *Amphibians in decline: Canadian studies of a global problem*. Society for the Study of Amphibians and Reptiles, St. Louis, MO, USA.

- Harding, J. H. 1997. *Amphibians and Reptiles of the Great Lakes Region*. University of Michigan Press, Ann Arbor, USA.
- Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. 1994. *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press, Washington, D.C., USA.
- Johnson, D. H., and R. D. Batie. 2001. Surveys of calling amphibians in North Dakota. *Prairie Naturalist* 33:227-247.
- Kéry, M. 2002. Inferring the absence of a species – a case study of snakes. *Journal of Wildlife Management* 66:330-338.
- Kline, J. 1998. Monitoring amphibians in created and restored wetlands. Pages 360-368 *in* M. J. Lannoo, editor. *Status and conservation of Midwestern amphibians*. University of Iowa Press, Iowa City, USA.
- Lannoo, M. J., editor. 2005. *Amphibian Declines: The Conservation Status of United States Species*. University of California Press, Berkeley, USA.
- MacKenzie, D. I. 2005. What are the issues with presence-absence data for wildlife managers? *Journal of Wildlife Management* 69:849-860.
- MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83:2248-2255.
- Mackenzie, D. I., J. D. Nichols, J. E. Hines, M. G. Knutson, and A. B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology* 84:2200-2207.
- Mackenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: General advice and allocating survey effort. *Journal of Applied Ecology* 42:1105-1114.
- Mossman, M. J., L. M. Hartman, R. Hay, J. R. Sauer, and B. J. Dhuey. 1998. Monitoring long-term trends in Wisconsin frog and toad populations. Pages 169-205 *in* M. J. Lannoo, editor. *Status and conservation of Midwestern amphibians*. University of Iowa Press, Iowa City, USA.
- Pechmann, J. H. K., D. E. Scott, R. D. Semlitsch, J. P. Caldwell, L. J. Vitt, and J. W. Gibbons. 1991. Declining amphibian populations: The problem of separating human impacts from natural fluctuations. *Science* 253:892-895.
- Peterson, C. R., S. R. Burton, and D. A. Patla. 2005. Geographic information systems and survey designs. Pages 320-325 *in* M. J. Lannoo, editor. *Amphibian declines: The conservation status of United States species*. University of California Press, Berkeley, USA.

- Route, B. 2000. Study plan for conducting biological inventories: 2001-2004. U.S. National Park Service. Great Lakes Inventory and Monitoring Network. Technical Report GLKN/2000/01. National Park Service, Ashland, WI, USA.
- Route, B. 2004. Process and results of selecting and prioritizing vital signs for the Great Lakes Network. Great Lakes Inventory and Monitoring Network. Technical Report GLKN/2004/05. National Park Service, Ashland, WI, USA.
- Route, B., and J. Elias. 2007. Chapter 1 –Background information. Pages 1-28 *in* B. Route, and J. Elias. Long-term ecological monitoring plan: Great Lakes Inventory and Monitoring Network. Natural Resource Report NPS/GLKN/NRR/2007/001. National Park Service, Fort Collins, CO, USA.
- Semlitsch, R. D. 2000. Principles for management of aquatic-breeding amphibians. *Journal of Wildlife Management* 64:615-631.
- Skelly, D. K., E. E. Werner, and S. A. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. *Ecology* 80:2326-2337.
- Stebbins, R. C., and N. W. Cohen. 1995. *A Natural History of Amphibians*. Princeton University Press, Princeton, NJ, USA.
- Thoms, C., C. C. Corkran, and D. H. Olson. 1997. Basic amphibian survey for inventory and monitoring in lentic habitats. Pages 35-46 *in* D. H. Olson, W. P. Leonard, and R. B. Bury, editors. *Sampling amphibians in lentic habitats*. Society for Northwestern Vertebrate Biology, Olympia, WA, USA.
- Wake, D. B. 1991. Declining amphibian populations. *Science* 253:860.
- Weir, L. A., and M. J. Mossman. 2005. North American Amphibian Monitoring Program (NAAMP). Pages 307-313 *in* M. J. Lannoo, editor. *Amphibian declines: The conservation of United States species*. University of California Press, Berkeley, USA.
- Weir, L. A., J. A. Royle, P. Nanjappa, and R. E. Jung. 2005. Modeling anuran detection and site occupancy on North American Amphibian Monitoring Program (NAAMP) routes in Maryland. *Journal of Herpetology* 39:627-639.
- Welsh, H. H., and S. Droege. 2001. A case for using plethodontid salamanders for monitoring biodiversity and ecosystem integrity of North American forests. *Conservation Biology* 15:558-569.
- Whiteman, H. H., and S. A. Wissinger. 2005. Amphibian population cycles and long-term data sets. Pages 177-184 *in* M. J. Lannoo, editor. *Amphibian declines: The conservation of United States species*. University of California Press, Berkeley, USA.

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