



Bat Monitoring Protocol for the Great Lakes Inventory and Monitoring Network *Version 1.0*

Natural Resource Report NPS/GLKN/NRR—2020/2126



ON THE COVER

Bat acoustic monitoring equipment at Sleeping Bear Dunes National Lakeshore. National Park Service photo.

Bat Monitoring Protocol for the Great Lakes Inventory and Monitoring Network

Version 1.0

Natural Resource Report NPS/GLKN/NRR—2020/2126

Katy R. Goodwin

National Park Service
Great Lakes Inventory and Monitoring Network
2800 Lakeshore Drive East
Ashland, Wisconsin 54806

May 2020

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the [Great Lakes Inventory and Monitoring Network website](#) and the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Goodwin, K. R. 2020. Bat monitoring protocol for the Great Lakes Inventory and Monitoring Network: Version 1.0. Natural Resource Report NPS/GLKN/NRR—2020/2126. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vii
Abstract.....	ix
Acknowledgments.....	xi
List of Abbreviations.....	xiii
Revision History Log.....	xv
1.0 Background and Objectives.....	1
1.1 Overview and History of Bat Surveys.....	1
1.2 Rationale for Monitoring Bats.....	2
1.2.1 Threats to Bats.....	2
1.2.2 Species of Conservation Concern.....	3
1.2.3 Limited Baseline Data.....	3
1.3 Program Objectives.....	4
2.0 Sampling Design.....	7
2.1 Rationale for Survey Methodology.....	7
2.2 Rationale for Selecting Sampling Locations.....	8
2.3 Rationale for Selecting Sample Size.....	8
2.4 Rationale for Sampling Schedule.....	10
2.5 Comparison to Other Acoustic Monitoring Protocols.....	10
3.0 Field Methods.....	13
3.1 Preparation for the Field Season.....	13
3.2 Procedures During the Field Season.....	13
3.3 End-of-Season Procedures.....	13
4.0 Data Handling, Analyses, and Reporting.....	15
4.1 Metadata Procedures.....	15
The FGDC Biological Data Profi.....	15

Contents (continued)

	Page
4.2 NPS Bat Acoustic Survey Database	15
4.3 Data Entry, Verification and Editing.....	16
4.4 Data Analyses and Reporting	16
4.4.1 Yearly Summaries for Individual Parks	17
4.4.2 Overall Yearly Summaries	17
4.4.3 Multi-Year Reporting	17
4.5 Data Archival Procedures.....	18
4.6 Data Sharing	18
5.0 Personnel Requirements and Training	21
5.1 Roles and Responsibilities.....	21
5.1.1 GLKN Program Manager	21
5.1.2 GLKN Protocol Lead	21
5.1.4 GLKN Data Manager	22
5.1.5 Field Personnel at Parks	22
5.2 Training Procedures.....	23
6.0 Operational Requirements	25
6.1 Annual Workload and Field Schedule.....	25
6.2 Equipment Needs and Costs.....	25
6.3 Contracting Costs	27
6.4 Procedures for Revising and Archiving Previous Versions of the Protocol.....	27
Literature Cited	29
List of Standard Operating Procedures	37
Appendix A. Bat species of the Great Lakes Region.....	39
Appendix B. Comparison of GLKN and NABat Sampling Frames	41

Figures

	Page
Figure 1. Power of the sampling design to detect a 10%, 20%, or 30% annual reduction in bat activity and probability of spurious trend detection (when annual reduction is 0%).....	9
Figure B1. Locations of GLKN sample sites (as of 2019) at Apostle Islands National Lakeshore, overlaid with the NABat sampling frame.....	42
Figure B2. Locations of GLKN sample sites (as of 2019) at Grand Portage National Monument, overlaid with the NABat sampling frame.....	43
Figure B3. Locations of GLKN sample sites (as of 2019) at Indiana Dunes National Park, overlaid with the NABat sampling frame.....	44
Figure B4. Locations of GLKN sample sites (as of 2019) at Isle Royale National Park, overlaid with the NABat sampling frame	45
Figure B5. Locations of GLKN sample sites (as of 2019) at Mississippi National River and Recreation Area, overlaid with the NABat sampling frame	46
Figure B6. Locations of GLKN sample sites (as of 2019) at Pictured Rocks National Lakeshore, overlaid with the NABat sampling frame.....	47
Figure B7. Locations of GLKN sample sites (as of 2019) on the Namekagon and upper St. Croix Rivers (<i>above</i>) and the middle St. Croix River (<i>below</i>) at St. Croix National Scenic Riverway, overlaid with the NABat sampling frame.	48
Figure B8. Locations of GLKN sample sites (as of 2019) at Sleeping Bear Dunes National Lakeshore, overlaid with the NABat sampling frame.....	49
Figure B9. Locations of GLKN sample sites (as of 2019) at Voyageurs National Park, overlaid with the NABat sampling frame	50

Tables

	Page
Table 1. Bat species of the Great Lakes region*	4
Table 2. Comparison between bat acoustic monitoring protocols used by Great Lakes Network (GLKN), the North American Bat Monitoring Program (NABat), and the Northwestern Hub for Bat Population Research and Monitoring (NW Bat Hub)	11
Table 3. Summary of necessary equipment and cost per item for bat monitoring in Great Lakes Network parks.	26
Table A-1. Bat species of the Great Lakes region and occurrences recorded at GLKN's national park units prior to the initiation of the current acoustic monitoring program in 2015.....	39
Table B1. Overlap between GLKN bat monitoring sample sites and the NABat sampling frame	41

Abstract

The National Park Service's (NPS) Great Lakes Inventory and Monitoring Network (GLKN) monitors long-term ecosystem health in parks of the Great Lakes ecoregion. Bat population monitoring has been implemented in nine NPS units: Apostle Islands National Lakeshore, Grand Portage National Monument, Indiana Dunes National Park, Isle Royale National Park, Mississippi National River and Recreation Area, Pictured Rocks National Lakeshore, Saint Croix National Scenic Riverway, Sleeping Bear Dunes National Lakeshore, and Voyageurs National Park. Sampling began in 2015 and has continued each year since.

The bat monitoring program uses acoustic detectors to passively record bat echolocation calls. Sampling is conducted yearly between June and August at a set of 18–35 sites per park. Acoustic files and associated deployment data are archived at each park and submitted to GLKN for centralized data management and analysis. Data are processed through specialized acoustic analysis software to obtain automated species-level classifications for echolocation calls, followed by manual vetting of a subset of calls. Data analysis focuses on species richness, species distributions, and relative activity levels. Yearly summary reports and multi-year trend analyses are produced by park staff, the protocol lead, and contractors.

Acknowledgments

Initial development of this protocol and associated standard operating procedures was completed by M. Romanski and B. Route of the National Park Service; J. Gruver, P. Rabie, and L.A. Starcevich of Western EcoSystems Technology, Inc.; and P. Matzinger of Northland College. Their 2015–2016 documents provided a basis for this protocol. We are grateful for the ongoing support and contributions of many park employees, partners, and volunteers who have completed fieldwork and provided recommendations for improving this monitoring program. We also appreciate the thoughtful comments and valuable input provided by A. Kirschbaum, T. Parr, E. Gillam, D. Licht, and J. Siemers who reviewed preliminary versions of this protocol. The maps in Appendix B were created by T. Pichler. Development of this protocol was supported by the National Park Service’s Natural Resource Stewardship and Science Directorate White-Nose Syndrome funding.

List of Abbreviations

APIS:	Apostle Islands National Lakeshore
GLKN:	Great Lakes Inventory and Monitoring Network
GRPO:	Grand Portage National Monument
INDU:	Indiana Dunes National Park
ISRO:	Isle Royale National Park
MISS:	Mississippi National River and Recreation Area
NABat:	North American Bat Monitoring Program
NPS:	National Park Service
NW Bat Hub:	Northwestern Hub for Bat Population Research and Monitoring
SACN:	Saint Croix National Scenic Riverway
SLBE:	Sleeping Bear Dunes National Lakeshore
USFWS:	U.S. Fish and Wildlife Service
VOYA:	Voyageurs National Park

Revision History Log

The following table lists all edits and amendments to this document since the original publication date. Information entered in the log must be complete and concise. Users of this protocol will promptly notify the GLKN protocol lead about recommended and required changes. The protocol lead must review and incorporate all changes, complete the revision history log, and change the date and version number on the title page and in the header of the document file. For complete instructions, please refer to SOP #11, Procedure for Revising Protocol.

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
Add rows as needed for each change or set of changes tied to an updated version number					

1.0 Background and Objectives

1.1 Overview and History of Bat Surveys

The National Park Service's (NPS) Inventory and Monitoring program encompasses both point-in-time inventories to identify what resources are present, and consistent long-term monitoring to identify changes over time. As part of this program, the Great Lakes Inventory and Monitoring Network (GLKN) coordinates and conducts inventory and monitoring projects across nine national park units located in Minnesota, Wisconsin, Michigan, and Indiana. The parks are Apostle Islands National Lakeshore (APIS), Grand Portage National Monument (GRPO), Indiana Dunes National Park (INDU), Isle Royale National Park (ISRO), Mississippi National River and Recreation Area (MISS), Pictured Rocks National Lakeshore (PIRO), Saint Croix National Scenic Riverway (SACN), Sleeping Bear Dunes National Lakeshore (SLBE), and Voyageurs National Park (VOYA).

GLKN began conducting baseline natural resource inventories in 2000, resulting in species occurrence and status lists for each park unit, which are documented in the NPS web-based tool NPSpecies (NPSpecies 2019). GLKN also developed a list of natural resource indicators, called "Vital Signs", to guide and prioritize long-term monitoring efforts (Route and Elias 2007). These Vital Signs are "a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values" (Route and Elias 2007). A final group of 21 Vital Signs was selected based on importance to the parks and feasibility and cost effectiveness to implement. Bats are included in GLKN's general species inventories, but targeted monitoring of mammalian communities (including bats) was not selected as a priority Vital Sign due to lack of time and funding. Mammal studies were, however, considered to be an area for potential future work (Route and Elias 2007).

GLKN and some individual park units conducted bat surveys prior to 2013, but there was no coordinated, consistent, or comprehensive region-wide effort. Though limited in scope, these older surveys provided important occurrence data and documented three to six species per park through a combination of acoustic, capture, direct observation, and genetic methods (Appendix A).

In recent decades, North American bat populations have been increasingly threatened by a number of environmental pressures including the fungal disease white-nose syndrome (WNS), mortality from wind turbines, and changing land use and climatic conditions. Due to the increase in conservation concerns, many U.S. federal agencies have begun implementing or expanding bat research and monitoring programs (e.g., Loeb et al. 2015, Rodhouse et al. 2016 Rodriguez et al. 2019). The NPS has been very active in this area, funding over 150 bat-focused research, conservation, and education projects at 78 parks since 2013 (National Park Service 2016).

In 2015, GLKN and the network parks established a bat monitoring program with a particular focus on documenting the impacts of WNS. When the project was initiated, the Great Lakes region was at the leading edge of the disease's spread, with WNS documented within 50 miles of most parks (U. S. Geological Survey 2019), making it a very real and imminent threat. GLKN's monitoring program is

helping parks to document baseline data on their bat populations and assess changes over time as WNS continues to move west.

1.2 Rationale for Monitoring Bats

Bat monitoring at GLKN parks is important for several reasons. Bats are facing numerous threats and are species of conservation concern, some even federally listed by the U. S. Fish and Wildlife Service (USFWS). Additionally, baseline data such as species occurrence, distribution, and relative abundance is lacking at a detailed level for the parks.

1.2.1 Threats to Bats

North American bat populations are subject to a number of major stressors and some species have experienced rapid declines. The most substantive threats facing bat communities include WNS, wind energy-related mortality, and changes in land use and climatic conditions. The impetus for establishing this project was to obtain baseline data on species occurrence and activity levels in the GLKN parks and monitor trends over time as our bats are faced with increasing stressors, particularly WNS.

WNS is a disease caused by the fungal pathogen *Pseudogymnoascus destructans*. Both behavioral and physiological effects have been observed in infected bats, including fungal growth on the muzzle, ears, and wing membranes; increased frequency of arousals during hibernation; depletion of fat reserves and emaciation; and high rates of mortality (Blehert et al. 2009, Warnecke et al. 2012). The pathogen was first documented in North America in 2006; since then it has spread to 33 U.S. states and 7 Canadian provinces (U. S. Geological Survey 2019), with an estimated total mortality of at least 6 million bats (U. S. Fish and Wildlife Service 2014). Previous work has documented steep declines in local bat populations after the arrival of WNS to an area. A variety of methods including winter hibernacula counts (Turner et al. 2011, Frick et al. 2015, Powers et al. 2015), summer capture surveys (Pettit and O’Keefe 2017), and summer acoustic surveys (Brooks 2011, Dzal et al. 2011) have all corroborated the declines and the disease continues to threaten new areas.

Wind energy development has grown substantially in the U.S. over the last two decades, reaching a current installed capacity of over 105,000 megawatts (American Wind Energy Association 2019). Estimates based on data prior to 2012 suggest 1–11 bats are killed per megawatt per year (Arnett et al. 2015), or a total of 651,000–888,000 bat fatalities per year (Smallwood 2013). However, due to the continued increase in installed capacity, current impacts are likely higher. Although not all species are equally impacted (Kunz et al. 2007, Arnett et al. 2015), projections for one of the most affected species (Hoary Bat, *Lasiurus cinereus*) suggest that mortality due to wind energy could cause significant population declines and increased risk of extinction over the next 50–100 years (Frick et al. 2017).

Strong relationships have been observed between changing climatic conditions and some aspects of bat behavior (Frick et al. 2012) and physiology (Adams 2010). Modeling suggests climate change will lead to shifts in the geographic range of suitable conditions for both hibernacula (Humphries et al. 2002) and maternity colonies (Loeb and Winters 2013). Altered land use patterns and habitat fragmentation can also have impacts. For example, highly urbanized areas may have reduced species

richness compared to nearby natural areas, though not necessarily a reduction in overall bat activity (Avila-Flores and Fenton 2005, Krauel and LeBuhn 2016). Specific factors associated with anthropogenic development, including impervious surfaces (Dixon 2012), roads (Kitzes and Merenlender 2014, Pourshoushtari et al. 2018) and artificial lighting (Cravens and Boyles 2019) have been shown to negatively impact bat activity, though varying responses are observed depending on species.

1.2.2 Species of Conservation Concern

Nine species of bats are found in the Upper Midwest/Great Lakes region (Kurta 2017). Details on each species are found in Table 1. All nine species in our region are insectivores belonging to the Family Vespertilionidae, the largest and most common group of bats in North America. They can be divided into two broad groups based on their behavior and natural history: tree-roosting, migratory bats and cavity-roosting, hibernating bats. The five hibernating species are confirmed to be susceptible to WNS; additionally, the Eastern Red Bat (*Lasiurus borealis*) and Silver-haired Bat (*Lasionycteris noctivagans*) have been documented with the fungal agent *P. destructans*, though not showing signs of the disease itself (U. S. Fish and Wildlife Service 2014). Meanwhile, migratory species make up the majority of bat fatalities due to wind turbines (Arnett et al. 2015).

The USFWS lists the Indiana Myotis (*Myotis sodalis*) as federally endangered and the Northern Myotis (*Myotis septentrionalis*) as federally threatened under the Endangered Species Act (U. S. Fish and Wildlife Service 1967, 2016). Additionally, all nine species are listed as endangered, threatened, or of special concern by one or more states in which GLKN parks are located (Michigan Natural Features Inventory 2009, Minnesota Department of Natural Resources 2013, Wisconsin Department of Natural Resources 2016, Indiana Division of Fish and Wildlife 2019).

1.2.3 Limited Baseline Data

Bat surveys were conducted prior to 2013 at some parks. These surveys were generally limited in scope; for example, visiting only easily accessible sites, sampling for only a few nights per site, or sampling only a single season. Furthermore, sites were not selected following an intentional sampling design, and can not be considered representative of the park as a whole. The current GLKN monitoring program substantially expands survey efforts and establishes a more robust probabilistic sampling design to enable statistical analyses.

Table 1. Bat species of the Great Lakes region*. Species affected by white-nose syndrome (WNS) are listed as “Confirmed” if they have been identified with diagnostic symptoms of the disease, or “Pd Positive” if the causative fungus *Pseudogymnoascus destructans* has been detected but without diagnostic symptoms of the disease. Federal/state status is indicated as E (Endangered), T (Threatened), or SC (Special Concern). Nomenclature follows Simmons and Cirranello (2020).

Species Name	Roosting / Wintering Behavior	WNS Affected?	Federal Status	State Status
Big Brown Bat <i>Eptesicus fuscus</i>	Cavity-roosting/ Hibernating	Confirmed WNS	–	T (WI), SC (MN)
Eastern Red Bat <i>Lasiurus borealis</i>	Tree-roosting/ Migratory	Pd Positive	–	SC (IN)
Hoary Bat <i>Lasiurus cinereus</i>	Tree-roosting/ Migratory	–	–	SC (IN)
Silver-haired Bat <i>Lasionycteris noctivagans</i>	Tree-roosting/ Migratory	Pd Positive	–	SC (IN, WI)
Little Brown Myotis <i>Myotis lucifugus</i>	Cavity-roosting/ Hibernating	Confirmed WNS	–	E (IN), T (WI), SC (MI, MN)
Northern Myotis <i>Myotis septentrionalis</i>	Cavity-roosting/ Hibernating	Confirmed WNS	T	E (IN), T (WI), SC (MI, MN)
Indiana Myotis <i>Myotis sodalis</i>	Cavity-roosting/ Hibernating	Confirmed WNS	E	E (IN, MI)
Evening Bat <i>Nycticeius humeralis</i>	Tree-roosting/ Migratory	–	–	E (IN), T (MI)
Tricolored Bat <i>Perimyotis subflavus</i>	Cavity-roosting/ Hibernating	Confirmed WNS	–	E (IN), T (WI), SC (MI, MN)

*Sources: Indiana Division of Fish & Wildlife 2019; Michigan Natural Features Inventory 2009; Minnesota Department of Natural Resources 2013; U. S. Fish and Wildlife Service 1967, 2014, 2016; Wisconsin Department of Natural Resources 2016

1.3 Program Objectives

The overall goal of the GLKN bat monitoring program is to assess the status of bat populations in the parks and detect population trends over time. Acquiring this information will assist parks in filling gaps in knowledge and in making informed decisions when management actions may impact bats. Because obtaining direct abundance measures of bat populations is not feasible with acoustic methods (Miller 2001, Frick 2013), the focus will be on assessing species distribution patterns and activity levels. Surveys will utilize appropriate sampling design and methods to support the secondary goal of incorporation and/or comparison of our data with other large-scale monitoring projects.

Specific objectives include the following:

- 1) Identify what species are present in each park and where they are found within the park.
- 2) Track changes in activity levels and distribution patterns over time for each species.
- 3) Compare bat activity levels among species and among parks.
- 4) Compare species distribution patterns among species and among parks.

2.0 Sampling Design

When selecting the sampling design, factors requiring consideration included: a) minimizing costs while maximizing efficiency, b) accounting for challenging logistics and difficult access, c) maintaining simplicity such that non-experts would be able to collect the data, d) maintaining rigorous scientific standards to allow for statistical analyses, and e) allowing data to be comparable/compatible with other monitoring programs (e.g., NABat). The field of bat monitoring and acoustic data analysis is rapidly advancing, therefore we acknowledge that the selected sampling design may need to be adjusted in the future.

2.1 Rationale for Survey Methodology

The GLKN bat monitoring program utilizes passive acoustic survey methods. Passive acoustic detection, in which ultrasonic recording devices are systematically deployed throughout a landscape to record the echolocation calls of passing bats, is a commonly used method to monitor bats and gain information on species richness (Skalak et al. 2012), occupancy and detection probability (Gorresen et al. 2008), and relative activity levels (Ford et al. 2011). Following data collection, echolocation call sequences can be identified to species using specialized software, such as SonoBat (J. Szweczek, www.sonobat.com) or Kaleidoscope Pro (Wildlife Acoustics, Inc., www.wildlifeacoustics.com)¹. Despite the fact that call variation within species, overlap among species, recording quality, and other factors place limitations on the accuracy of identification of echolocation calls (Barclay 1999, Frick 2013, Russo et al. 2018), passive acoustic monitoring is still a widely accepted and useful method. Expert manual review of calls can help minimize errors and verify the results of automated identification.

Several alternative bat survey methods are available but were not feasible for this project. Active acoustic surveys (recording echolocation calls of directly observed bats) are less efficient and do not result in an unbiased sample. Mobile acoustic transects (recording echolocation calls while walking, driving, or boating a specified path) are also less efficient and would limit the areas available for surveys to places that have trails, roads, or navigable waterways. Hibernacula counts (recording the number and species of bats during hibernation) are not possible because no known hibernacula are located in GLKN parks. Emergence counts (observing how many bats depart a roost in the evening) would limit sampling to the small number of known roost sites, or require extensive effort to locate additional roosts, plus it may not allow species identification. Mist-netting or other capture methods are invasive and may result in stress/injury to the bats, as well as being time-intensive and requiring more personnel with higher levels of training and federal/state wildlife handling permits. Furthermore, acoustic surveys have been shown to document more species than capture surveys (Dixon et al. 2014).

¹ Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

2.2 Rationale for Selecting Sampling Locations

Sampling locations are selected using a probabilistic sample design. We follow the master sample approach described by Larsen et al. (2008), using Generalized Random Tessellation Stratification (GRTS) to select a set of locations that are both randomized and spatially balanced (Stevens and Olson 2004). One advantage of this design is that sampling is spread across the geographic extent of the survey area, avoiding the bias that could result from sampling a group of sites in close proximity to each other. Secondly, it allows flexibility to add or delete sample sites from year to year, making it suitable for long-term studies where funds and personnel may vary over time. Similar methods have been used for other wildlife research, including for bat surveys (e.g., Rodhouse et al. 2011). The NABat protocol (Loeb et al. 2015) provides further details about the advantages of this sample design.

To implement this sample design, the following steps were taken at each park: 1) a grid of 1-km² cells was overlaid on the park, 2) cells were arranged into an ordered list using the GRTS algorithm, and 3) cells to be sampled were then selected by starting with Cell #001 and working through the list in consecutive order. Some cells were eliminated based on poor access, safety concerns, or lack of suitable habitat.

Within each 1-km² cell to be sampled, the specific sample site was selected by identifying an area that was reasonably accessible and had suitable bat habitat (travel corridors and/or proximity to water) with relatively low clutter to optimize recording quality. This was typically done through a combination of examining aerial imagery and scouting potential sites on the ground. Additional details on sampling design and site selection can be found in SOP #1.

2.3 Rationale for Selecting Sample Size

Our initial goal was to sample a minimum of 15 cells per park (Gruver et al. 2016). This goal was established based on the number of detector units available and the estimated time required to access and sample each location. Also taken into consideration was the power analysis conducted by Western EcoSystems Technology to assess the ability of different sampling designs to detect trends in bat activity over time (Gruver et al. 2016). Models were fitted using preliminary field data collected from four parks (APIS, ISRO, SLBE, VOYA) during 2015. Models were run for four scenarios: either two or four acoustic detectors per park rotated among sites (approximately 15 or 30 total sites sampled, respectively), and either low or high variance among parks (Figure 1). Models also accounted for differences in habitat type and time of year.

Results of the power simulation suggest a 30% annual decline in overall bat activity would have an 80%–100% probability of being detected after five years of sampling. Similarly, a 20% annual decline would have a 30%–90% probability of being detected after five years of sampling. The probability of detecting a spurious trend was estimated to be as high as 20%.

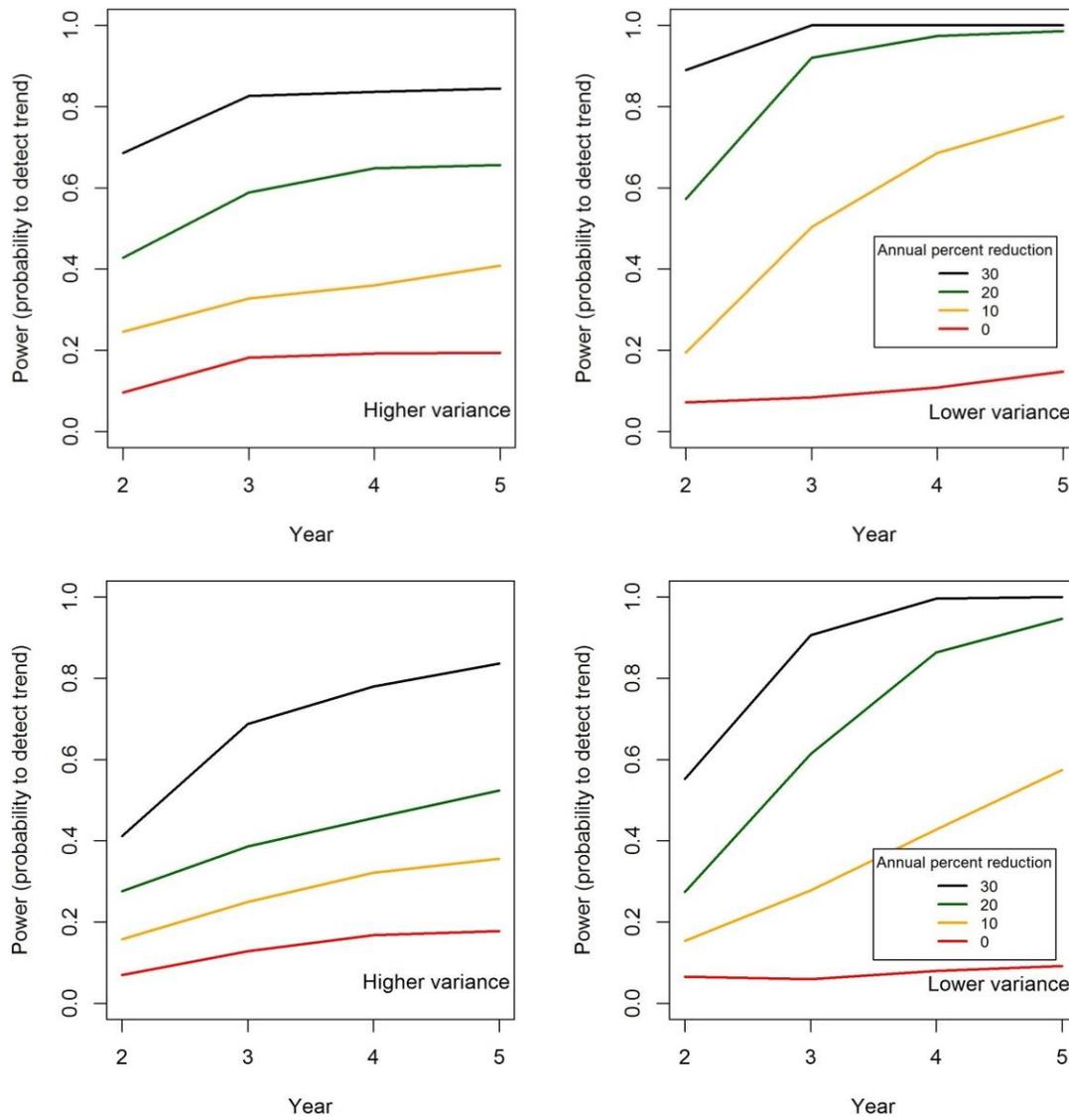


Figure 1. Power of the sampling design to detect a 10%, 20%, or 30% annual reduction in bat activity and probability of spurious trend detection (when annual reduction is 0%). Factors modeled include number of acoustic detectors used and degree of park-to-park variation in activity trends. Upper left panel shows power for four detectors with higher variation; upper right panel shows power for four detectors with lower variation; lower left panel shows power for two detectors with higher variation; lower right panel shows power for two detectors with lower variation. Level of effort, time and variability all influence power.

The final number of sites established ranges from 18–35 per park. This equates to a range of 3.6%–88.9% (average 20.4%) of cells sampled out of each park’s sampling frame. In comparison, the Northwestern Hub for Bat Population Research and Monitoring (NW Bat Hub) monitoring effort has a target sample size of 60 cells per state for Oregon, Washington, and Idaho (Rodriguez et al. 2019). This sample size represents approximately 2.5% of their sampling frame and was selected because it should provide sufficient statistical power for detecting trends using occupancy modeling (Rodriguez et al. 2019, Banner et al. 2019). Given that the GLKN program has a higher sampling intensity, with

a minimum of 3.6% of the sampling frame surveyed, our sample size should also allow sufficient power for trend analyses.

2.4 Rationale for Sampling Schedule

Acoustic monitoring will be conducted using an “always revisit” design wherein the same sampling locations are visited every sampling season, to allow for optimal detection of trends (McDonald 2003, Urquhart et al. 1998). The “always revisit” design is preferred over sampling a new set of locations each year, because it allows us to separate out the differences attributable to location from the differences attributable to year. Further details on the advantages of this design are provided in the NABat protocol (Loeb et al. 2015).

All sampling will occur during the summer season, which we define as 1 June 1–15 August. This time frame was selected because it captures the period when resident bat species are most active and when activity levels are the least variable (because it excludes spring and fall migration periods), providing the best opportunity to estimate trends (Gruver et al. 2016). It is also very similar to the survey window recommended by the USFWS for the federally listed Indiana and Northern Myotis (15 May–15 August) (U. S. Fish and Wildlife Service 2019). Our sampling season includes the time period when juvenile bats become volant (begin to fly) in late July to August. An increase in bat activity is expected in the later part of the summer due to these newly volant young bats. This seasonal change in activity could potentially confound our year-over-year comparisons, however our protocol mitigates for this issue by sampling each particular site at approximately the same time each year. Any individual site should therefore be consistently documenting either the pre-volancy or post-volancy period. Furthermore, our data analyses could include sampling date as a variable to account for this seasonal pattern.

Each location will be sampled for a period of 7–14 consecutive nights, once per year. Sampling multiple nights per site will help account for night to night variation in bat activity due to weather conditions, insect abundance, or other factors (Hayes 1997). More nights of sampling may also increase the probability of documenting rarer species (Skalak et al. 2012). In terms of data analysis, multiple nights per site provides temporal replication and allows for estimation of detection probabilities, an important part of occupancy modeling. However, the potential for correlation among nights must not be overlooked (Wright et al. 2016). Finally, because many of our sample locations are remote and not easily accessed, the range of 7–14 days will allow field crews flexibility to accommodate logistical challenges.

Detectors will be programmed to record every night from 6:00 p.m. to 8:00 a.m. Because total bat activity varies over the course of the night (Hayes 1997) and because different species have different nightly patterns of activity (Kurta 2017, Skalak et al. 2012), it is important to sample the entire night rather than only a few hours. The schedule we have selected covers the active foraging period of all local bat species and allows a consistent recording schedule across all locations and times of year.

2.5 Comparison to Other Acoustic Monitoring Protocols

The GLKN bat monitoring protocol is overall very similar to the protocols developed by the NABat program (Loeb et al. 2015) and the NW Bat Hub (Rodriguez et al. 2019). All three protocols use a

probabilistic sample design with a finite grid-based sampling frame and follow the GRTS algorithm to maintain spatial balance when selecting cells to be sampled. However, there are a number of areas where our approach differs from the others due to logistical considerations and prioritization of park needs. These differences are summarized below and in Table 2.

Table 2. Comparison between bat acoustic monitoring protocols used by Great Lakes Network (GLKN), the North American Bat Monitoring Program (NABat), and the Northwestern Hub for Bat Population Research and Monitoring (NW Bat Hub). “GRTS” refers to the Generalized Random Tessellation Stratification algorithm for spatially balanced selection of sampling units (Stevens and Olson 2004).

Protocol Component	GLKN	NABat	NW Bat Hub
Acoustic monitoring method	Stationary points	Stationary points and mobile transects	Stationary points
Sampling frame	1-km ² cells	10-km ² cells	10-km ² cells
Target sample size	15 cells per park	30 cells per jurisdiction	60 cells per state
Cell selection method	Probabilistic; GRTS	Probabilistic; GRTS	Probabilistic; GRTS
Sample sites (stationary points) per cell	1	2–4*	4*
Nights of recording per sample site	7–14	4	1

*Ideally with each site in a different quadrant of the cell

First, the NABat program encompasses multiple monitoring methods including acoustic surveys at stationary points, acoustic surveys along mobile transects, and both internal and external hibernacula or roost counts. Both the NW Bat Hub and GLKN monitoring programs focus solely on passive acoustic surveys at stationary points. For GLKN, other methods are impractical or inappropriate for our parks, as described in Section 2.1 above.

Secondly, NABat and the NW Bat Hub both use a sampling frame consisting of a grid of 10-km² cells, while the GLKN sampling frame consists of 1-km² cells. The NABat and NW Bat Hub programs are designed to allow analyses at the regional level and assess distributions of bat species across their range. In contrast, GLKN primarily aims to provide data that are meaningful at the park level. Therefore, we selected a finer-grained grid that is more appropriate for our goals. When contributing data to NABat, we will be able to associate each of our sample sites with the specific NABat grid cell in which it is located. Detailed information on the overlap between GLKN sites and the NABat sampling frame is located in Appendix B.

We established only one sample site per cell, whereas the NABat protocol suggests two to four sites per cell, and the NW Bat Hub suggests four sites per cell, for the purposes of spatial replication. With multiple sites per cell, both protocols advise placing one site in each of the four quadrants of the cell.

The sites within any particular cell should also be sampled concurrently or as close as possible. The GLKN protocol does not allow for spatial replication at the cell level, only at the park level.

Another significant difference between the three protocols is the number of recording nights per sample site. The NABat program recommends a minimum of four consecutive nights of recording per site, and also suggests conducting surveys during optimal weather conditions if possible. Due to challenging logistics and limited staff time at our parks, it is not feasible for us to deploy equipment only during optimal weather conditions. Instead, our protocol suggests recording for 7–14 consecutive nights per sample site. This longer sampling period is intended to mitigate for fluctuations in bat activity due to weather conditions or insect activity (Hayes 1997), and to increase the probability of detecting rarer species (Skalak et al. 2012). The NW Bat Hub protocol utilizes only a single night of recording per site. This design was selected to avoid the potential for correlation between consecutive nights in a deployment (Wright et al. 2016) while maintaining sufficient statistical power and reducing the time spent sampling each cell.

3.0 Field Methods

3.1 Preparation for the Field Season

- 1) Hiring for field personnel should begin several months prior to the field season.
- 2) Training and any protocol updates for field personnel should be provided at least two weeks prior to the beginning of the field season. Refer to SOP #2.
- 3) Staff should assemble, test, and organize all requisite equipment and supplies beginning approximately two weeks prior to the field season. This may include printing datasheets, maps, and reference documents; preparing folders/hard drives for data storage; formatting SD cards; calibrating microphones; and programming acoustic detector units. Refer to SOP #3.

3.2 Procedures During the Field Season

- 1) Field personnel should plan to deploy acoustic detectors starting 1 June, or earlier if a delayed start program is utilized.
- 2) At the time of deployment, field personnel should complete a datasheet (including GPS coordinates) and take site photos. Refer to SOP #4.
- 3) Equipment should be left at each sampling location for 7–14 nights, then moved to the next location. The same sites and sampling order should be used each year.
- 4) Equipment can be re-deployed at the next sampling location once used SD cards have been removed, batteries have been replaced, and empty SD cards have been inserted. Refer to SOP #4.
- 5) After each deployment, acoustic files, summary files, and the program file should be downloaded from the SD cards and securely stored along with site photos and a scanned copy of the field datasheet. Standard file structures and naming conventions will be used. Refer to SOP #5.
- 6) Field personnel should upload deployment data to the project's shared online drive to be reviewed by the protocol lead. Refer to SOPs #5 and #6.

3.3 End-of-Season Procedures

- 1) Field personnel should plan to complete all deployments by 15 August.
- 2) Before storing equipment for the winter, acoustic detector units should be cleaned and batteries removed. Equipment should be inventoried and any needed repairs or replacements should be addressed. Refer to SOP #4.
- 3) All deployment data should be securely stored in two separate locations. One copy of the data will be sent to GLKN while the second copy will be retained by the park. GLKN will then be responsible for storing and maintaining data, including an offsite backup copy. Refer to SOPs #5 and #6.
- 4) Each park should prepare a summary report and submit to GLKN. Refer to SOP #9.

- 5) GLKN staff and interns will perform data entry and quality assurance. The finalized database and all acoustic files will then be provided to a contractor for processing to obtain species classifications and manual vetting results. Refer to SOPs #7 and #8.

4.0 Data Handling, Analyses, and Reporting

4.1 Metadata Procedures

The network's overall strategy for the generation, management, and distribution of metadata is described in Chapter 7 (Data Documentation) of the GLKN Data Management Plan (Hart and Gafvert 2006) and the appendices of that document.

Executive Order 12906 mandates that federal agencies document all new geospatial data they collect or produce, either directly or indirectly using the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM; <https://www.fgdc.gov/metadata/geospatial-metadata-standards>). In addition, EO 12906 directs agencies to plan for legacy data documentation and provide metadata and data to the public. GLKN will also generate FGDC-style metadata for non-spatial datasets that meets this standard, absent only the geospatial-specific elements.

The FGDC Biological Data Profile

(<https://www.fgdc.gov/standards/projects/metadata/biometadata>) contains all the elements of the CSDGM and includes additional elements for describing biological data sets. All GIS data layers must be documented with applicable FGDC metadata standards.

Metadata allows potential data users to evaluate the quality and usefulness of the data based on an understanding of the complete process under which it was collected and maintained. In this respect, all of the protocol documentation, including SOPs, are part of a dataset's metadata. A reference to the appropriate version of these documents is part of the metadata for any particular element of a dataset. The relationship between a data element and the appropriate versions of documented procedures is based on the date and time the procedures are performed. Thus, the documentation must have accurate records on each version indicating the start and end date it was in effect, an indication of which version it replaced and, if applicable, the version which replaced it—both a forward and reverse documentation trail. Although perhaps obvious, all data must have an associated value for the date and time it was collected.

Most of the remaining metadata will be recorded directly in the project-specific databases and tables. The GLKN database has fields and tables which incorporate the metadata elements specified by NPS standards. During collection of field data, these metadata elements are entered by selecting an existing profile of metadata, or by entering specific elements in data fields using pre-determined lookup values selected from dropdown menus.

4.2 NPS Bat Acoustic Survey Database

The GLKN bat monitoring program will utilize the NPS Bat Acoustic Survey database to manage and store data. This is a Microsoft Access database developed by the NPS Biological Resources Division and Inventory and Monitoring Division. The database (Version 1.7) and an associated reference manual can be downloaded from the NPS Data Store, Reference Profile 2230347 and Reference Profile 2231984, respectively.

GLKN data managers and protocol leads have modified the NPS Bat Acoustic Survey database to accommodate the specific needs of the GLKN program. For example, modifications include creating additional queries and reports and adjusting the layout of data entry forms.

The GLKN office will maintain one master copy of the database on a central server. This is the only copy that can be used to export data to other locations. Additional copies (replicas) of the database may be used for data entry and data analysis by outside contractors, always followed by importation of data to GLKN's master version of the database.

In brief, the data management process for bat acoustic monitoring data involves entering deployment information into the database; processing acoustic files through call analysis software and importing results into the database; conducting formal quality assurance/quality control (QA/QC) checks on the data; and backing up and storing digital files for archive and analysis.

4.3 Data Entry, Verification and Editing

Data will be entered into the bat database each year after the completion of the field season. The database includes sections for site information, deployment information, and species detection information. Following data entry, a series of QA/QC procedures will be performed. Any issues identified during the QA/QC process will be reviewed by the protocol lead and/or data manager and corrections will be made as necessary. Detailed instructions for data entry and QA/QC are provided in SOP #7.

Each individual record in the bat monitoring dataset has a status field indicating whether the data has undergone QA/QC checks. Only after the record has passed all QA/QC checks will it be flagged as having final status. Finalized data can still be edited and changed if errors are discovered after review in reporting and analysis.

Identity of the person responsible is recorded for each aspect of data handling, from field data collection through to the final steps of QA/QC. Names of field personnel are recorded on datasheets and transcribed into the database. During data entry, the database records the name of the user who made each record or modification. During QA/QC, the names of the persons doing the review and making corrections are recorded on the QA/QC sheets. Only qualified users who have been trained are allowed to enter or edit data in the master database. These procedures protect the integrity of the data and allow the history of each data record to be traced.

4.4 Data Analyses and Reporting

Data processing will be completed by either an outside contractor or GLKN staff. Acoustic data will be analyzed using the specialized software program Kaleidoscope Pro. For consistency, this is the only program being used for this project, however other similar software programs are available. Kaleidoscope Pro is used for two main functions: 1) to filter out audio files containing noise from those containing bat calls, and 2) to obtain automated species-level classifications for files containing bat calls. Kaleidoscope Pro also offers the option to attribute audio files with additional user-defined metadata if desired (e.g., a description of the sample site). Because audio file names already include the Site IDs, GLKN protocol does not currently call for attributing files with additional metadata.

Following automated classification with Kaleidoscope Pro, a subset of the audio files containing bat calls will be manually reviewed (manually vetted). This review must be performed by a qualified biologist with specific training in bat call identification. The purpose of manually reviewing bat call files is to verify the species classifications assigned by the software. Automated classifications are expected to include some errors due to factors such as similarity of calls among different species, variation of calls within the same species, poor quality or truncated calls, clutter effects, or multiple bats recorded together (Britzke et al. 2013, Reichert et al. 2018). Due to the enormous quantity of data produced by the GLKN monitoring program, it will not be feasible to manually review every bat call file. Instead, our protocol recommends manual review of at least 1% of call files within each park/species combination, with files selected at random. Results of the manual review may be used in multiple ways. For example, to estimate the error rate for automated classifications, or to calculate percent of sites or percent of nights with a species' presence verified. Additional call files beyond the 1% may be reviewed for specific purposes such as endangered species compliance, assessing suspicious records outside of a species' documented range, or developing occupancy models. In these cases, instead of a random sample, it may be more appropriate to specifically focus on the call files that offer the greatest chance of verification, such as search-phase type calls, longer call sequences, or files assigned a higher confidence score by the software. Details of data processing and manual vetting are provided in SOP #8.

Reporting will occur both on the park-level and network-wide and will include both yearly summaries and longer term multi-year trend analyses.

4.4.1 Yearly Summaries for Individual Parks

Field personnel at each park will be required to create a summary report at the end of each field season. The report is crucial for conveying methods used, problems that arose, and suggestions for changes to the protocol. The report will be submitted to GLKN as well as kept at the park for park staff to reference. Detailed requirements and a report template are provided in SOP #9.

4.4.2 Overall Yearly Summaries

An overall summary report should be produced each year, describing results from all participating parks. This report should include information such as survey effort, results of automated species classification by park and by site, and results of manual vetting. It should also highlight interesting observations, changes from previous years, issues encountered, and recommendations for future seasons. More detailed information is provided in SOP #9.

4.4.3 Multi-Year Reporting

Multi-year reports should be completed approximately every five years. These reports will include more in-depth analysis than the yearly summaries. Detailed guidance is provided in SOP #10. As a general overview, the following types of data should be included:

- Survey effort by park and by year (number of sites, number of deployment nights, average nights per site)

- Survey results by park and by year (total number of files recorded that met protocol requirements, number of files that were identified to a specific species vs. noise vs. unknown bats)
- Species-level results by park and by year (number of files identified to each species by Kaleidoscope Pro, indication of which species were/were not verified present through manual vetting, error rates associated with software's classifications, total species richness, mean species richness)
- Spatial and temporal distribution of species (number and percent of sites where each species was detected; number and percent of deployment nights on which each species was detected)
- Methods and results of bat activity modeling and statistical tests
- Discussion of trends observed and management implications

4.5 Data Archival Procedures

GLKN's general strategy for data archiving is described in GLKN's Data Management Plan and appendices (Hart and Gafvert 2006). Guidance specific to the bat monitoring program is presented here. Data archiving should be coordinated with the GLKN IT Specialist and Data Manager.

During the field season, each participating park will store two copies of their raw data at the park. The first copy will be on a GLKN-provided external hard drive; the second copy will be in a separate location such as another external hard drive or the park's server. Data include audio files; acoustic detector status files, program files, and diagnostic (dump) files; site photos; and field datasheets. Data management guidance for park staff is found in SOP #5.

At the conclusion of the field season, each park will send their data to the GLKN office. The protocol lead will create two copies of the raw data received from the parks on two separate high capacity hard drives. One of these, plus the individual drives sent in by the parks, will be set aside as backups of the raw data. The remaining high capacity drive will be used as the working copy for file organization, review, and corrections. Once the dataset is corrected and finalized, additional copies will be made so that it can be stored in three separate locations. These include 1) onsite at the GLKN office, 2) offsite at Apostle Islands National Lakeshore, and 3) at each park. Corrected data are returned to each park so that park staff have the most up-to-date information on which to base their continuing field work. Raw data may be deleted after corrected data is finalized and backed up. Data management guidance for the protocol lead is found in SOP #6.

GLKN's master version of the bat database is maintained on a central server in the GLKN office. The server is backed up daily and backed up off-site every week. Complete details of the server archiving procedure can be found in Chapter 4 (Data Management Infrastructure) of GLKN's Data Management Plan (Hart and Gafvert 2006).

4.6 Data Sharing

Data from the GLKN bat monitoring program may be shared with other entities such as state and federal agency partners, university researchers, or large-scale programs such as NABat. Data to be shared may include the full database, tables or reports exported from the database, and/or audio files

with species identification information. All data will undergo quality control and certification procedures prior to distribution. Legally or operationally protected data may be withheld from public distribution to protect sensitive resources or personal information. Data to be disseminated will be properly documented with accompanying metadata and data quality information. Further details regarding data sharing procedures can be found in the Quality Assurance Plan.

5.0 Personnel Requirements and Training

5.1 Roles and Responsibilities

The bat monitoring program will be a collaborative effort between GLKN staff, parks, and other partners. It is expected that individual parks will implement the protocol with administrative support, guidance, training, and data management/analysis provided by GLKN. Colleges and universities may participate by arranging student internships. Outside contractors may also assist with data processing, data analysis, and reporting.

5.1.1 GLKN Program Manager

The program manager is responsible for overseeing the development and implementation of the bat monitoring project and ensuring that the project is aligned with and contributing towards overall Network goals. The program manager also provides support in budget, personnel, and logistical matters.

5.1.2 GLKN Protocol Lead

The protocol lead is responsible for administering and coordinating the overall program, keeping the program manager apprised of progress, and coordinating staffing, logistics, and information transfer with park staff. The protocol lead also oversees the seasonal staff conducting fieldwork, manages and reviews incoming data, and coordinates with other GLKN employees leading other GLKN monitoring efforts. Finally, the protocol lead serves as a liaison among the various collaborators: park staff, network staff, outside contractors, and college/university partners. Ideally, in the future this role would be filled by a permanent full-time GLKN Wildlife Biologist. However, GLKN does not currently have a Wildlife Biologist on staff, therefore these duties are being performed jointly by a GLKN employee in collaboration with a temporary project coordinator hired through a cooperative agreement. Specific responsibilities of the protocol lead include the following:

- Prepare and submit proposals for funding and manage project budgets.
- Prepare and manage cooperative agreements with college/university partners.
- Prepare and manage contracts for independent consultants.
- Purchase of equipment and supplies.
- Hire, onboard, and train seasonal field personnel.
- Ensure timely field data collection and adherence to protocols.
- Conduct quality assurance checks during the sampling season and provide feedback to field personnel.
- Maintain equipment inventory and ensure availability of equipment and supplies.
- Develop and update protocols and SOPs for field data collection and data management.
- Communicate project information to park resource managers and field personnel.
- Serve as the main point of contact concerning data content.

5.1.4 GLKN Data Manager

Data management for this monitoring effort is the shared responsibility of the field personnel at each park, the GLKN protocol lead, and GLKN data manager. The data manager is responsible for overseeing data verification and validation procedures, data archiving, data security, data dissemination, and database maintenance.

The protocol lead and data manager will all work closely together to:

- Develop data quality assurance, quality control, validation, and verification measures for the project.
- Coordinate changes to data entry forms and the user interface for the project database.
- Ensure staff is trained in the use of database software and QA/QC procedures.
- Supervise or perform data entry, verification, and validation.
- Conduct routine data analysis, summaries, and annual reporting.
- Identify whether sensitive information should be omitted prior to distribution.
- Ensure regular archiving of raw data, corrected data, project database, reports and summaries, and other products/documentation related to the project.

5.1.5 Field Personnel at Parks

Field personnel at each park are responsible for conducting all field work related to the bat monitoring project. Training and protocol updates will be provided by the protocol lead on a yearly basis. Day-to-day supervision and logistical support will be provided by the park resource manager. Specific responsibilities of field personnel include:

- Reading and understanding protocols and SOPs.
- Preparing and maintaining equipment during the field season. Cleaning and properly storing equipment after field work has been completed.
- Deploying equipment following SOPs. Verifying proper functioning of equipment at each deployment.
- Regularly communicating progress and problems encountered to the park resource manager and GLKN protocol lead.
- Downloading and securely saving deployment data.
- Submitting data to the GLKN protocol lead for quality assurance checks throughout the field season.
- Submitting the complete dataset to the GLKN office at the end of the field season.
- Documenting data collection issues such as failed deployments, omitted sites, and deviations from standard procedures.

5.2 Training Procedures

Before participation in field data collection, data entry, or QA/QC, personnel must become familiar with the SOPs and monitoring equipment. Training procedures for new personnel will include the following:

- Review of this protocol, associated SOPs, and QAP.
- Familiarity with procedures for calibration, operation, maintenance, and deployment of acoustic detectors and microphones.
- Familiarity with collecting data in the field, including datasheets, site photos, and GPS coordinates.
- Familiarity with procedures for data storage and data submission.
- Park-specific training (to be provided on-site by park staff) including safety procedures, use of radios, and vehicle/boat operation.

6.0 Operational Requirements

6.1 Annual Workload and Field Schedule

The workload for the bat acoustic monitoring program is concentrated on data collection during the summer and data processing during the fall and winter. Approximate schedules for GLKN staff and for field personnel are described below.

Schedule for GLKN staff:

- January–March: Work with park supervisors to hire field personnel; receive and review summary report from contractor
- April–May: Purchase replacement equipment and supplies; put corrected data on external hard drives and deliver to parks
- Late May: Train field personnel and assist them with preparing for field season
- June–August: Review field data submitted by field personnel, provide feedback, and troubleshoot problems
- September–October: Receive complete field data from parks; enter data into database; run QA/QC checks
- November–December: Provide finalized data to contractor for analysis

Schedule for field personnel:

- 15–31 May: Inventory and prepare equipment and supplies; arrange logistics
- 1 June–15 August: Deploy equipment for data collection; submit data periodically to GLKN for review
- 15–30 August: Inventory, clean, and repair equipment; finalize data; prepare summary report; submit data and report to GLKN

6.2 Equipment Needs and Costs

A summary of the necessary equipment discussed here, along with the cost per item is provided in Table 3. Approximately 65 Wildlife Acoustics Song Meter² full-spectrum acoustic detectors have been purchased by GLKN for this project (a combination of SM3BAT and SM4BAT models), allowing for each park to have 5–10 units for sampling. The current price for a Wildlife Acoustics Song Meter SM4BAT-FS is \$899. The SM3BAT model is no longer available so any future replacements will be SM4BAT units.

² Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

Table 3. Summary of necessary equipment and cost per item for bat monitoring in Great Lakes Network parks.

Item	Number Needed	Purchased By	Approx. Cost
Wildlife Acoustics Song Meter SM4BAT-FS full-spectrum acoustic detector	approx. 65	GLKN	\$899
SMM-U2 ultrasonic microphone	–	GLKN	\$200
3-meter microphone cable	–	GLKN	\$59
Wildlife Acoustics microphone calibrator	–	GLKN	\$199
Wildlife Acoustics GPS attachment for SM4BAT	–	GLKN	\$149
D-size alkaline batteries	4 per deployment	GLKN	\$10 for a 12-pack
64-GB-capacity SD cards (Sandisk Ultra 64-GB class-10 SDXC card)	2 per song meter per deployment	GLKN	\$15
Mounting equipment such as poles, tripods, bungees, electrical tape, zip ties, and cable locks	–	GLKN	–
Handheld GPS unit, compass, and clipboard	–	Parks	–
Kaleidoscope Pro acoustic data analysis/processing software	–	GLKN	\$399 for 12-month subscription
One 2-TB-capacity external hard drive per park, plus several extras to use for data transfer	9+	GLKN	\$80
High capacity drives (e.g., 4- or 8-TB Seagate Desktop HDD) and an array	–	GLKN	\$100–\$200 (drive), \$200–300 (array)

Required accessory equipment includes microphones, microphone cables, microphone calibrators, and GPS attachments. These items can generally be reused year after year. However, microphones may become damaged or lose sensitivity after a few seasons and will need to be repaired or replaced. The current price for a Wildlife Acoustics SMM-U1 ultrasonic microphone is \$240 (no cable included). This is the microphone that GLKN has used consistently since 2016, however it is being phased out by the manufacturer and replaced with the SMM-U2. The current price for a SMM-U2

ultrasonic microphone is \$200. The newer SMM-U2 microphone is more sensitive and produces cleaner recordings than the SMM-U1 (D. Licht, personal communication). Because of these differences, careful consideration should be given to how the data collected from each type of microphone are compared. A 3-meter cable, sufficient for most applications, can be purchased for \$59, and longer cables are also available. The current price for a Wildlife Acoustics microphone calibrator is \$199. The current price for a Wildlife Acoustics GPS attachment for SM4BAT is \$149.

Each park requires a new supply of batteries each year to power the Song Meters. Four standard alkaline D-size batteries are needed per deployment. These batteries may be purchased at approximately \$10 for a 12-pack (\$0.83 each or \$3.33/deployment). Rechargeable batteries should not be used. Our protocol uses two 64-GB-capacity SD cards in each Song Meter per deployment, which allows for continuous recording in case one card fails or fills up. We have purchased the Sandisk Ultra 64-GB class-10 SDXC card, at a cost of approximately \$15 each. SD cards can be reused through multiple deployments and seasons, but the repeated write/erase cycles may eventually lead to corrupt cards that need to be replaced.

Additional costs will include mounting equipment such as poles, tripods, bungees, electrical tape, zip ties, and cable locks. Each park is expected to provide general field supplies needed by their field technician, including a handheld GPS unit, compass, and clipboard. For GLKN staff, the acoustic data analysis/processing software Kaleidoscope Pro will also be necessary (\$399 for 12-month subscription).

Due to the large amount of data generated by this project, dedicated data storage costs will be significant. Data storage includes a minimum of one 2-TB-capacity external hard drive per park, plus several extras to use for data transfer with contractors. The current price for this type of drive is approximately \$80. Drives can be reused year after year and should not generally need replacement. High capacity drives (e.g., 4- or 8-TB Seagate Desktop HDD) and an array are also required for data transfer, data processing, and data backups at the GLKN office. The current price for this type of drive is approximately \$100–\$200 and for the array \$200–300. Data storage methods will likely be adjusted as technology continues to improve.

To date, GLKN has invested over \$100,000 in equipment to get the program up and running. Ongoing annual expenses of approximately \$5,000 will cover the cost of batteries, replacement of damaged microphones, and other miscellaneous supplies.

6.3 Contracting Costs

GLKN will request bids for contracting services to help implement portions of this protocol, primarily for data processing, analysis, and reporting. The cost of the contract may vary, depending on factors such as the amount of data included and the depth of data analysis required. The cost of the contract is estimated at \$35,000–40,000 per year at this time.

6.4 Procedures for Revising and Archiving Previous Versions of the Protocol

As the bat monitoring program matures, revisions to both the protocol narrative and specific standard operating procedures (SOPs) are likely. Documenting changes and archiving copies of previous

versions are essential for maintaining consistency in the collection of data and for appropriate interpretation of data summaries and analyses.

This protocol narrative includes a general overview of the history and justification for doing the work and an outline of the sampling methods. The SOPs are more detailed step-by-step procedures of methods. Whenever an SOP is revised, the corresponding section of the protocol may or may not need to be revised depending on the type of change. All old versions of the protocol narrative and SOPs will be archived.

The steps for changing either the protocol narrative or the SOPs are outlined in SOP #11. Each SOP contains a Revision History Log that should be filled out each time a SOP is revised to explain why the change was made, and to assign a new version number to the revised SOP. The old version of the SOP or protocol narrative should then be archived in the appropriate folder of the GLKN database structure.

Literature Cited

- Adams, R. A. 2010. Bat reproduction declines when conditions mimic climate change projections for western North America. *Ecology* 91:2437–2445.
- American Wind Energy Association. 2019. Wind Facts at a Glance. Available at: www.awea.org/wind-101/basics-of-wind-energy/wind-facts-at-a-glance (accessed 9 March 2020).
- Arnett, E. B., E. F. Baerwald, F. Mathews, L. Rodrigues, A. Rodriguez-Duran, J. Rydell, R. Villegas-Patraca, and C. C. Voigt. 2015. Impacts of wind energy development on bats: A global perspective. Pages 295–323 in C. C. Voigt and T. Kingston, editors. *Bats in the Anthropocene: Conservation of Bats in a Changing World*. Springer International Publishing, Basel, Switzerland.
- Avila-Flores, R., and M. B. Fenton. 2005. Use of spatial features by foraging insectivorous bats in a large urban landscape. *Journal of Mammalogy* 86:1193–1204.
- Banner, K. M., K. M. Irvine, T. J. Rodhouse, D. Donner, and A. R. Litt. 2019. Statistical power of dynamic occupancy models to identify temporal change: Informing the North American Bat Monitoring Program. *Ecological Indicators* 105:166–176.
- Barclay, R. M. R. 1999. Bats are not birds—A cautionary note on using echolocation calls to identify bats: A comment. *Journal of Mammalogy* 80:290–296.
- Blehert, D. S., A. C. Hicks, M. Behr, C. U. Meteyer, B. M. Berlowski-Zier, E. L. Buckles, J. T. H. Coleman, S. R. Darling, A. Gargas, R. Niver, J. C. Okoniewski, R. J. Rudd, and W. B. Stone. 2009. Bat white-nose syndrome: An emerging fungal pathogen? *Science* 323:227.
- Britzke, E. R., E. H. Gillam, and K. L. Murray. 2013. Current state of understanding of ultrasonic detectors for the study of bat ecology. *Acta Theriologica* 58(2):109–117.
- Brooks, R. T. 2011. Declines in summer bat activity in central New England 4 years following the initial detection of white-nose syndrome. *Biodiversity and Conservation* 20:2537–2541.
- Byrne, C. 2014. Acoustic bat survey at the Indiana Dunes National Lakeshore. Unpublished Investigator's Annual Report to the National Park Service, Porter, Indiana.
- Cravens, Z. M., and J. G. Boyles. 2019. Illuminating the physiological implications of artificial light on an insectivorous bat community. *Oecologia* 189:69–77.
- Dixon, M. D. 2010. July 2010 Voyageurs bat survey final report. Unpublished report submitted to Voyageurs National Park, International Falls, Minnesota.
- Dixon, M. D. 2012. Relationship between land cover and insectivorous bat activity in an urban landscape. *Urban Ecosystems* 15:683–695.

- Dixon, M. T., R. M. Rodriguez, and L. K. Ammerman. 2014. Comparison of two survey methods used for bats along the lower canyons of the Rio Grande and in Big Bend National Park. In C. A. Hoyt and J. Karges, editors. Proceedings of the Sixth Symposium on the Natural Resources of the Chihuahuan Desert Region, October 14–17. Chihuahua Desert Research Institute, Fort Davis, Texas.
- Dzal, Y., L. P. McGuire, N. Veselka, and M. B. Fenton. 2011. Going, going, gone: The impact of white-nose syndrome on the summer activity of the little brown bat (*Myotis lucifugus*). *Biology Letters* 7:392–394.
- Ford, W. M., E. R. Britzke, C. A. Dobony, J. L. Rodrigue, and J. B. Johnson. 2011. Patterns of acoustical activity of bats prior to and following white-nose syndrome occurrence. *Journal of Fish and Wildlife Management* 2:125–134.
- Frick, W. F. 2013. Acoustic monitoring of bats, considerations of options for long-term monitoring. *Therya* 4:69–78.
- Frick, W. F., E. F. Baerwald, J. F. Pollock, R. M. R. Barclay, J. A. Szymanski, T. J. Weller, A. L. Russell, S. C. Loeb, R. A. Medellin, and L. P. McGuire. 2017. Fatalities at wind turbines may threaten population viability of a migratory bat. *Biological Conservation* 209:172–177.
- Frick, W. F., S. J. Puechmaille, J. R. Hoyt, B. A. Nickel, K. E. Langwig, J. T. Foster, K. E. Barlow, T. Bartonička, D. Feller, A. J. Haarsma, C. Herzog, I. Horáček, J. van der Kooij, B. Mulken, B. Petrov, R. Reynolds, L. Rodrigues, C. W. Stihler, G. G. Turner, and A. M. Kilpatrick. 2015. Disease alters macroecological patterns of North American bats. *Global Ecology and Biogeography* 24:741–749.
- Frick, W. F., P. M. Stepanian, J. F. Kelly, K. W. Howard, C. M. Kuster, T. H. Kunz, and P. B. Chilson. 2012. Climate and weather impact timing of emergence of bats. *PLoS ONE* 7:e42737. Available at: <https://doi.org/10.1371/journal.pone.0042737> (accessed 3 April 2020).
- Gehring, J. 2011. Bat migration along the Lake Michigan and Lake Huron coastline: A pilot study to inform wind turbine siting. Report Number 2011-19. Michigan Natural Features Inventory, Lansing, Michigan.
- George, K., and A. Kurta. 2016. A search for the northern long-eared bat (*Myotis septentrionalis*) at Sleeping Bear Dunes National Lakeshore. Unpublished report on Cooperative Agreement P14AC01364 submitted to Sleeping Bear Dunes National Lakeshore, Empire, Michigan.
- Goodwin, K. R. 2012. Acoustic and visual surveys of bats (Chiroptera) in Isle Royale National Park. Unpublished National Park Service report, Houghton, Michigan.
- Gorresen, P. M., A. C. Miles, C. M. Todd, F. J. Bonaccorso, and T. J. Weller. 2008. Assessing bat detectability and occupancy with multiple automated echolocation detectors. *Journal of Mammalogy* 89:11–17.

- Graetz, J. L., R. A. Garrott, and S. R. Craven. 1995. Faunal surveys of Agate Fossil Beds and Grand Portage National Monuments. Unpublished report to the National Park Service, Harrison, Nebraska, and Grand Portage, Minnesota.
- Gruver, J., P. Rabie, L. A. Starcevich, M. Romanski, and B. Route. 2016. Monitoring protocol for bats in the Great Lakes Inventory and Monitoring Network. Unpublished report to the National Park Service, Ashland, Wisconsin.
- Hahn, W. L. 1909. The mammals of Indiana. A descriptive catalogue of the mammals occurring in Indiana in recent times. Pages 417–663 *in* W. S. Blatchley, editor. Thirty-third Annual Report, Indiana Department of Geology and Natural Resources, Indianapolis, Indiana.
- Hart, M., and U. Gafvert (editors). 2006. Data management plan: Great Lakes Inventory and Monitoring Network. Great Lakes Inventory and Monitoring Network Report GLKN/2006/20. National Park Service, Ashland, Wisconsin.
- Hayes, J. P. 1997. Temporal variation in activity of bats and the design of echolocation-monitoring studies. *Journal of Mammalogy* 78(2):514–524.
- Humphries, M. M., D. W. Thomas, and J. R. Speakman. 2002. Climate-mediated energetic constraints on the distribution of hibernating mammals. *Nature* 418:313–316.
- Indiana Division of Fish and Wildlife. 2019. Endangered and Special Concern species list. Available at: www.in.gov/dnr/naturepreserve/files/fw-Endangered_Species_List.pdf (accessed 3 April 2020).
- Jackson, H. H. T. 1920. An apparent effect of winter inactivity upon distribution of mammals. *Journal of Mammalogy* 1(2):58–64.
- Kitzes, J., and A. Merenlender. 2014. Large roads reduce bat activity across multiple species. *PLoS ONE* 9:e96341. Available at: <https://doi.org/10.1371/journal.pone.0096341> (accessed 3 April 2020).
- Krauel, J. J., and G. LeBuhn. 2016. Patterns of bat distribution and foraging activity in a highly urbanized temperate environment. *PLoS ONE* 11:e0168927. Available at: <https://doi.org/10.1371/journal.pone.0168927> (accessed 3 April 2020).
- Kruger, L., and R. O. Peterson. 2008. Occurrence of temperate bat species at three national parks in the Great Lakes region. Natural Resource Technical Report NPS/GLKN/NRTR–2008/128. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/DownloadFile/152134> (accessed 3 April 2020).
- Kunz, T. H., E. B. Arnett, W. P. Erickson, A. R. Hoar, G. D. Johnson, R. P. Larkin, M. D. Strickland, R. W. Thresher, and M. D. Turtle. 2007. Ecological impacts of wind energy development on bats: Questions, research needs, and hypotheses. *Frontiers in Ecology and the Environment* 5:315–324.

- Kurta, A. 2017. *Mammals of the Great Lakes Region* (third edition). University of Michigan Press, Ann Arbor, Michigan.
- Kurta, A., and H. Rice. 2001. Bats and insects in Sleeping Bear Dunes National Lakeshore. Unpublished Investigator's Annual Report to the National Park Service, Empire, Michigan.
- Kurta, A., and H. Rice. 2002. Bats and insects in Sleeping Bear Dunes National Lakeshore. Unpublished Investigator's Annual Report to the National Park Service, Empire, Michigan.
- Kurta, A., and R. Slider. 2017. The bat community at Pictured Rocks National Lakeshore, with emphasis on the northern long-eared bat. Unpublished report submitted to Pictured Rocks National Lakeshore, Munising, Michigan.
- Kurta, A., L. Winhold, J. O. Whitaker, Jr., and R. Foster. 2007. Range expansion and changing abundance of the eastern pipistrelle (Chiroptera: Vespertilionidae) in the central Great Lakes region. *American Midland Naturalist* 157(2):404–411.
- Larsen, D. P., A. R. Olsen, and D. L. Stevens, Jr. 2008. Using a master sample to integrate stream monitoring programs. *Journal of Agricultural, Biological, and Environmental Statistics* 13(3):243–254.
- Lehnert, E. 2013. Capture and sample collection of bats (Chiroptera) in Isle Royale National Park: 2013 sampling report. Unpublished Isle Royale National Park Natural Resources Management Report, Houghton, Michigan.
- Loeb, S. C., T. J. Rodhouse, L. E. Ellison, C. L. Lausen, J. D. Reichard, K. M. Irvine, T. E. Ingersoll, J. T. H. Coleman, W. E. Thogmartin, J. R. Sauer, C. M. Francis, M. L. Bayless, T. R. Stanley, and D. H. Johnson. 2015. A plan for the North American Bat Monitoring Program (NABat). General Technical Report SRS-208. U.S. Department of Agriculture Forest Service, Southern Research Station, Asheville, North Carolina.
- Loeb, S. C., and E. A. Winters. 2013. Indiana bat summer maternity distribution: Effects of current and future climates. *Ecology and Evolution* 3:103–114.
- Lyon, M. W., Jr. 1922. Notes on the mammals of the dune region of Porter County, Indiana. *Proceedings of the Indiana Academy of Science* 32:209–221.
- McDonald, T. L. 2003. Review of environmental monitoring methods: Survey designs. *Environmental Monitoring and Assessment* 85: 277–292.
- Michigan Natural Features Inventory. 2009. Michigan's special animals: Endangered, Threatened, Special Concern, and Probably Extirpated. April 2020 version available at: <https://mnfi.anr.msu.edu/species/animals> (accessed 3 April 2020).
- Miller, B. W. 2001. A method for determining relative activity of free flying bats using a new activity index for acoustic monitoring. *Acta Chiropterologica* 3(1):93–105.

- Miller, B. W. 2010. Revised relative abundance estimates and temporal activity of bats at three Great Lakes national parks based on acoustic data. Natural Resource Report NPS/GLKN/NRR—2010/178. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/DownloadFile/152470> (accessed 3 April 2020).
- Minnesota Department of Natural Resources. 2013. Minnesota’s list of Endangered, Threatened, and Special Concern species. Available at: http://files.dnr.state.mn.us/natural_resources/ets/endlist.pdf (accessed 3 April 2020).
- National Park Service. 2016. Protecting bats in parks. Available at: www.nps.gov/subjects/bats/protecting-bats-in-parks.htm (accessed 12 August 2019).
- NPSpecies. 2019. NPSpecies—The National Park Service biodiversity database. Available at: <https://irma.nps.gov/npspecies/> (accessed 12 August 2019).
- Parker, E. S. 2002. Bat survey summary report. Isle Royale National Park. Unpublished National Park Service report, Houghton, Michigan.
- Pettit, J. L., and J. M. O’Keefe. 2017. Impacts of white-nose syndrome observed during long-term monitoring of a Midwestern bat community. *Journal of Fish and Wildlife Management* 8:69–78.
- Pourshoushtari, R. D., B. P. Pauli, P. A. Zollner, and G. S. Haulton. 2018. Road and habitat interact to influence selection and avoidance behavior of bats in Indiana. *Northeastern Naturalist* 25:236–247.
- Powers, K. E., R. J. Reynolds, W. Orndorff, W. M. Ford, and C. S. Hobson. 2015. Post-White-nose syndrome trends in Virginia’s cave bats, 2008–2013. *Journal of Ecology and the Natural Environment* 7:113–123.
- Rand, A. L., and A. S. Rand. 1951. Mammal bones from dunes south of Lake Michigan. *American Midland Naturalist* 46:649–659.
- Reichert, B., C. Lausen, S. Loeb, T. Weller, R. Allen, E. Britzke, T. Hohoff, J. Siemers, B. Burkholder, C. Herzog, and M. Verant. 2018. A guide to processing bat acoustic data for the North American Bat Monitoring Program (NABat). U.S. Geological Survey Open-File Report 2018–1068. U.S. Geological Survey, Reston, Virginia. Available at: <https://doi.org/10.3133/ofr20181068> (accessed 3 April 2020).
- Rodhouse, T. J., K. T. Vierling, and K. M. Irvine. 2011. A practical sampling design for acoustic surveys of bats. *Journal of Wildlife Management* 75:1094–1102.
- Rodhouse, T. J., T. E. Phillipi, W. B. Monahan, and K. T. Castle. 2016. A macroecological perspective on strategic bat conservation in the U.S. National Park Service. *Ecosphere* 7:1–17.
- Rodriguez, R. M., T. J. Rodhouse, J. Barnett, K. M. Irvine, K. M. Banner, J. Lonneker, and P. C. Ormsbee. 2019. North American Bat Monitoring Program regional protocol for surveying with

- stationary deployments of echolocation recording devices: Version 1.0, Pacific Northwestern US. Natural Resource Report NPS/UCBN/NRR—2019/1975. National Park Service, Fort Collins, Colorado.
- Route, B. 2001. A field inventory of bats (Chiroptera) occurring in Voyageurs National Park, Minnesota. Unpublished Investigator's Annual Report to the National Park Service, International Falls, Minnesota.
- Route, B., and J. Elias (editors). 2007. Vital signs monitoring plan: Phase 3 report. Version 1.0. Great Lakes Inventory and Monitoring Network. Technical Report GLKN/2005/17. National Park Service, Ashland, Wisconsin.
- Route, B. and J. Schaberl. 2013. A cursory survey of bats in Voyageurs National Park, Minnesota. Natural Resource Technical Report NPS/GLKN/NRTR—2013/701. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/DownloadFile/466004> (accessed 3 April 2020).
- Russo, D., L. Ancillotto, and G. Jones. 2018. Bats are still not birds in the digital era: Echolocation call variation and why it matters for bat species identification. *Canadian Journal of Zoology* 96:63–78.
- Shier, T. A., C. M. Hudson, and S. A. Johnson. 2015. Indiana Fixed-location Acoustic Bat Monitoring Program. Indiana Department of Natural Resources Report, Bloomington, Indiana. Available at: https://secure.in.gov/dnr/fishwild/files/fw-MR_2028_March_Fixed_locations_Report_2015.pdf (accessed 3 April 2020).
- Simmons, N. B., and A. L. Cirranello. 2020. Bat Species of the World: A taxonomic and geographic database. Available at: www.batnames.org (accessed 29 January 2020).
- Skalak, S. L., R. E. Sherwin, and R. M. Brigham. 2012. Sampling period, size and duration influence measures of bat species richness from acoustic surveys. *Methods in Ecology and Evolution* 3:490–502.
- Smallwood, K. S. 2013. Comparing bird and bat fatality-rate estimates among North American wind-energy projects. *Wildlife Society Bulletin* 37:19–33.
- Stantec Consulting. 2012a. Mount Ojibway 2012 (Great Lakes Region). Unpublished report to the National Park Service, Houghton, Michigan.
- Stantec Consulting. 2012b. Rock of Ages 2012 (Great Lakes Region). Unpublished report to the National Park Service, Houghton, Michigan.
- Stantec Consulting. 2013. Mount Ojibway 2013 (Great Lakes Region). Unpublished report to the National Park Service, Houghton, Michigan.

- Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99:262–278.
- Turner, G. G., D. M. Reeder, and J. T. H. Coleman. 2011. A five-year assessment of mortality and geographic spread of white-nose syndrome in North American bats, with a look to the future. *Bat Research News* 52:13–27.
- Urquhart, N. S., S. G. Paulsen, and D. P. Larsen. 1998. Monitoring for policy-relevant regional trends over time. *Ecological Applications* 8(2):246–257.
- U. S. Fish and Wildlife Service. 1967. Native fish and wildlife—Endangered species. Federal Register 32(48). Available at: www.fws.gov/endangered/species/pdf/32FedReg_pg%204001.pdf (accessed 6 April 2020).
- U. S. Fish and Wildlife Service. 2014. White-nose syndrome: The devastating disease of hibernating bats in North America. Fact sheet. Available at: <https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1457&context=usfwspubs> (accessed 6 April 2020).
- U. S. Fish and Wildlife Service. 2016. Endangered and threatened wildlife and plants; Determination that designation of critical habitat is not prudent for the northern long-eared bat. Federal Register, 81(81). Available at: www.govinfo.gov/content/pkg/FR-2016-04-27/pdf/2016-09673.pdf (accessed 6 April 2020).
- U. S. Fish and Wildlife Service. 2019. Range-wide Indiana bat survey guidelines. Available at: www.fws.gov/midwest/endangered/mammals/inba/inbasummersurveyguidance.html (accessed 6 April 2020).
- U. S. Geological Survey. 2019. White-nose syndrome spread maps (August 30, 2019 version). www.whitenosesyndrome.org/resources/map (accessed 9 March 2020).
- Warnecke, L., J. M. Turner, T. K. Bollinger, J. M. Lorch, V. Misra, P. M. Cryan, G. Wibbelt, D. S. Blehert, and C. K. R. Willis. 2012. Inoculation of bats with European *Geomyces destructans* supports the novel pathogen hypothesis for the origin of white-nose syndrome. *Proceedings of the National Academy of Sciences* 109:6999–7003.
- Whitaker, J. O., J. Gible, and E. Kjellmark. 1994. Mammals of Indiana Dunes National Lakeshore. Scientific Monograph NPS/NRINDU/NRSM-94/24. Available at: <http://npshistory.com/series/science/24/mammals.pdf> (accessed 6 April 2020).
- Wisconsin Department of Natural Resources. 2010. Acoustic survey results from Wisconsin Bat Program. Available at: <http://wiatri.net/Inventory/Bats/Volunteer/Results/> (accessed 3 September 2019).

Wisconsin Department of Natural Resources. 2016. Wisconsin Natural Heritage working list.
Available at: <https://dnr.wi.gov/topic/NHI/documents/NHIWorkingList.pdf> (accessed 6 April 2020).

Wright, W. J., K. M. Irvine, and T. J. Rodhouse. 2016. A goodness-of-fit test for occupancy models with correlated within-season revisits. *Ecology and Evolution* 6(15):5404–5415.

List of Standard Operating Procedures

A series of Standard Operating Procedures (SOPs) accompany this protocol document, listed below.

SOP #1: Sampling Design and Site Selection

SOP #2: Training and Safety for Field Personnel

SOP #3: Preparing for the Field Season

SOP #4: Deploying and Retrieving Acoustic Detectors

SOP #5: Data Management by Field Staff

SOP #6: Data Management by the Protocol Lead

SOP #7: Data Entry and QAQC Using the NPS Bats Acoustic Survey Database

SOP #8: Processing Acoustic Data

SOP #9: Yearly Summary Reports

SOP #10: Multi-Year Data Analysis

SOP #11: Procedure for Revising Protocol

Appendix A. Bat species of the Great Lakes Region

Table A-1. Bat species of the Great Lakes region and occurrences recorded at GLKN's national park units prior to the initiation of the current acoustic monitoring program in 2015.

Species Name	Prior Park Records and Methods ^{1, 2}								
	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Big Brown Bat <i>Eptesicus fuscus</i>	A	A	A, O, S	A, C	–	A, C	A	A ³ , C	–
Eastern Red Bat <i>Lasiurus borealis</i>	A, C, G	A, C	A, C, O, S	A	–	A, C	A	A, C	–
Hoary Bat <i>Lasiurus cinereus</i>	A, O	A, C	A	A	–	A, C	A	C	–
Silver-haired Bat <i>Lasionycteris noctivagans</i>	A, C	A, C, G	A, C, O, S	A	O	A, C	A	A ³ , C	C, G
Little Brown Myotis <i>Myotis lucifugus</i>	A, C, G	A, C, G	A ³	A, C, S	O	A, C, G	A	A, C	C, G, O
Northern Myotis <i>Myotis septentrionalis</i>	A, C, G	A, C, G	A ³	A, C	–	A, C, G	A	–	C, G
Indiana Myotis <i>Myotis sodalis</i>	–	–	A ³	–	–	–	–	–	–

¹ Data Sources: Byrne 2014 (INDU); Dixon 2010 (VOYA); Gehring 2011, George and Kurta 2016 (SLBE); Goodwin 2012 (ISRO); Graetz et al. 1995 (GRPO); Hahn 1909 (INDU); Jackson 1920 (APIS); Kruger and Peterson 2008 (APIS, GRPO, PIRO); Kurta and Rice 2001, Kurta and Rice 2002 (SLBE); Kurta and Slider 2017 (PIRO); Kurta et al. 2007 (INDU); Lehnert 2013 (ISRO); Lyon 1922 (INDU); Miller 2010 (APIS, GRPO, PIRO); N. Duncan, pers. comm., March 2019 (MISS); Parker 2002 (ISRO); Rand and Rand 1951 (INDU); Route 2001, Route and Schaberl 2013 (VOYA); Shier et al. 2015 (INDU); Stantec Consulting 2012a, 2012b, 2013 (ISRO); Whitaker et al. 1994 (INDU); Wisconsin DNR 2010 (SACN).

² Where “A” indicates acoustic records; “C” indicates live captures; “O” indicates direct observations; “G” indicates genetic vouchers; “S” indicates specimen collected. Nomenclature follows Simmons and Cirranello (2020).

³ Identification only to the level of a species pair or group.

Table A-1 (continued). Bat species of the Great Lakes region and occurrences recorded at GLKN’s national park units prior to the initiation of the current acoustic monitoring program in 2015.

Species Name	Prior Park Records and Methods ^{1, 2}								
	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Evening Bat <i>Nycticeius humeralis</i>	–	–	A ³ , S	–	–	–	–	–	–
Tricolored Bat <i>Perimyotis subflavus</i>	–	–	A, C	S	–	–	A	–	–

¹ Data Sources: Byrne 2014 (INDU); Dixon 2010 (VOYA); Gehring 2011, George and Kurta 2016 (SLBE); Goodwin 2012 (ISRO); Graetz et al. 1995 (GRPO); Hahn 1909 (INDU); Jackson 1920 (APIS); Kruger and Peterson 2008 (APIS, GRPO, PIRO); Kurta and Rice 2001, Kurta and Rice 2002 (SLBE); Kurta and Slider 2017 (PIRO); Kurta et al. 2007 (INDU); Lehnert 2013 (ISRO); Lyon 1922 (INDU); Miller 2010 (APIS, GRPO, PIRO); N. Duncan, pers. comm., March 2019 (MISS); Parker 2002 (ISRO); Rand and Rand 1951 (INDU); Route 2001, Route and Schaberl 2013 (VOYA); Shier et al. 2015 (INDU); Stantec Consulting 2012a, 2012b, 2013 (ISRO); Whitaker et al. 1994 (INDU); Wisconsin DNR 2010 (SACN).

² Where “A” indicates acoustic records; “C” indicates live captures; “O” indicates direct observations; “G” indicates genetic vouchers; “S” indicates specimen collected. Nomenclature follows Simmons and Cirranello (2020).

³ Identification only to the level of a species pair or group.

Appendix B. Comparison of GLKN and NABat Sampling Frames

The GLKN bat monitoring protocol is similar to the protocol developed by the NABat program (Loeb et al. 2015). Both protocols use a probabilistic sample design with a finite grid-based sampling frame and follow the GRTS algorithm to maintain spatial balance when selecting cells to be sampled. However, the NABat sampling frame is a continent-wide grid of 10-km² cells, while the GLKN sampling frame is a grid of 1-km² cells specific to each park. We established only one sample site per 1-km² cell, whereas NABat uses two to four sites per 10-km² cell, with one site in each quadrant and all sites within a cell sampled concurrently. For the purposes of contributing our data to NABat, we can overlay our sample sites on the NABat grid to determine the specific NABat grid cells in which our sites are located (Table B1, Figures B1 through Figure B9). For 29% of the NABat grid cells that overlap our parks' boundaries, we have at least two GLKN sample sites, though these are not necessarily sampled concurrently.

Table B1. Overlap between GLKN bat monitoring sample sites and the NABat sampling frame. “Total” columns show the total number of 10-km² NABat cells that overlap the park boundaries (for APIS and ISRO, this refers to the land boundaries). “Priority cells” refer to the 5% of NABat cells that are the highest priority for sampling, based on the GRTS order. “Sampled” columns show the number of cells that contain at least two GLKN sample sites that were being actively monitored as of 2019.

Park	Total Number of NABat Cells	Number of NABat Cells Sampled (Percent)	Total Number of NABat Priority Cells	Number of NABat Priority Cells Sampled (Percent)
APIS	20	5 (25%)	0	n/a
GRPO	2	1 (50%)	0	n/a
INDU	11	3 (27%)	0	n/a
ISRO	18	6 (33%)	1	0 (0%)
MISS	17	7 (41%)	0	n/a
PIRO	12	5 (42%)	1	1 (100%)
SACN	44	7 (16%)	3	1 (33%)
SLBE	14	7 (50%)	1	1 (100%)
VOYA	18	5 (28%)	0	n/a
Total	156	46 (29%)	6	3 (50%)

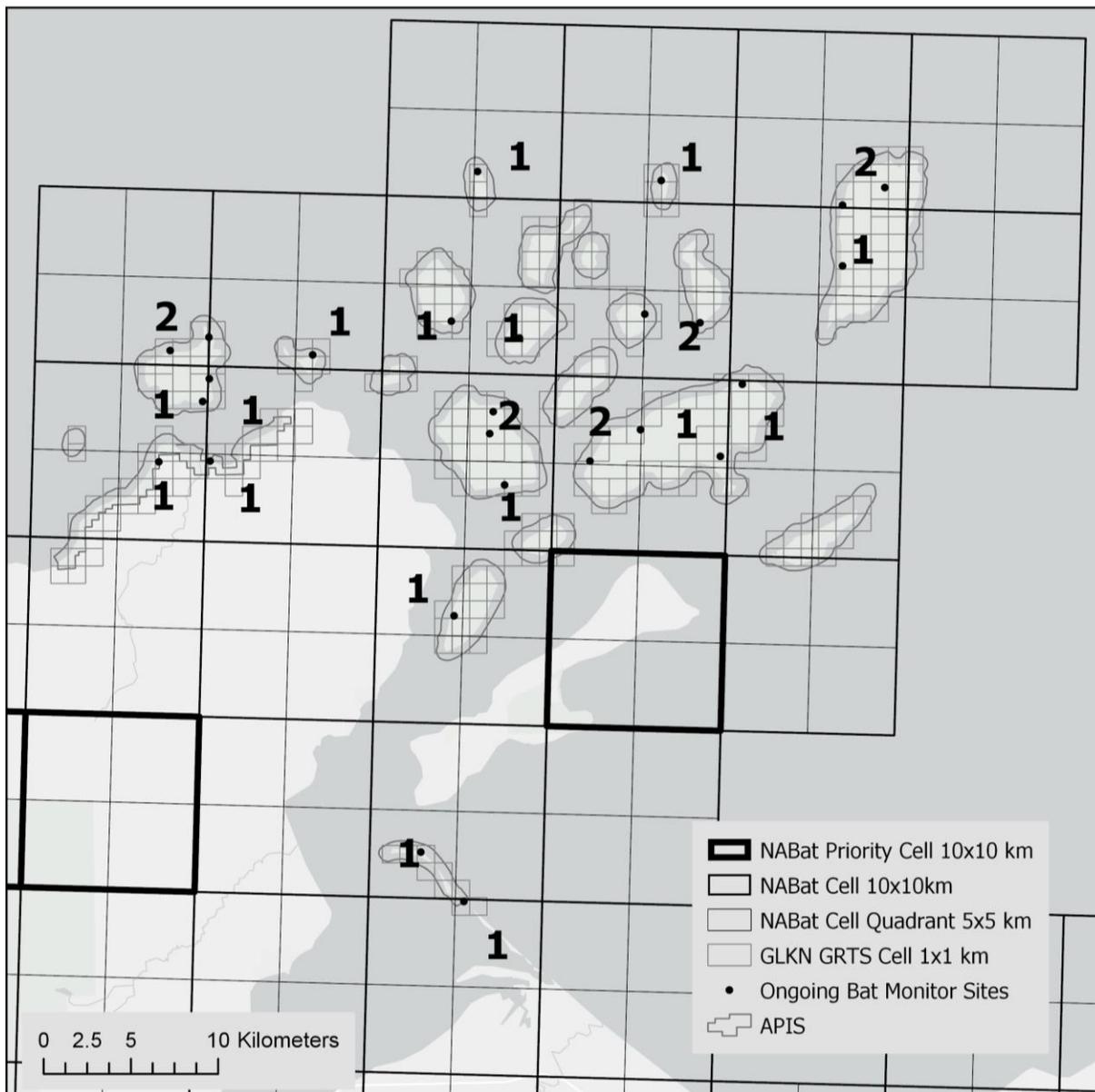


Figure B1. Locations of GLKN sample sites (as of 2019) at Apostle Islands National Lakeshore, overlaid with the NABat sampling frame. Numbers indicate the count of GLKN sample sites per NABat cell quadrant.

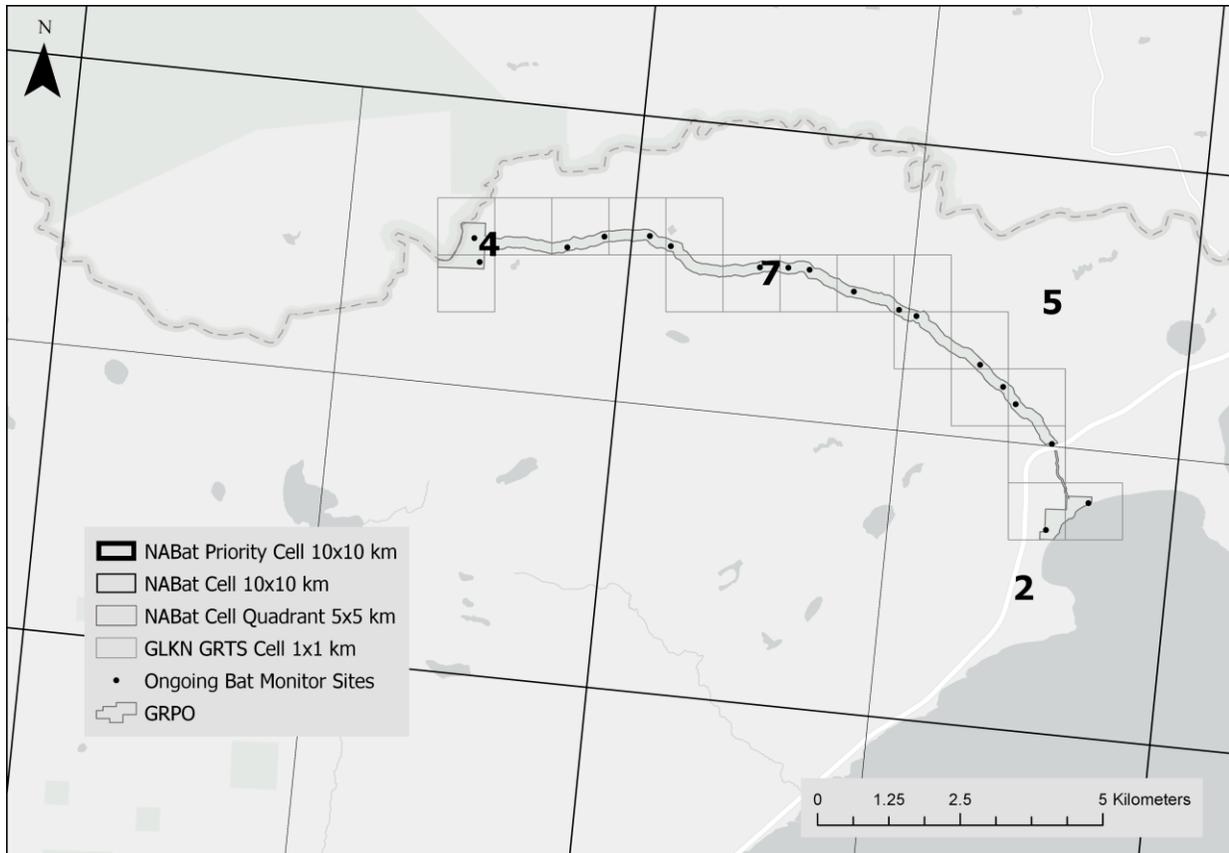


Figure B2. Locations of GLKN sample sites (as of 2019) at Grand Portage National Monument, overlaid with the NABat sampling frame. Numbers indicate the count of GLKN sample sites per NABat cell quadrant.

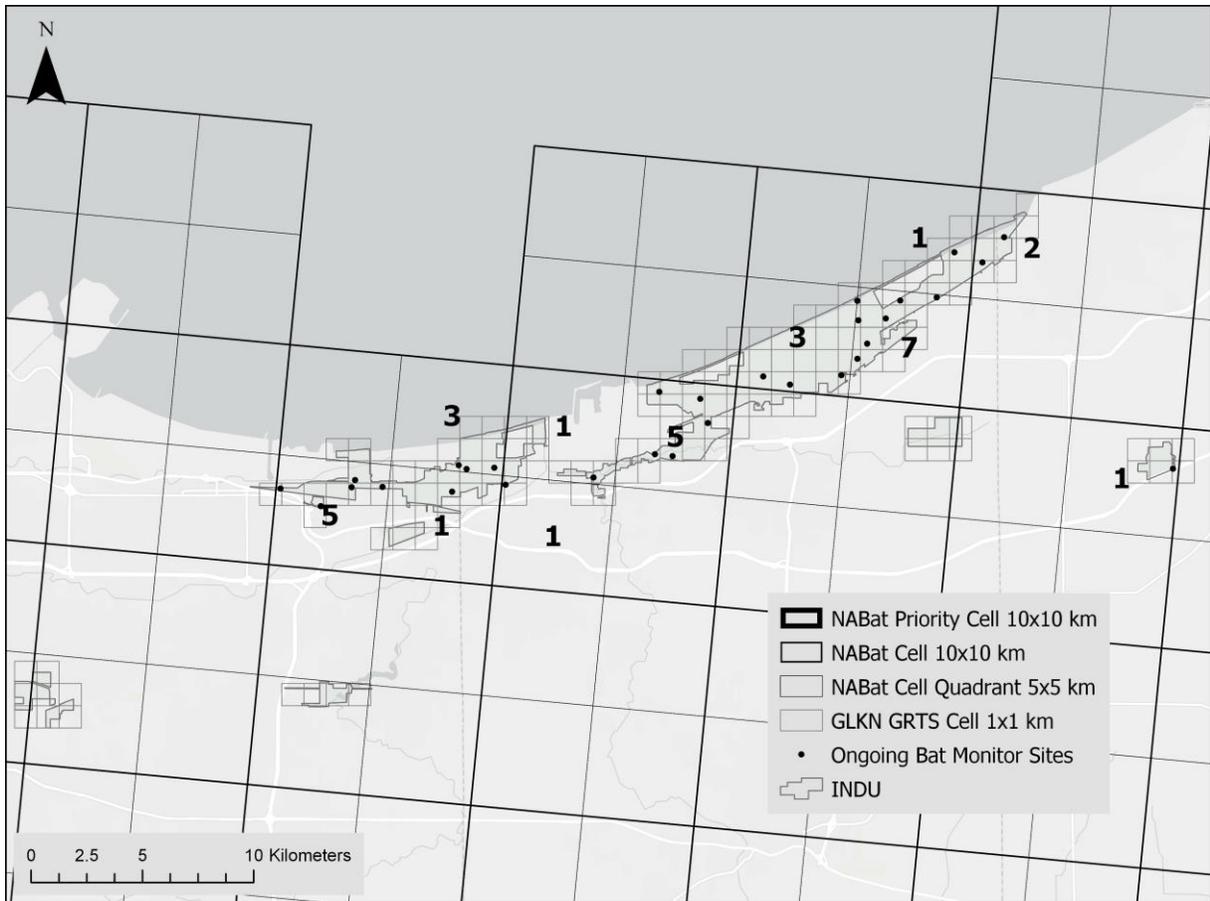


Figure B3. Locations of GLKN sample sites (as of 2019) at Indiana Dunes National Park, overlaid with the NABat sampling frame. Numbers indicate the count of GLKN sample sites per NABat cell quadrant.

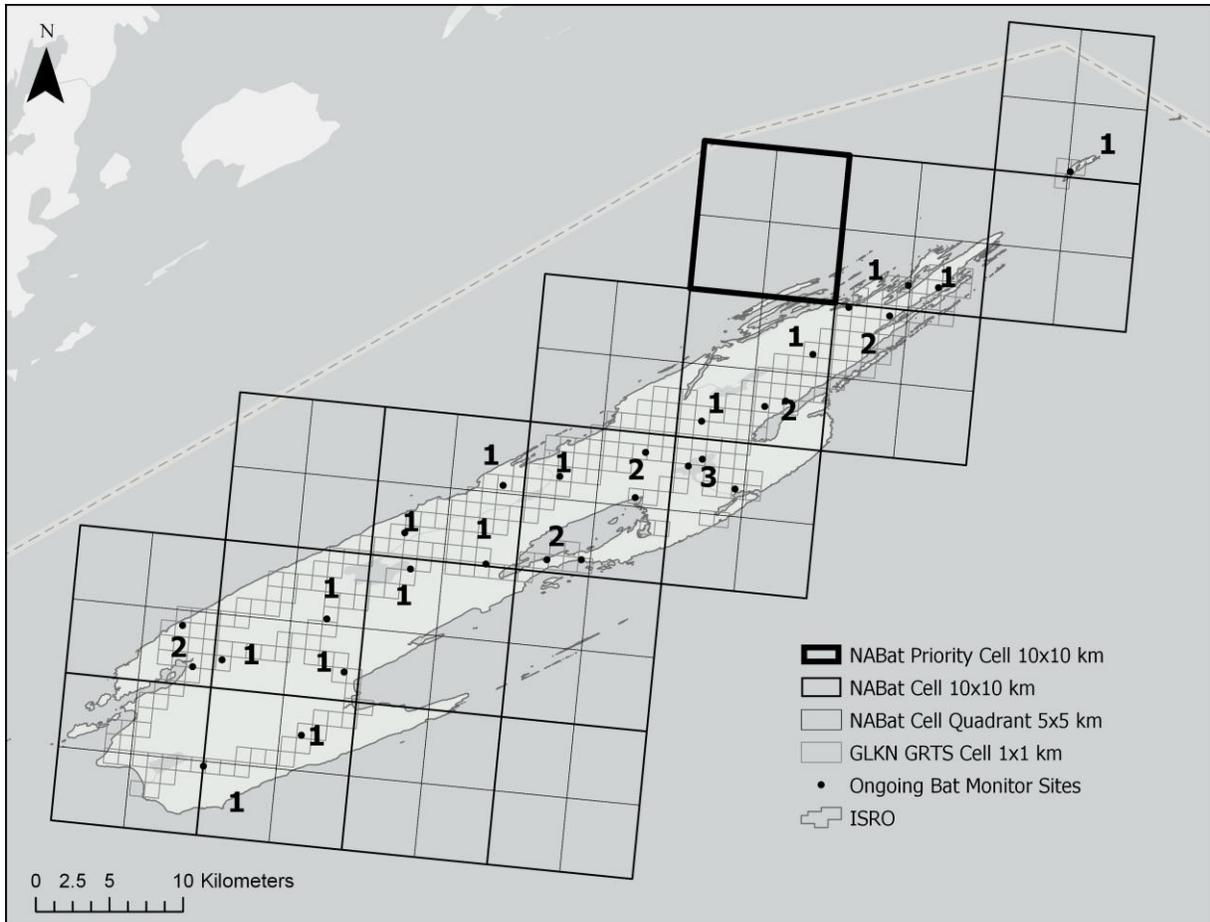


Figure B4. Locations of GLKN sample sites (as of 2019) at Isle Royale National Park, overlaid with the NABat sampling frame. Numbers indicate the count of GLKN sample sites per NABat cell quadrant.

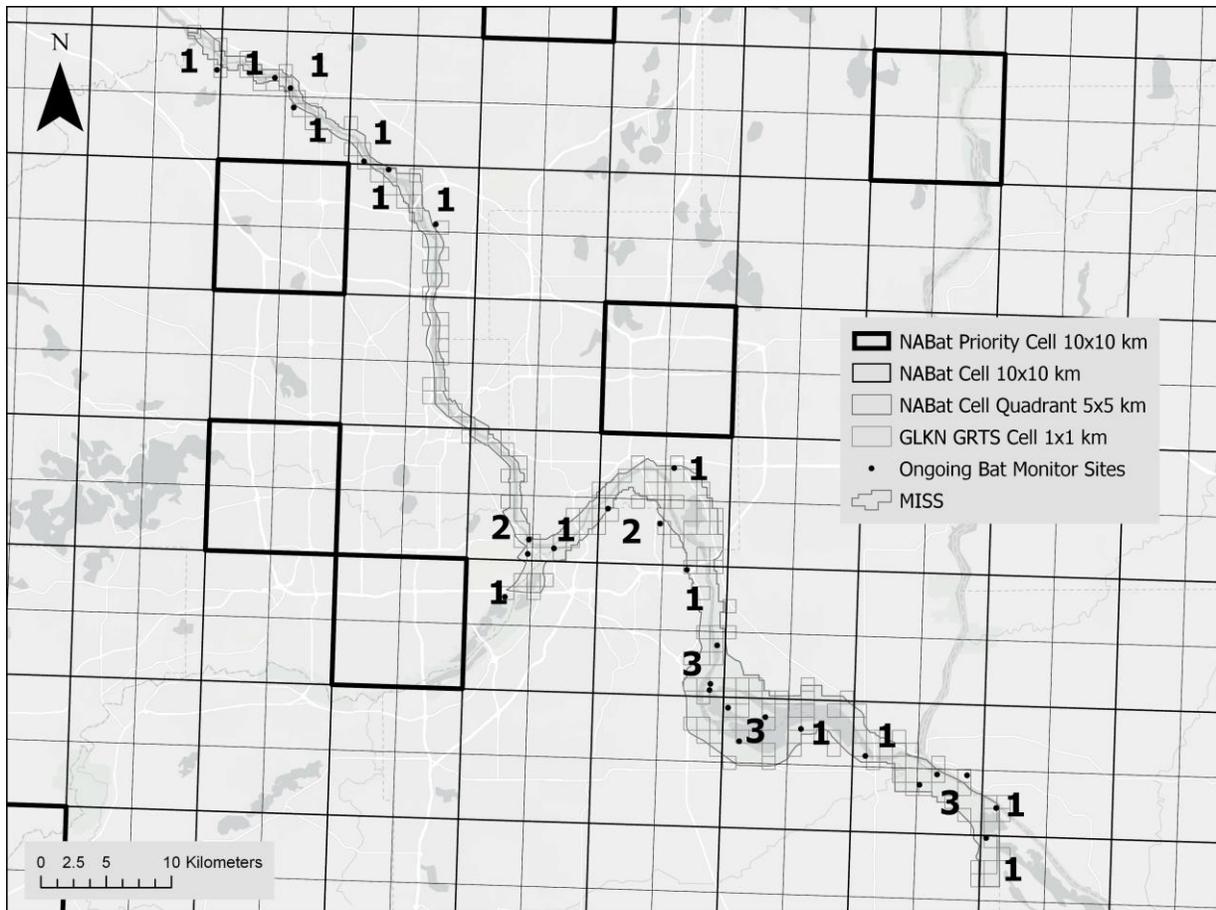


Figure B5. Locations of GLKN sample sites (as of 2019) at Mississippi National River and Recreation Area, overlaid with the NABat sampling frame. Numbers indicate the count of GLKN sample sites per NABat cell quadrant.

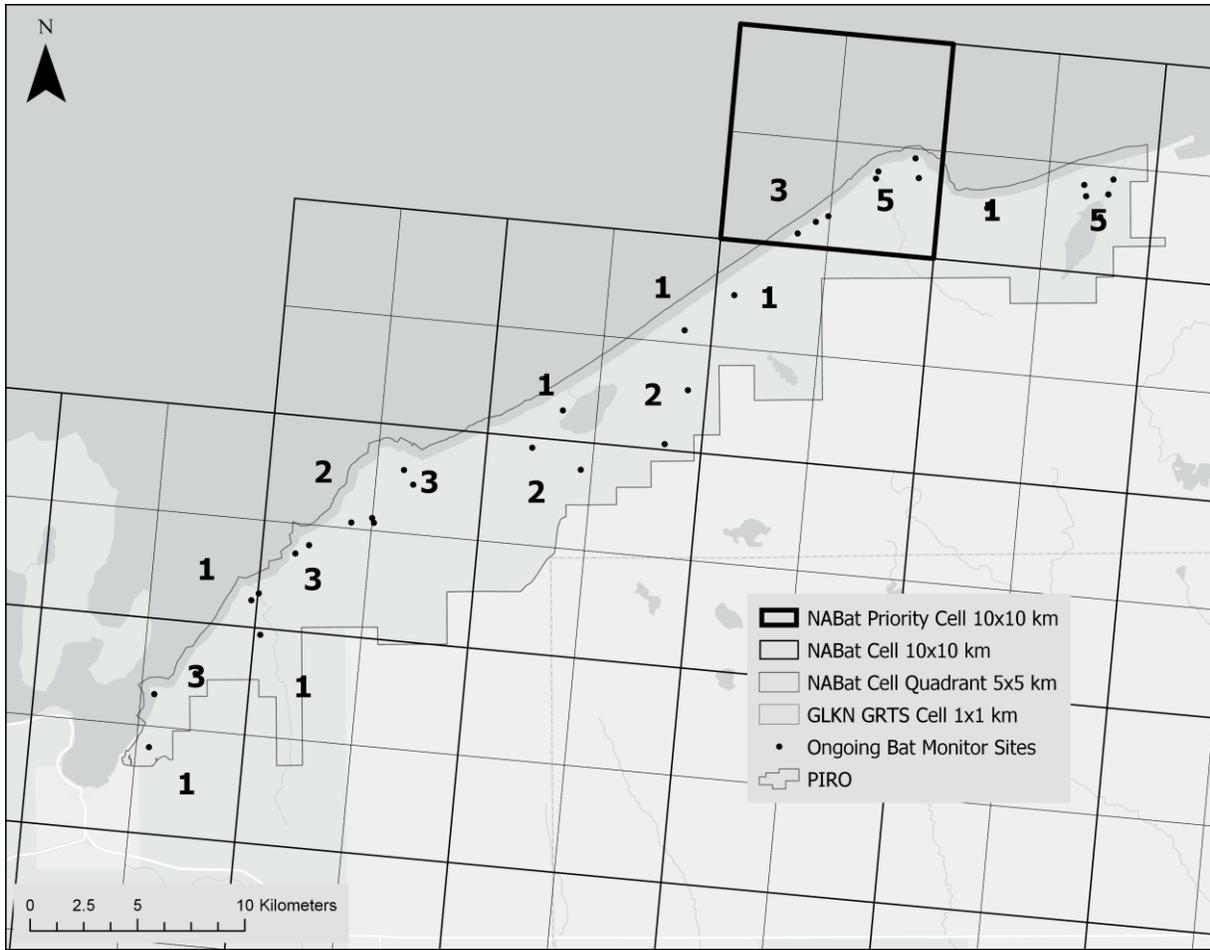


Figure B6. Locations of GLKN sample sites (as of 2019) at Pictured Rocks National Lakeshore, overlaid with the NABat sampling frame. Numbers indicate the count of GLKN sample sites per NABat cell quadrant.

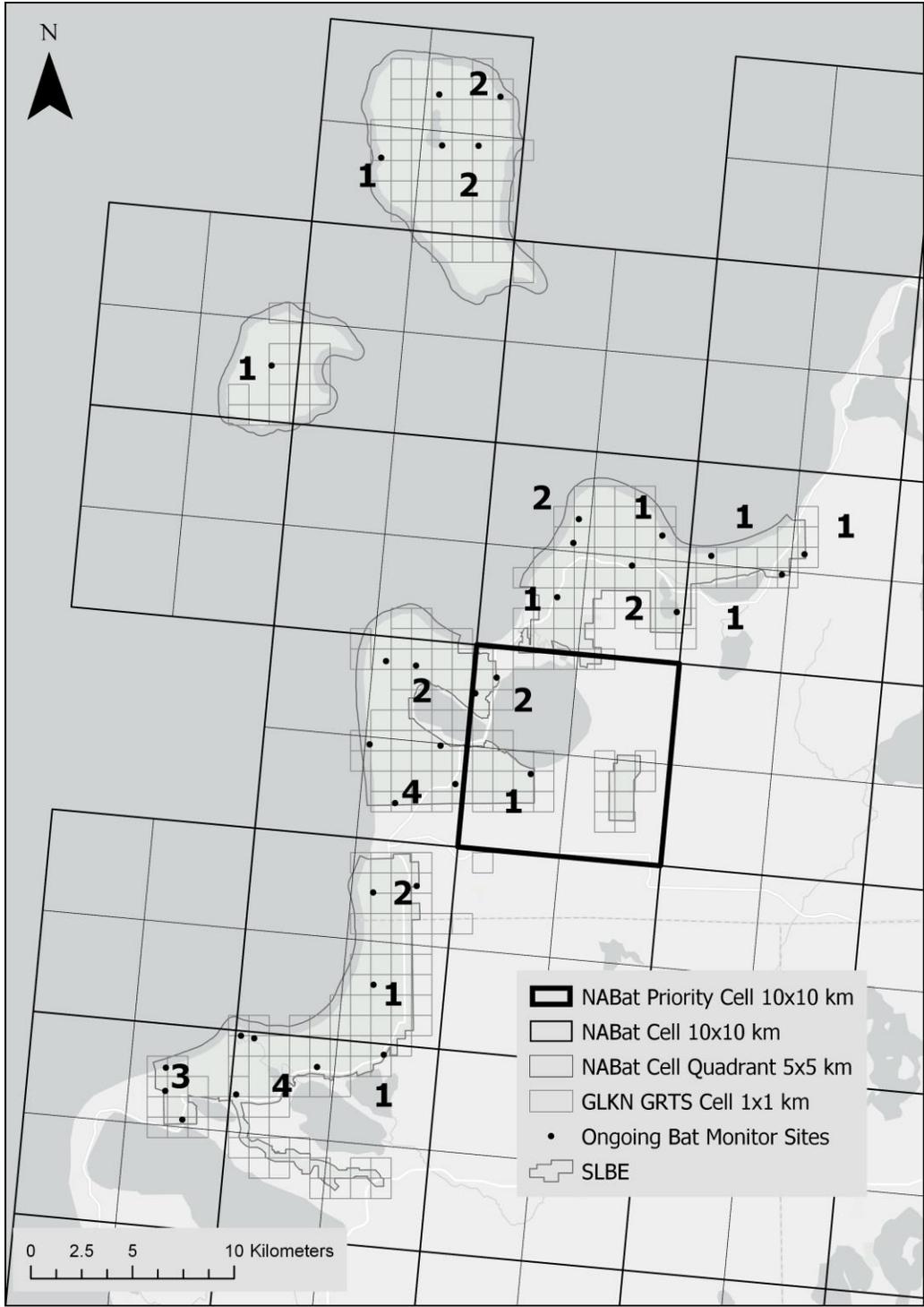


Figure B8. Locations of GLKN sample sites (as of 2019) at Sleeping Bear Dunes National Lakeshore, overlaid with the NABat sampling frame. Numbers indicate the count of GLKN sample sites per NABat cell quadrant.

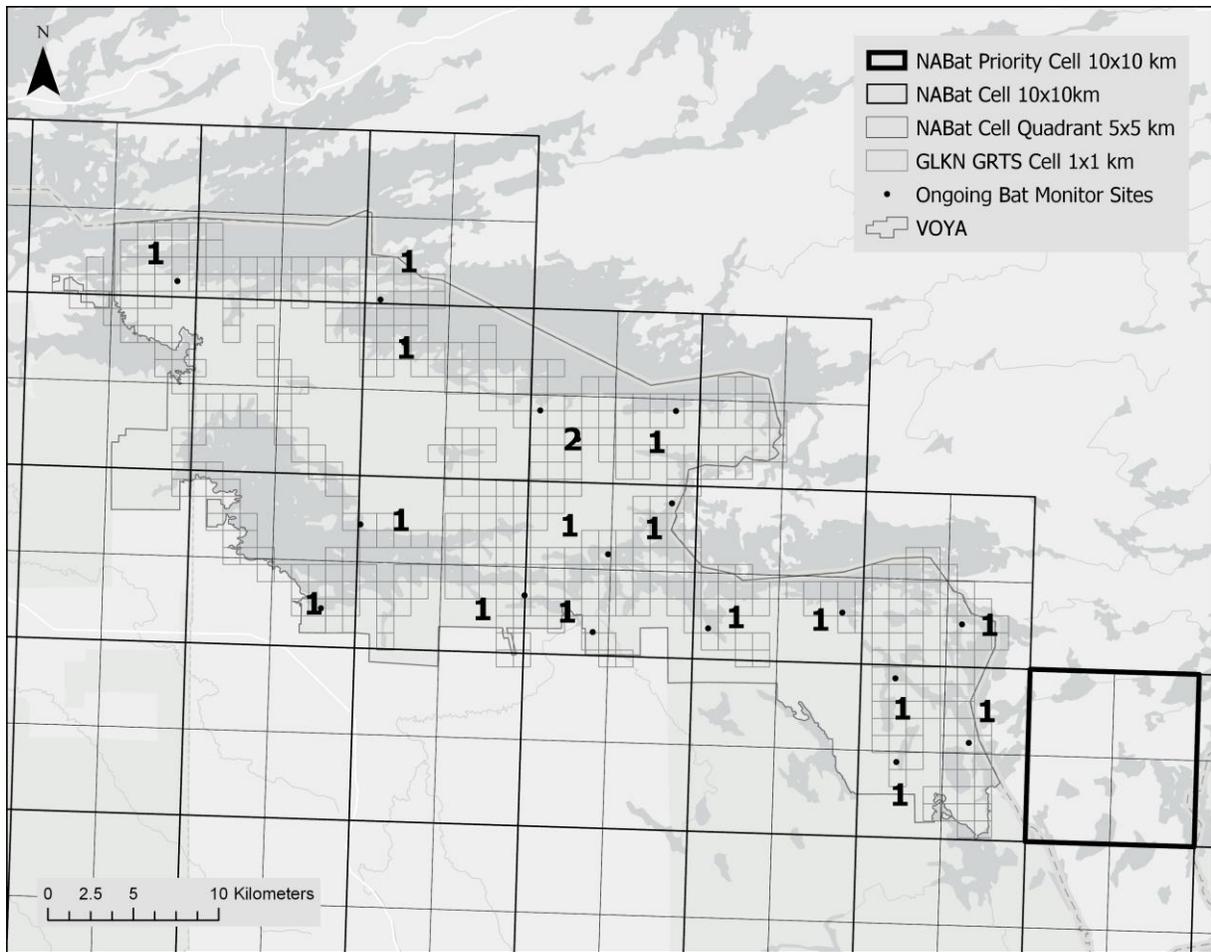


Figure B9. Locations of GLKN sample sites (as of 2019) at Voyageurs National Park, overlaid with the NABat sampling frame. Numbers indicate the count of GLKN sample sites per NABat cell quadrant.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 920/168842, May 2020

National Park Service
U.S. Department of the Interior



[Natural Resource Stewardship and Science](#)

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525