



Acoustic Amphibian Monitoring, 2019 Data Summary

Indiana Dunes National Park

Natural Resource Data Series NPS/GLKN/NRDS—2022/1384



ON THE COVER

Boreal Chorus Frog (*Pseudacris maculata*).

Photo © G.S. CASPER

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Natural Resource Data Series NPS/GLKN/NRDS—2022/1384

Gary S. Casper,¹ Stefanie M. Nadeau,¹ and Thomas B. Parr²

¹Great Lakes Ecological Services, LLC

P.O. Box 375

Slinger Wisconsin 53086

²National Park Service

Great Lakes Inventory and Monitoring Network

800 Lakeshore Drive East

Ashland, Wisconsin 54806

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Abstract

Amphibians are a Vital Sign indicator for monitoring long-term ecosystem health in seven national park units that comprise the Great Lakes Network. We present here the results for 2019 amphibian monitoring at Indiana Dunes National Park (INDU). Appendices contain tabular summaries for six years of cumulative results.

The National Park Service Great Lakes Inventory and Monitoring Network established 10 permanent acoustic amphibian monitoring sites at INDU in 2013. Acoustic samples are collected by placing automated recorders with omnidirectional stereo microphones at each of the 10 sample sites. Temperature loggers co-located with the recorders also collect air temperature during the sampling period.

The monitoring program detected eight of the nine species of frog and toad known to still occur at INDU in 2019, with Eastern American Toad, Gray Treefrog, Green Frog and Spring Peeper occurring at every site sampled. Boreal Chorus Frog was found at all but one site. American Bullfrog, Northern Leopard Frog, and Wood Frog were found at five, two and two sites, respectively.

We expanded analyses and reporting in 2018 to address calling phenology and to provide a second metric for tracking changes in abundance (as opposed to occupancy) across years. Occupancy analyses track whether or not a site was occupied by a species. Abundance is tracked by assessing how the maximum call intensity changes on sites across years, and by how many automated detections are reported from sites across years. Using two independent survey methods, manual and automated, with large sample sizes continues to return reliable results, providing a confident record of site occupancy for most species.

There were no significant data collection issues in 2019 except failure of the temperature logger and early cessation of data collection at INDU03, neither of which compromised sampling rigor or analysis. We now recommend a start date of 10–15 March rather than 1 April based on the temperature logs showing that the threshold of $\geq 40^{\circ}\text{F}$ was exceeded by 1 April in 2019.

Introduction

The National Park Service Great Lakes Inventory and Monitoring Network (GLKN) established 10 permanent amphibian monitoring sites at Indiana Dunes National Park (INDU) in 2013. Acoustic recordings are collected and analyzed to determine the species of frogs and toads calling at each location and their calling intensity. Both metrics are used to track trends in species richness and calling intensity across years.

The program monitors for all fourteen anuran species found within the western Great Lakes region. Raw data and confirmed acoustic detections are archived at the Great Lakes Network office. This annual summary report presents results for 2019. Six years of cumulative results for INDU are summarized in Appendices E and F (data in 2013 were incomplete). In automated analysis, current recognizers do not distinguish between the two treefrog species (HYCH, HYVE). Subsequently, discussion of automated detection for these species combines them as *Hyla* species (HYSP).

Eleven frog and toad species are known to have occurred historically at INDU, but two of these are thought to be extirpated (Table 1).

Table 1. Species monitored and their current status at Indiana Dunes National Park.

Common Name	Scientific Name	Code	Status
Blanchard's Cricket Frog	<i>Acris blanchardi</i>	ACBL	Extirpated
Eastern American Toad	<i>Anaxyrus americanus americanus</i>	ANAM	Present
Fowler's Toad	<i>Anaxyrus fowleri</i>	ANFO	Extirpated
Cope's Gray Treefrog	<i>Hyla chrysoscelis</i>	HYCH	Present
Gray Treefrog	<i>Hyla versicolor</i>	HYVE	Present
American Bullfrog	<i>Lithobates catesbeianus</i>	LICA	Present
Green Frog	<i>Lithobates clamitans</i>	LICL	Present
Pickerel Frog	<i>Lithobates palustris</i>	LIPA	Absent
Northern Leopard Frog	<i>Lithobates pipiens</i>	LIPI	Present
Mink Frog	<i>Lithobates septentrionalis</i>	LISE	Absent
Wood Frog	<i>Lithobates sylvaticus</i>	LISY	Present
Spring Peeper	<i>Pseudacris crucifer</i>	PSCR	Present
Boreal Chorus Frog	<i>Pseudacris maculata</i>	PSMA	Present
Western Chorus Frog	<i>Pseudacris triseriata</i>	PSTR	Absent

Methods

2.1 Site Selection

Candidate monitoring sites were initially selected based on a stratified random study design (Route et al. 2014). A pool of 30–40 points were selected from GIS environmental data for the park using a Generalized Random Tessellation Stratified (GRTS) process, with selections at least 1 km apart. The objective was to ensure an adequate pool of candidate wetlands for selecting 3–4 permanent monitoring sites that represent each of three wetland types: permanent, semi-permanent, and ephemeral, for a total of 10 sites. The candidate sites were unbiased and spatially balanced (spread relatively evenly across the park). Candidate sites were then visited in an iterative fashion to verify that suitable breeding habitat was present and to confirm the wetland classification type (permanent, semi-permanent, and ephemeral). We used this process to select or reject sites until 3–4 sites of each wetland type were verified (Figure 1). Park personnel were also consulted on final site selections to ensure logistical feasibility for annual visits. Final site selection for monitoring stations at INDU were three permanent (sites 3, 6, and 8), four semi-permanent (sites 4, 5, and 9), and three ephemeral (sites 1, 2, and 10) wetlands.

2.2 Data Collection

2.2.1 Temperature Logs

Temperature logs are recorded at each site and used for filtering samples for data analyses, where only samples with an ambient air temperature of $\geq 40^{\circ}\text{F}$ are used for manual surveys. In 2019, loggers (HOBO UA-002-08, Onset Computer Corporation, Bourne, Massachusetts, USA) were programmed to record temperature every hour. Loggers are deployed with the Automated Recording Systems (ARS) within a solar shield and shaded from overhead sunlight (Figure 2). ARS and loggers are photographed in the field each year to document placement and habitat.

2.2.2 Automated Recording Systems

Automated recording systems with omnidirectional stereo microphones (Song Meter model SM4; Wildlife Acoustics, Inc., Concord, Massachusetts, USA) were co-located with temperature loggers (Figure 2). Beginning on 1 April 2019, one 5-minute sample (.wav file) was collected each day at the top of each hour and four extra samples were collected on the half-hour mark from 19:30 to 22:30 h. ARS are programmed at a 16000 Hz sample rate, and in 2019 a high pass filter excluded frequencies below 220 Hz. Data are collected on SD cards.

ARS are deployed as soon as possible after ice-out, or in the previous autumn on a delayed start, for 1 April of the following year. Earlier start dates are being considered as climate change progresses. Data cards are retrieved after 31 July each year. Units often record beyond 31 July until batteries fail. Data collected after 31 July is archived but not used in our analyses.

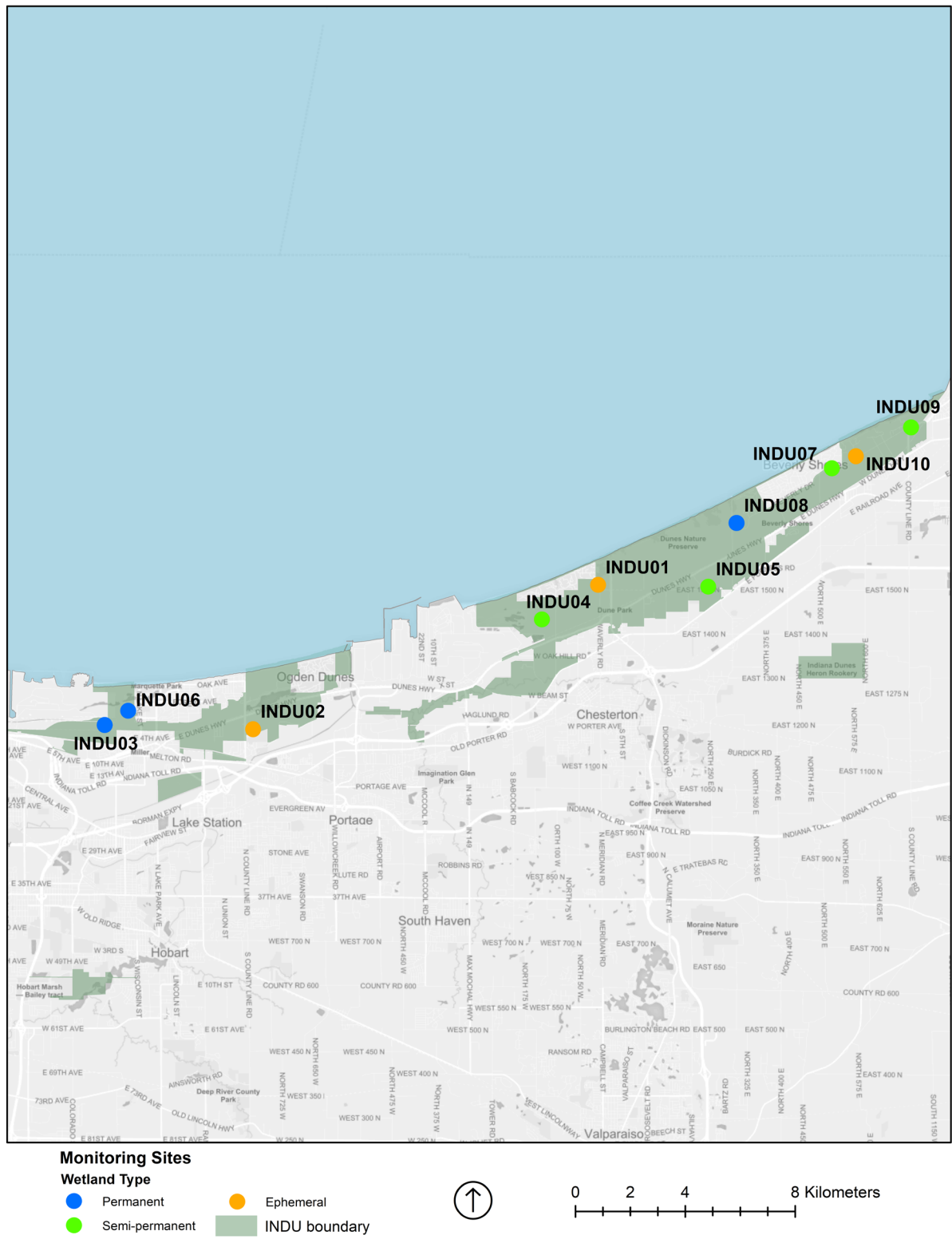


Figure 1. Monitoring site locations at Indiana Dunes National Park.



Figure 2. Example of automated recording system (ARS) deployed in the field. This device is attached to a backer board and strapped or bolted to a tree or post. The temperature logger is situated nearby within a solar shield.

2.3 Data Analysis Methods

Please see Casper and Nadeau (2019) for detailed analysis steps. A simplified workflow is outlined below. Digital acoustic data, scanned data forms, temperature logs, and digital photographs are archived at the network office.

In sum, the protocol steps are:

- 1) Obtain recordings and temperature logs (field component).
- 2) Filter recordings to a subset of those collected after sunset and run recordings through the automated recognition procedure (automated survey).
- 3) Proof automated output by manually confirming at least one auto-detection at each site in each year, thereby eliminating false presences for occupancy in this data set. Manual confirmation involves an experienced surveyor visually examining the place in the spectrogram where the algorithm reports a detection, then playing it back to confirm a correct species identification. Both first and last auto-detections are confirmed at each site, with proofing limited to within the calling periods determined from Appendix A. Note that false presences still persist on an individual sample level (between the first and last confirmed detections), but not on a site occupancy level (additional false presences do not matter if the site is already confirmed to be occupied). False absences for site occupancy also occur for most species (although mostly at low rates), but site occupancy can nevertheless be modeled with high confidence due to the large sample size. The next step eliminates most false absences.
- 4) Perform a manual scan of the same data and assign a Call Index Value (CIV) for each acoustic file. For this survey, 30 samples are equally distributed from the first auto-detection date for any frog species at the site, through 31 July, and where air temperature is $\geq 40^{\circ}\text{F}$. An additional six morning samples are scanned for Mink Frog, selecting one sample each week from 15 June through 31 July. CIV is scored for each species detected in each sample, and annotations are made for sample quality (i.e., noise) and any CIV or identification uncertainties. These survey results are then checked by a second observer, and if concurrence is not reached, they are checked by a third observer. This survey detects all species, including species with low auto-detection rates (i.e., Northern Leopard Frog). It also identifies to species pairs that are not separated by auto-detection (Cope's vs. Gray treefrogs; Western vs. Boreal Chorus frogs) and surveys for species for which no auto-detection algorithm is currently available (i.e., Mink Frog).
- 5) Report on combined results. The auto-detection analysis scores species site occupancy as 0 or 1; the manual scan analysis scores Call Index Values for each species. Results are combined in a cumulative master site occupancy table. Very few species escape detection by this dual survey approach.
- 6) Periodically model occupancy and CIV trends (ca. every five years). This analysis tracks frog occupancy trends and allows for early warnings of declines by tracking changes in Call Index Values.

Results

3.1 Phenology

Phenology tracking assesses the trends in annual first calling dates over time. Initially we are restricting analyses to three species common to all parks in the network: Eastern American Toad, Treefrog spp. (aggregating data for both treefrog species), and Green Frog. Eastern American Toad and Treefrog spp. typically begin calling in early to mid-May, and Green Frog represents a late season species with calling typically beginning in late May to early June. Three species were chosen for tracking mid-season phenology because Treefrog spp. are very rare at two network parks (Isle Royale National Park and Grand Portage National Monument). Note that auto-detections do not distinguish between the closely related Gray Treefrog and Cope's Gray Treefrog owing to the similarity of their calls. Manual scans however do attempt to distinguish between these species. For phenology purposes, we treat these as a species pair, as calling periods do not differ between species (Mossman et al. 1998, Dodd 2013).

Calling is influenced by temperature and possibly day length. Water temperature in turn is influenced by sun and wind exposure of the surface water layer occupied by frogs, and, at INDU, by proximity to or connection with the cold waters of Lake Michigan. Typically, frogs are expected to call earlier from sunny wetlands away from Lake Michigan and later from shaded wetlands close to or connected with Lake Michigan (i.e., river mouths, lagoons).

At INDU in 2019, Eastern American Toad began calling slightly earlier at INDU04, INDU05 and INDU07, and then calling commenced at remaining sites fairly synchronized in time a few days later (Figure 3). Treefrog spp. calling commenced in three waves, first at INDU03, INDU06 and INDU10 around 20 April; then at INDU01, INDU02 and INDU04 around 4–6 May; and finally, not until 16 and 21 May at INDU08 and INDU05, respectively. Commencement of calling for Green Frog was variable from 15 May through 22 May. One outlier of 15 June at INDU05 is unusual but these calls persisted through the rest of the season at low levels (CIV=1), often distant.

As expected from climate differences, frogs begin calling earlier at INDU than at any other parks (Figure 4).

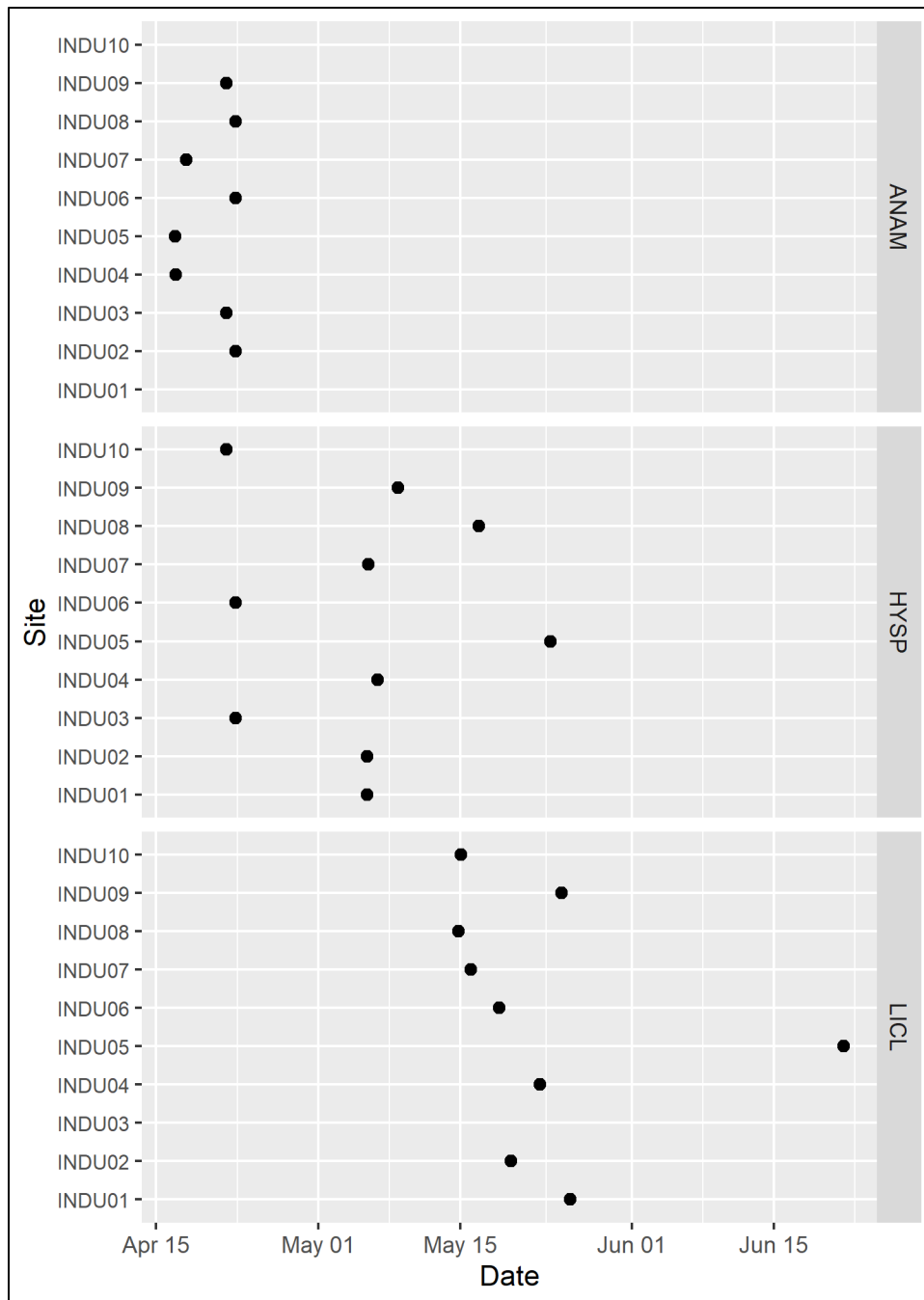


Figure 3. Dates of first confirmed automated detections for Eastern American Toad (ANAM), Treefrog spp. (HYSP; all were Gray Treefrog, *Hyla versicolor*), and Green Frog (LICL), Indiana Dunes National Park, 2019.

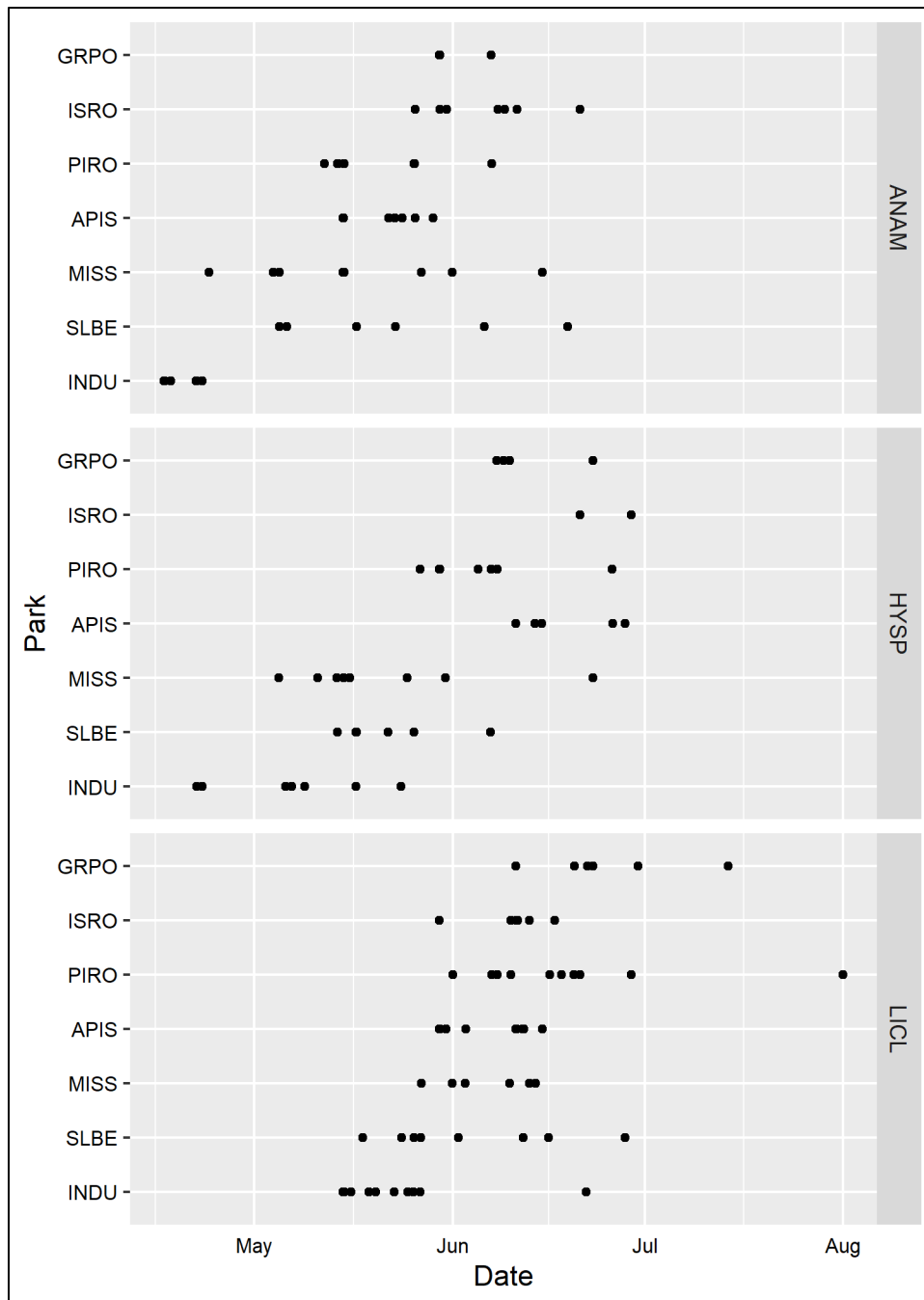


Figure 4. First detection dates of three species for all parks conducting monitoring in 2019. ANAM = Eastern American Toad, HYSP = Treefrog spp., LICL = Green Frog. Parks ordered north to south: GRPO = Grand Portage, ISRO = Isle Royale, PIRO = Pictured Rocks, APIS = Apostle Islands, MISS = Mississippi National River, SLBE = Sleeping Bear Dunes, INDU = Indiana Dunes.

3.2 Call Index Values (CIV)

We also tracked calling intensity among the 30 samples manually scanned at each site as the proportion of samples falling within each of three call intensity rank values (Figure 5). CIV is scored in manual surveys, where Cope's Gray Treefrog and Gray Treefrog are identified to species and are reported on separately. For example, in 2019 Green Frog (LICL) at INDU03 had 100% of samples scored as CIV=1 (non-overlapping calls indicating few singing males) in 2019, and the maximum CIV of 3 (calls too numerous to count individuals) was reached at least once at INDU02. Over time, we will track whether the proportion of samples with a CIV of 3 is increasing or decreasing, which will reveal whether the number of calling males is increasing or decreasing at a site. 2019 results indicate a robust anuran community dominated by Eastern American Toad, Gray Treefrog, Green Frog and Spring Peeper, with lesser representation of American Bullfrog and Boreal Chorus Frog. Northern Leopard Frog and Wood Frog appear at only two sites each in this data set.

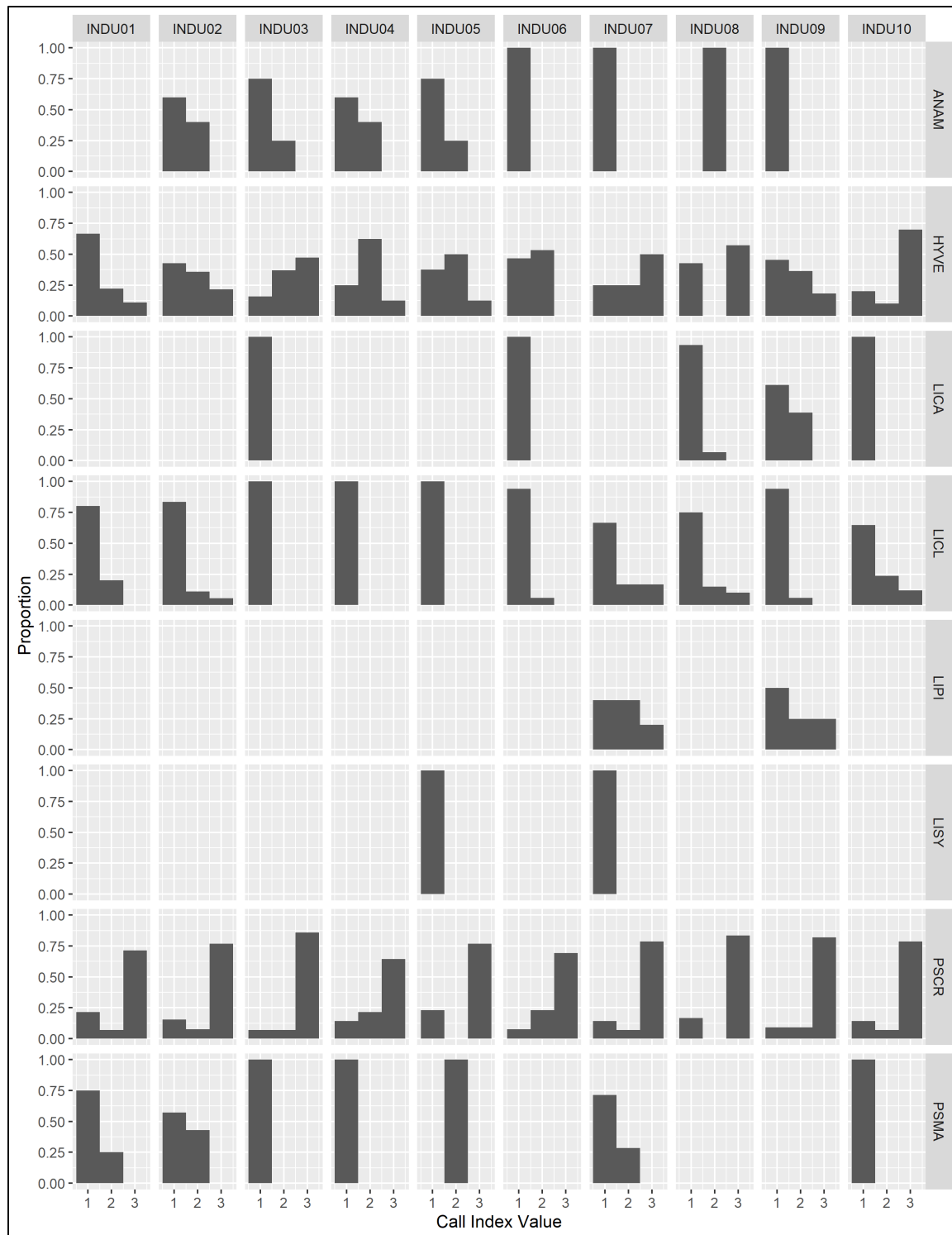


Figure 5. Call Index Value (CIV) distribution for each species at each site, Indiana Dunes National Park, 2019. Only species detected on at least one site are displayed. ANAM = Eastern American Toad, HYVE = Gray Treefrog, LICL = Green Frog, LIPI = Mink Frog, LISY = Wood Frog, PSCR = Spring Peeper. Call Index Values: 0 = No calls detected; 1 = Individuals of the species can be counted, there is silence between calls; 2 = Calls of individuals can be distinguished, but there is some overlapping of calls; 3 = Full chorus for the species, calls are constant, continuous, and overlapping.

3.3 Automated Detection Rates

Before calculating automated detection rates for each species, we first assessed error rates in automated detection by comparing results from automated detections and manual scans on the same 300 samples (30 samples per site), where manual scan results are assumed to be correct (at least two observers agree on the determination). Note that this process evaluates filtered automated scan results rather than raw results, and at the sample occupancy level rather than the individual call level. We then calculated the proportion of the 300 samples where automated detection returned a species when there was not a species present (commission error or false presence). Automated detection results were then corrected using these species-specific commission error rates to obtain final automated detection results for each species (Error rate multiplied by number automated detections = corrected N). See Appendix D for more details regarding detection error analyses. Overall agreement rates between manual and automated detections range from 0% to 100% (Table 2). Note that agreement rates between manual and automated surveys for site occupancy are much higher (see Casper and Nadeau 2018).

Table 2. Automated detection error rates for samples where manual verification identified a species in the sample. For example, for ANAM, of the 299 nighttime samples that were manually checked, 28 had ANAM present. Of these 28 samples, the automated method identified ANAM in 14 of these, giving an overall agreement rate of 50.00%.

Species*	Number of samples with species detected manually	Number of matches on automated detection	Agreement
ACBL	0	0	100.00%
ANAM	28	14	50.00%
ANFO	0	0	100.00%
HYSP	121	21	17.36%
LICA	53	16	30.19%
LICL	133	88	66.17%
LIPI	9	5	55.56%
LISY	3	0	0.00%
PSCR	132	126	95.45%
PSMA	31	29	93.55%

* ACBL = Blanchard's Cricket Frog, ANAM = Eastern American Toad, ANFO = Fowler's Toad, HYSP = Treefrog spp., LICL = Green Frog, LIPI = Northern Leopard Frog, LISY = Wood Frog, PSCR = Spring Peeper, PSMA = Boreal Chorus Frog.

In 2019 automated detections for Eastern American Toad (ANAM) were fairly consistent but with fewer detections at INDU06 and INDU10 (Figure 6). Gray Treefrog (HYSP) detection rates ranged from ca. 20%–60% of samples across all sites. American Bullfrog was common at INDU06, INDU08 and INDU09; less common at INDU10; and rare at INDU01 and INDU03. Green Frog (LICL)

detection rates were variable, with a low level at INDU03, moderate level at INDU01, INDU04 and INDU05; and robust level at remaining sites. Northern Leopard Frog calling was rare, detected only at INDU07 and INDU09. Wood Frog (LISY) was similarly rare, detected only at INDU05 and INDU07. Spring Peeper (PSCR) detection rates were consistently high for all sites. Boreal Chorus Frog (PSMA) had moderate detection rates at INDU02, INDU04 and INDU07; and low rates at INDU01, INDU03, INDU05 and INDU10.

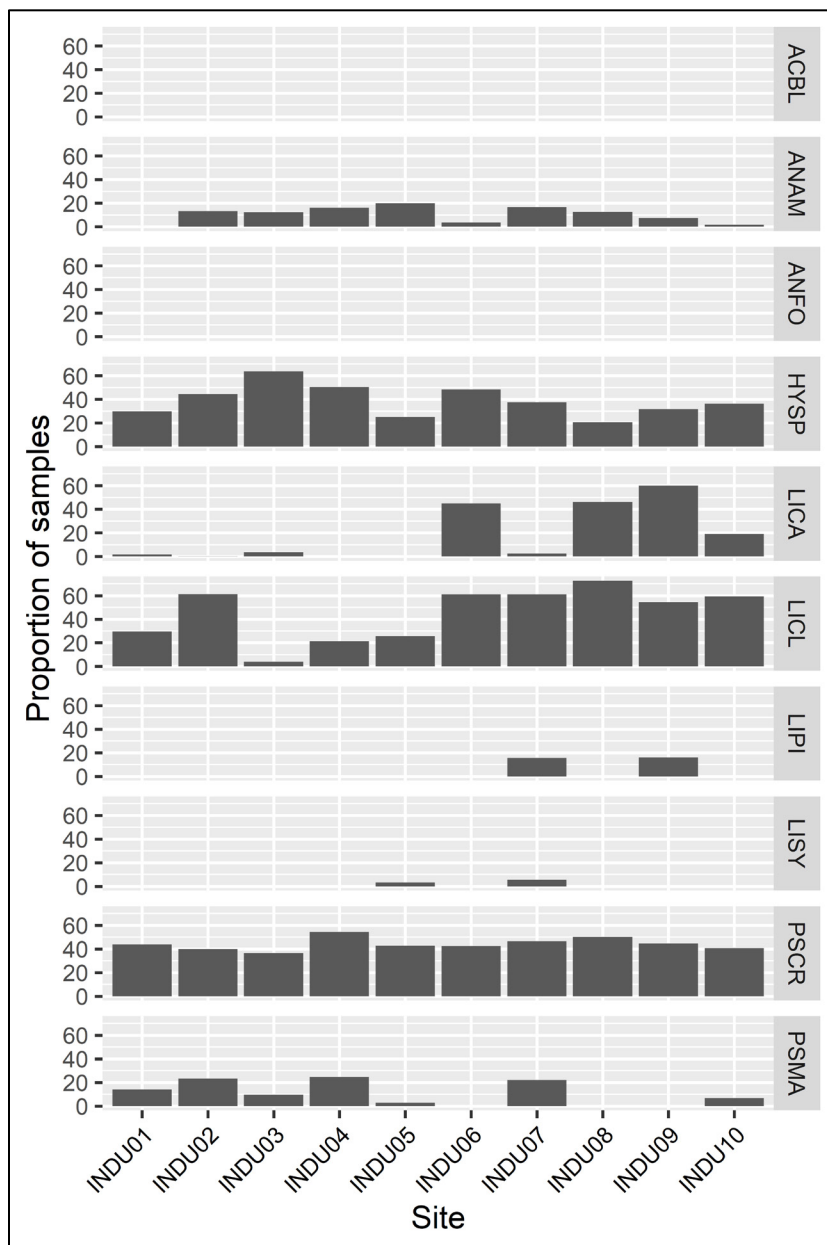


Figure 6. Estimated percent of samples with detections by species at each site at Indiana Dunes National Park in 2019. From top, ACBL = Blanchard's Cricket Frog, ANAM = Eastern American Toad, ANFO = Fowler's Toad, HYSP = Treefrog spp. (all were Gray Treefrog, *Hyla versicolor*), LICA = American Bullfrog, LICL = Green Frog, LIPI = Northern Leopard Frog, LISY = Wood Frog, PSCR = Spring Peeper, and PSMA = Boreal Chorus Frog.

Compared to other parks, 2019 detection rates at INDU were high for Gray Treefrog (HYSP) and Green Frog (LICL), and average for Eastern American Toad (ANAM), Spring Peeper (PSCR) and Boreal Chorus Frog (PSMA; Figure 7). American Bullfrog (LICA) was detected only at INDU in 2019. Compared to other parks INDU had a low rate for Wood Frog (LISY) in 2019. (Figure 7). Historically present species such as Blanchard's Cricket Frog (ACBL) and Fowler's Toad (ANFO) remain undetected by any method.

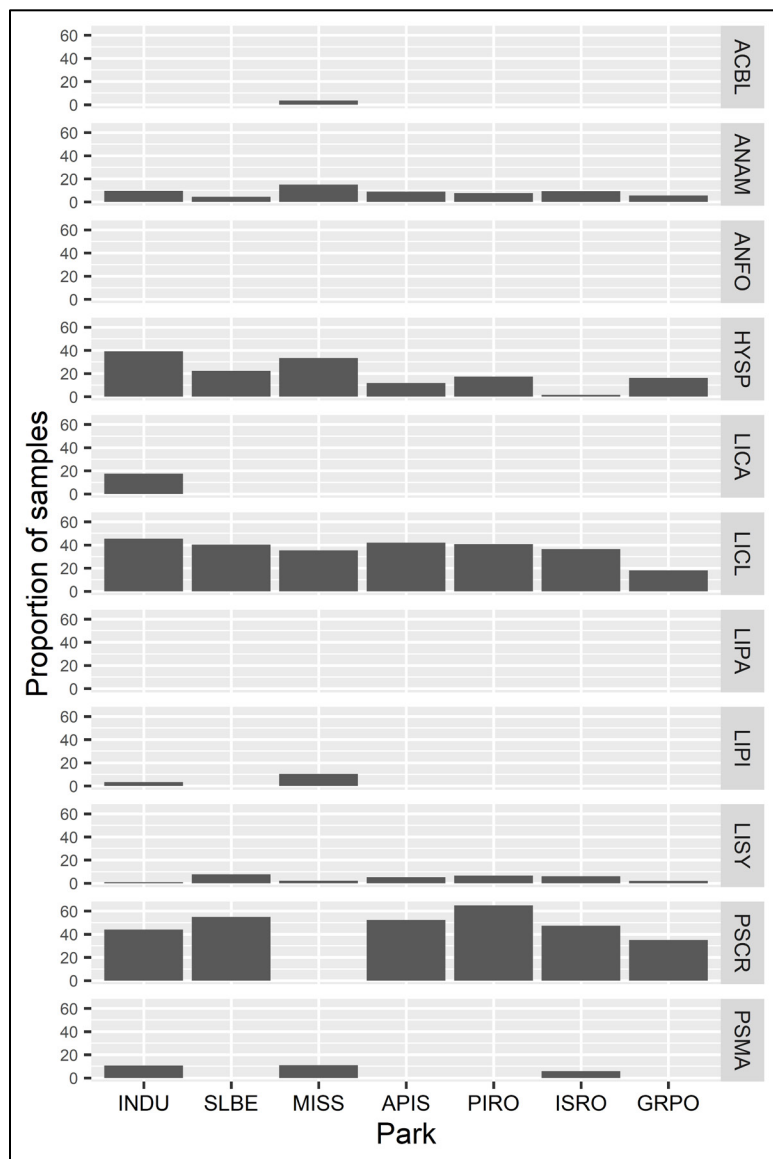


Figure 7. Percent of samples with detections by species across parks monitored in 2019. From top, ACBL = Blanchard's Cricket Frog, ANAM = Eastern American Toad, ANFO = Fowler's Toad, HYSP = Treefrog spp., LICA = American Bullfrog, LICL = Green Frog, LIPA = Pickerel Frog, LIPI = Northern Leopard Frog, LISY = Wood Frog, PSCR = Spring Peeper, PSMA = Boreal Chorus Frog. Parks ordered south to north: INDU = Indiana Dunes, SLBE = Sleeping Bear Dunes, MISS = Mississippi National River, APIS = Apostle Islands, PIRO = Pictured Rocks, ISRO = Isle Royale, GRPO = Grand Portage.

Discussion

The monitoring program detected eight of the nine species of frog and toad known to still occur at INDU in 2019 (Appendix F), with Eastern American Toad, Gray Treefrog, Green Frog and Spring Peeper occurring at every site sampled. Boreal Chorus Frog was found at all but one site (INDU06). American Bullfrog, Northern Leopard Frog, and Wood Frog were found at five, two and two sites, respectively.

We expanded analyses and reporting in 2018 to address calling phenology and to provide a second metric for tracking changes in abundance (as opposed to occupancy) across years. Occupancy analyses track whether or not a site was occupied by a species. Abundance is tracked by assessing how the maximum call intensity changes on sites across years, and by how many automated detections are reported from sites across years.

Using two independent survey methods, manual and automated, with large sample sizes continues to return reliable results, providing a confident record of site occupancy for most species. False absences are mostly attributable to weak signals (distant calls), obscuring noise (both natural and anthropogenic), and in some cases the rareness of a species calling. False absences are accounted for in periodic occupancy modeling. False positives for site occupancy are eliminated by dual observer proofing, although it is possible some could remain due to human error. More details regarding false absences (omission) can be found in Appendix D.

The most difficult species to confirm are American Bullfrog, Cope's Gray Treefrog, Mink Frog, and Northern Leopard Frog. American Bullfrog calls are often obscured by anthropogenic or natural noise sharing its low frequency band. Cope's Gray Treefrog calls can be distinguished from Gray Treefrog calls by pulse rates (Jaslow and Vogt 1977), but we find that counting pulses is not always possible unless a very clear recording with little background noise is obtained. In these cases, we still rely on qualitative call interpretation. Mink Frog calls are quiet, often obscured by noise or the calls of Green Frog, and they are often hard to distinguish from truncated Green Frog calls and natural or electronic interference sounds. The addition of early morning samples in our protocol, when Mink Frog tends to call more, has improved detection rates. Northern Leopard Frog calls are low frequency and low volume, a combination that results in little carrying power and calls often being masked by other natural and anthropogenic sounds. Moreover, Northern Leopard Frog calls sporadically and often from only a few small areas within larger wetlands; therefore, it is more often missed by chance (where selected samples are not at the times of peak calling) or because calling is too distant from the ARS. While these difficult species are adequately monitored by the dual survey approach, they do have higher false absence rates than other species (Table D1).

There were no significant data collection issues in 2019 except failure of the temperature logger at INDU03 (nearby INDU06 temperatures were substituted for analyses), and early cessation of data collection at INDU03 (no data collected after 16 July), neither of which compromised sampling rigor or analysis. Cumulative data collection result summaries are provided in Appendix E, and 2019 summaries in Appendices A, B and C.

However, we now recommend a start date of 10–15 March rather than 1 April based on the temperature logs showing that the threshold of $\geq 40^{\circ}\text{F}$ was exceeded by 1 April in 2019 (Appendix C).

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Appendix A. Acoustic Recorder Deployment Success

In 2019 all recorders collected data as programmed (Figure A1).

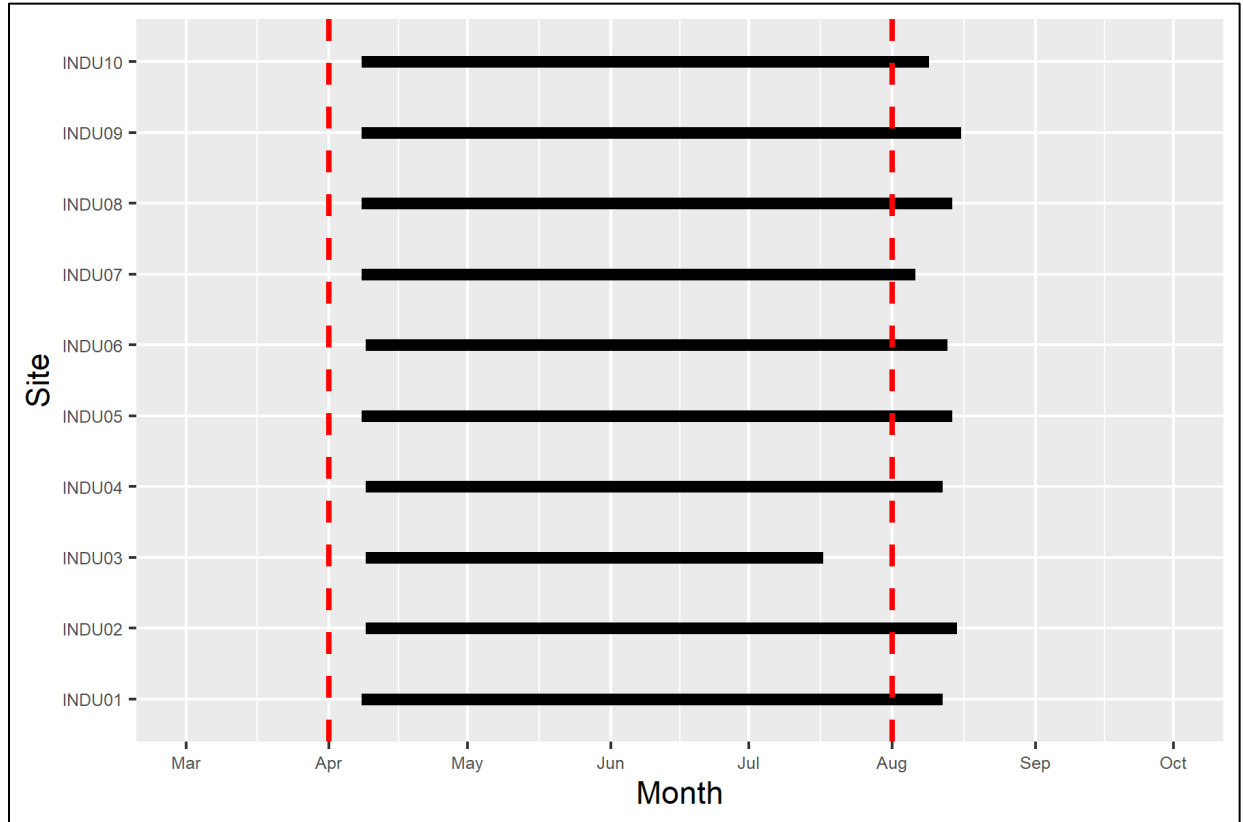


Figure A1. Successful recording periods for each monitoring site at Indiana Dunes National Park, 2019.

Appendix B. ARS Samples

No ARS programming errors occurred in 2019. All programmed samples were successfully recorded on the days that the recording devices were operational (Figure B1). Data collection ended early at INDU03 however, likely due to premature battery failure.

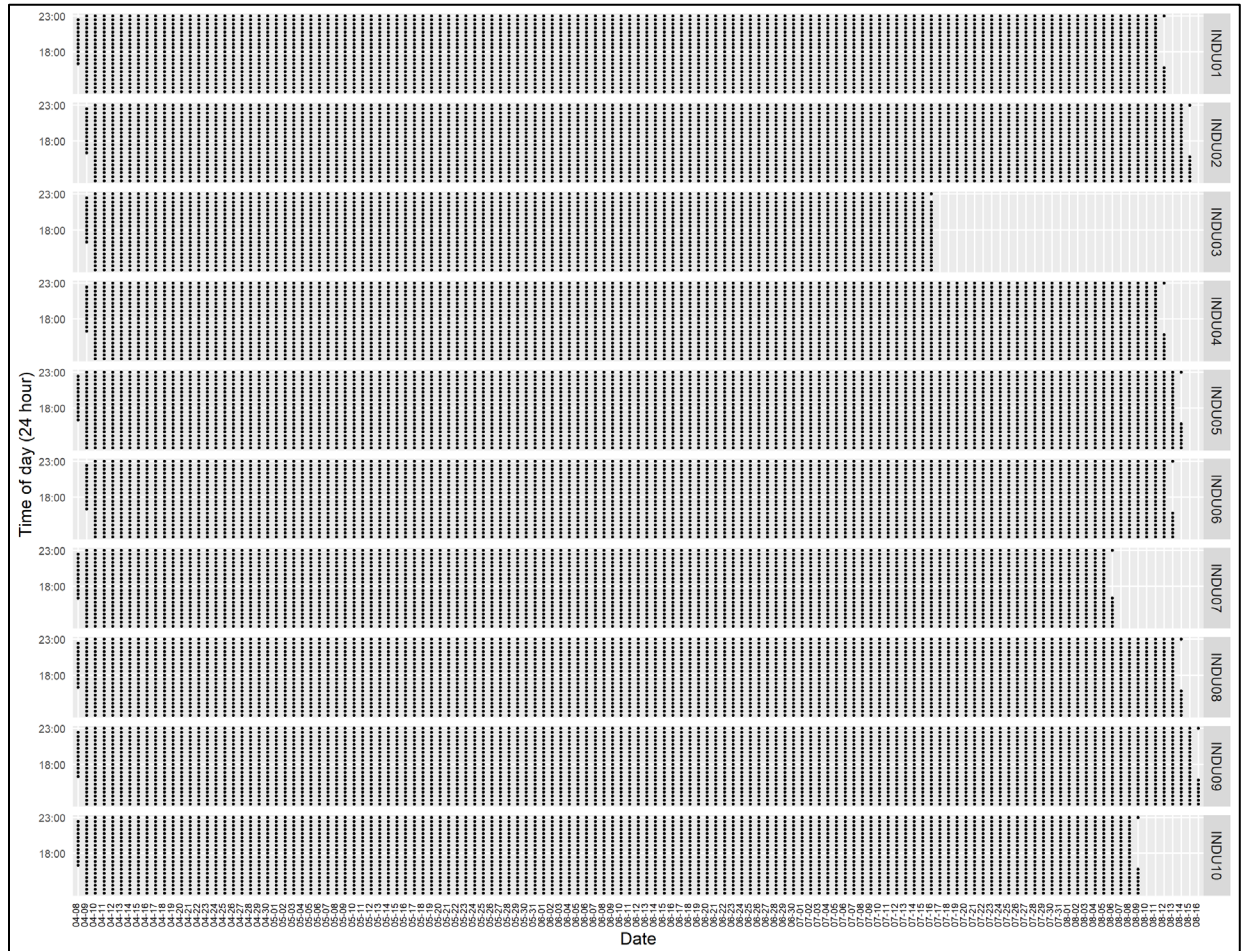


Figure B1. Sampling success for Indiana Dunes National Park, 2019. Each dot represents a recording. Figure shows the entire recording periods for each ARS, from 8 April through 16 August.

Appendix C. Temperature Logs

Temperature logs were successfully collected for all sites in 2019 (Figure C1). Since the $\geq 40^{\circ}\text{F}$ temperature threshold was met before recordings began, a recommendation for starting sampling earlier is made (ca. 10–15 March).



Figure C1. Temperature logs for each Indiana Dunes National Park site in 2019. The red line depicts daily maximum temperature, the blue line daily minimum temperature. The dashed green line is the 40°F minimum temperature threshold for selection of samples for manual scanning. This figure only shows data through the night of 31 July (when data analyses end).

Appendix D. Automated Detection Error Analysis

Automated survey error counts for each species in 2019 are presented in Table D1. For example, Eastern American Toad (ANAM) was detected in 28 of 299 samples by manual scans (Agree Present plus Omission), with automated detections agreeing in 14 of these and returning false absences in 14. Manual surveys concluded ANAM was absent from 271 samples (Agree Absent plus Commission), and automated surveys returned false positives in 51 of those. Note that false presences (Commission error) do not affect occupancy conclusions, but rather are used for estimating automated detection rates.

Table D1. Error counts for 30 samples per site (N=299 in 2019) for four conditions. Agree Absent = automated and manual results agree on species absent. Commission = automated survey falsely detected a species. Agree Present = automated and manual results agree on species present. Omission = automated survey missed a species that was present.

Species*	Agree Absent	Commission	Agree Present	Omission
ACBL	194	105	0	0
ANAM	220	51	14	14
ANFO	298	1	0	0
HYSP	178	0	21	100
LICA	245	1	16	37
LICL	149	17	88	45
LIPI	220	70	5	4
LISY	256	40	0	3
PSCR	125	42	126	6
PSMA	63	205	29	2

* ACBL = Blanchard's Cricket Frog, ANAM = Eastern American Toad, ANFO = Fowler's Toad, HYSP = Treefrog spp. (all were Gray Treefrog, *Hyla versicolor*), LICA = American Bullfrog, LICL = Green Frog, LIPI = Northern Leopard Frog, LISY = Wood Frog, PSCR = Spring Peeper, PSMA = Boreal Chorus Frog.

We assessed automated detection rates by correcting results obtained by running acoustic samples through the automated detection process (in which algorithms are used to identify call patterns assigned to specific species) for commission errors (i.e., false presences). Correction factors are calculated by comparing results from automated and manual surveys on the same 30 samples (Table D2). These correction factors are then applied to all samples run through the automated detection procedures (typically 100 to 200 samples per site per year) to estimate the number of samples with automated detections for each species at each site in each year as a metric for tracking trends in abundance.

Error rates for automated detection algorithms are variable, however all false presences for site occupancy are rejected by the proofing process.

Table D2. Percent error for automated detection results from 30 samples proofed manually at each site. Commission = automated survey falsely detected a species. Agree Present = automated and manual results agree on species present. Omission = automated survey missed a species that was present.

Species*	Agree Absent	Commission	Agree Present	Omission
ACBL	64.88	35.12	NA	NA
ANAM	81.18	18.82	50	50
ANFO	99.67	0.33	NA	NA
HYSP	100	0	17.36	82.64
LICA	99.59	0.41	30.19	69.81
LICL	89.76	10.24	66.17	33.83
LIPI	75.86	24.14	55.56	44.44
LISY	86.49	13.51	0	100
PSCR	74.85	25.15	95.45	4.55
PSMA	23.51	76.49	93.55	6.45

* ACBL = Blanchard's Cricket Frog, ANAM = Eastern American Toad, ANFO = Fowler's Toad, HYSP = Treefrog spp., LICA = American Bullfrog, LICL = Green Frog, LIPI = Northern Leopard Frog, LISY = Wood Frog, PSCR = Spring Peeper, PSMA = Boreal Chorus Frog.

Appendix E. Cumulative Data Collection Results

Data collection was successful at almost all sites in all years, with the exception of INDU06 in 2016, 2017, and 2018 (Figure E1). Our goal is to consistently collect data from ice-out through the end of July in each year.

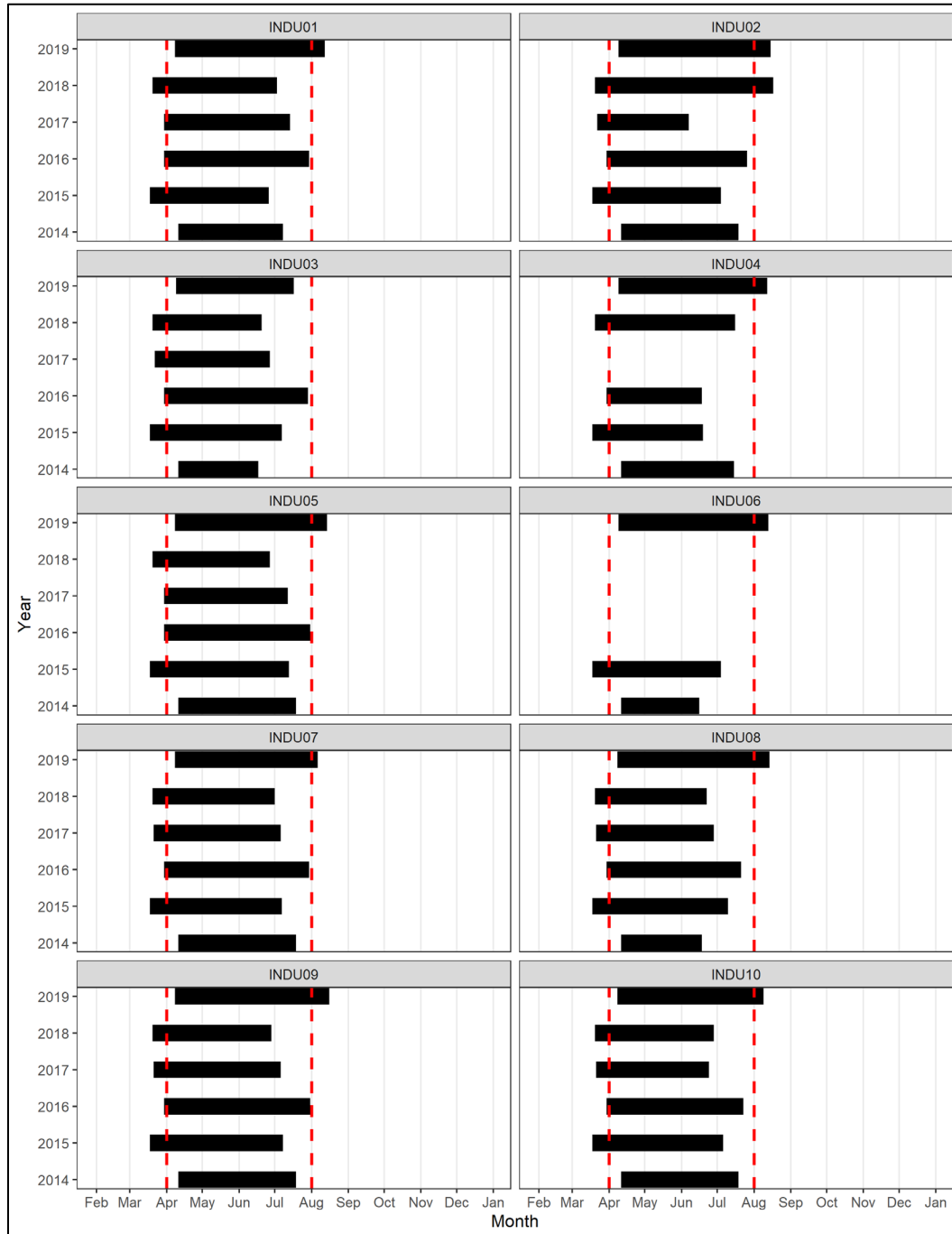
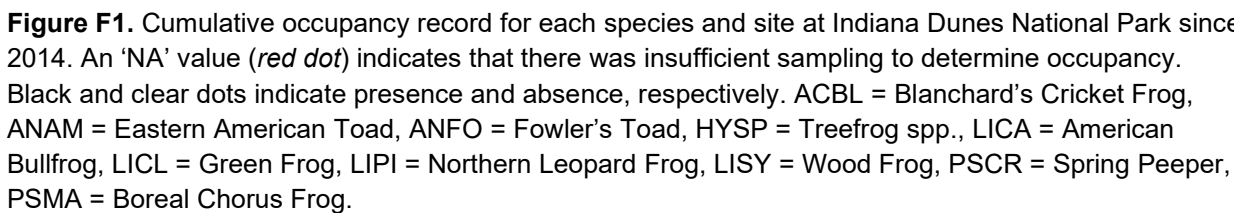


Figure E1. Successful data collection periods for each site at Indiana Dunes National Park, 2014–2019. Dotted lines bound 1 April through 1 August.

Appendix F. Cumulative Occupancy Record

The multi-year occupancy record (Figure F1) provides preliminary site occupancy trends. Solid dots indicate confirmed presence, while open dots indicate an absence conclusion (not detected by any method). Putative absences will be transformed to probabilities of absence when multi-year occupancy modeling is performed, but naïve absence data presented here are usually reliable due to large sample sizes. Red dots (NA) indicate that sampling was insufficient for reaching any conclusion on presence or absence, because too few or no samples were taken during the prime calling period for the species.



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1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525