



Acoustic Amphibian Monitoring, 2018

Indiana Dunes National Park

Natural Resource Data Series NPS/GLKN/NRDS—2020/1290



ON THE COVER

Indian Dunes National Park is the only park in the Great Lakes Network where the American Bullfrog is found.
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Natural Resource Data Series NPS/GLKN/NRDS—2020/1290

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Abstract

The National Park Service Great Lakes Inventory and Monitoring Network (GLKN) established 10 permanent acoustic amphibian monitoring sites at Indiana Dunes National Park (INDU) in 2014. Digital acoustic samples of 5-minute duration are collected by placing automated recorders with omnidirectional stereo microphones at each site. Temperature loggers co-located with the recorders collect air temperature during the sample period.

Eight species of frogs and toads were detected in 2018, with five species occurring at nearly every site: Eastern American Toad, Gray Treefrog, Green Frog, Spring Peeper, and Boreal Chorus Frog. Three species—American Bullfrog, Northern Leopard Frog, and Wood Frog—were detected on less than half of the monitored sites. No detections were confirmed for two species thought to be extirpated: Blanchard’s Cricket Frog and Fowler’s Toad.

Data collection issues in 2018 were generally good and cumulative multi-year results are provided. However, most recorders stopped logging before the desired end date, presumably due to battery drains, which reduced the number of detections for late-calling species. Replacement of the original aging ARS units in 2019 with new, more efficient units should resolve battery life issues moving forward. Monitoring at Site INDU06 was discontinued in 2016 due to worries over vandalism. We recommend re-starting data collection at Site INDU06 to meet the program goal of 10 monitored sites. We can assist with repositioning the ARS within the same wetland, or with finding a new monitoring site, based on program site selection criteria.

We expanded analyses and reporting in 2018 to address calling phenology and to provide additional metrics for tracking changes in abundance (in addition to occupancy) across years. 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. We also added analysis of false presence error rates for automated detection algorithms, which were less than 3.5% in 2018 for all but one species.

The dual survey approach with large sample sizes continues to return reliable results, providing a near-perfect record of site occupancy for most species. False absences are accounted for in periodic occupancy modeling. False positives for site occupancy are eliminated by dual observer proofing.

Appendices present summaries of five years of cumulative results.

Introduction

The National Park Service Great Lakes Inventory and Monitoring Network (GLKN) established 10 permanent acoustic amphibian monitoring sites at Indiana Dunes National Park (INDU) in 2013. Acoustic recordings are 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.

Eleven frog and toad species are known to have occurred historically at INDU, but two of these are thought to be extirpated (Table 1). All species are monitored by this program and confirmed acoustic detections are archived at the Great Lakes Network office. This annual summary report presents results for 2018. A summary of five years of cumulative results are presented in Appendices C and D.

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

Common Name	Scientific Name	Code	INDU Status	INDU Calling Period Analyzed
Blanchard's Cricket Frog	<i>Acris blanchardi</i>	ACBL	Extirpated	15 May–31 July
Eastern American Toad	<i>Anaxyrus americanus americanus</i>	ANAM	Present	1 April–30 June
Fowler's Toad	<i>Anaxyrus fowleri</i>	ANFO	Extirpated	1 April–30 June
Cope's Gray Treefrog	<i>Hyla chrysoscelis</i>	HYCH	Present	1 April–31 July
Gray Treefrog	<i>Hyla versicolor</i>	HYVE	Present	1 April–31 July
Treefrog spp.	<i>Hyla</i> spp.	HYSP	Present	1 April–31 July
American Bullfrog	<i>Lithobates catesbeianus</i>	LICA	Present	10 May–31 July
Green Frog	<i>Lithobates clamitans</i>	LICL	Present	15 April–31 July
Pickerel frog	<i>Lithobates palustris</i>	LIPA	Absent	NA
Northern Leopard Frog	<i>Lithobates pipiens</i>	LIPI	Present	1 March–31 May
Mink Frog	<i>Lithobates septentrionalis</i>	LISE	Absent	NA
Wood Frog	<i>Lithobates sylvaticus</i>	LISY	Present	1 March–10 May
Spring Peeper	<i>Pseudacris crucifer</i>	PSCR	Present	1 March–15 July
Boreal Chorus Frog	<i>Pseudacris maculata</i>	PSMA	Present	1 March–20 May
Western Chorus Frog	<i>Pseudacris triseriata</i>	PSTR	Absent	NA

Methods

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 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. We used this process to select or reject sites until 3–4 sites of each wetland type were verified. Park personnel were also consulted on final site selections to ensure logistical feasibility for annual visits (Figure 1). 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.

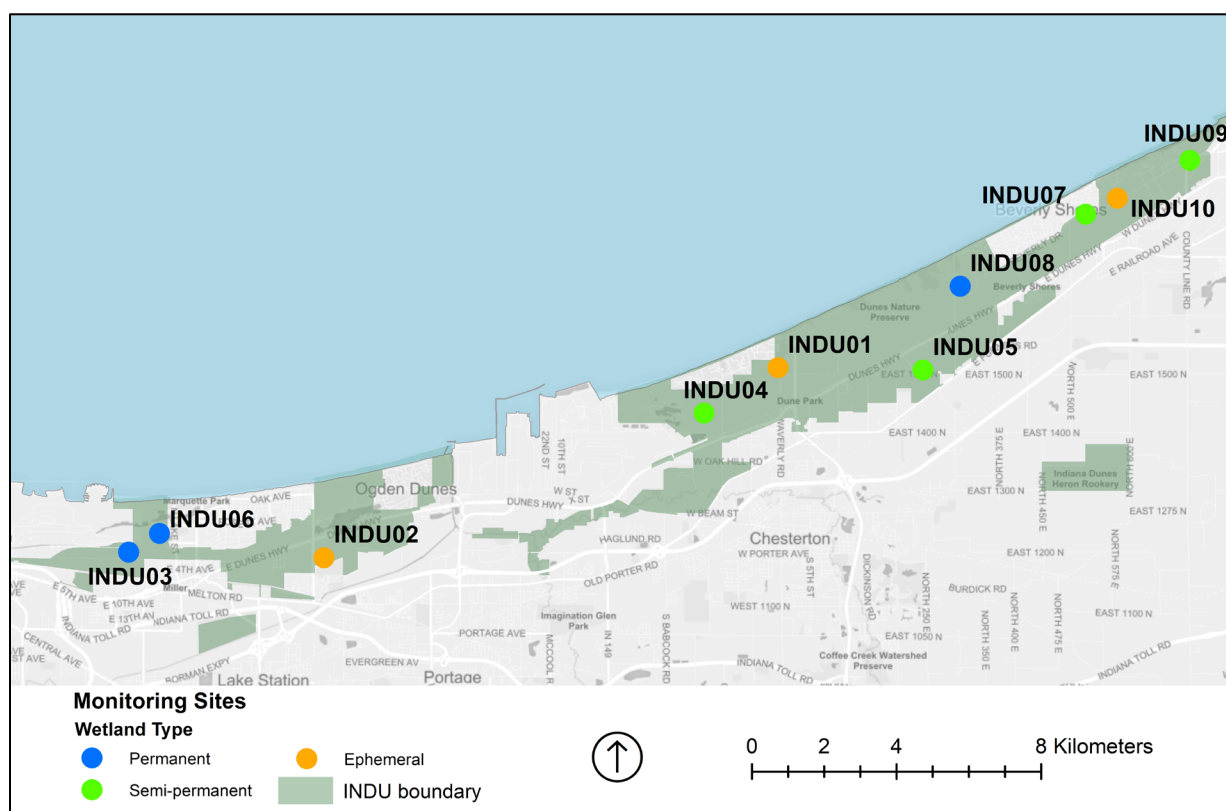


Figure 1. Locations of the ten monitoring sites chosen at Indiana Dunes National Park.

Data Collection

Automated Recording Systems

An automated recording system (ARS) with omnidirectional stereo microphones (Wildlife Acoustics, Inc., Concord, MA USA; Song Meter models SM3 and SM4) is placed at each monitoring site. They are programmed to record seventeen 5-minute samples each day on the top of each hour from 15:00h to 03:00h. Four extra samples are collected immediately after sunset on the half-hour mark. ARS are programmed at 16000 Hz sample rates, and data are saved as .wav files on SD cards.

ARS are deployed as soon as possible after ice-out, or in the previous autumn on a delayed start for 15 March. They 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.

Temperature Logs

Temperature loggers (HOBO Pendant® model UA-002-08, Onset Computer Corporation, Bourne, Massachusetts, USA) co-located with each ARS are programmed to record temperature every hour. Temperature data are used for filtering data analyses, where only samples with an ambient air temperature of $\geq 40^{\circ}\text{F}$ are used for manual surveys. Loggers are typically attached underneath the roof of the ARS mounting backboard (Figure 2) or hung within solar shields. In all instances, loggers are shaded from overhead sunlight. ARS and loggers are photographed in the field each year to document placement and habitat.



Figure 2. Example of automated recording device (ARS) deployed in the field. This device is attached to a backer board and to a metal t-post. The temperature logger is located in a shaded cup. With new SM4 units replacing old SM2+ units (shown here) in 2019, we recommend a roof be added to the backboard to better protect the ARS from rain, sun and birds, and that the logger be hung in the shade either under the roof or in a nearby shrub or tree.

Data Analysis

For detailed analysis steps, please see Casper and Nadeau (2019). 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 for each species 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 for each species, with proofing limited to within the calling periods determined from annually updated

results (Table 1). 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 $\geq 40^{\circ}\text{F}$. 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 Treefrog; Western vs. Boreal Chorus Frog), 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 to detect declines before a site becomes completely unoccupied.

Results

Acoustic Recorder Deployment Success

In 2018, ARS collected data for most of the target period of 1 April through 1 August; however INDU06 was not monitored (Figure 3). Additionally, all but one ARS failed before the target end date of 1 August, presumably due to battery drains. The number of valid samples for late calling species is thus lower than in most years.

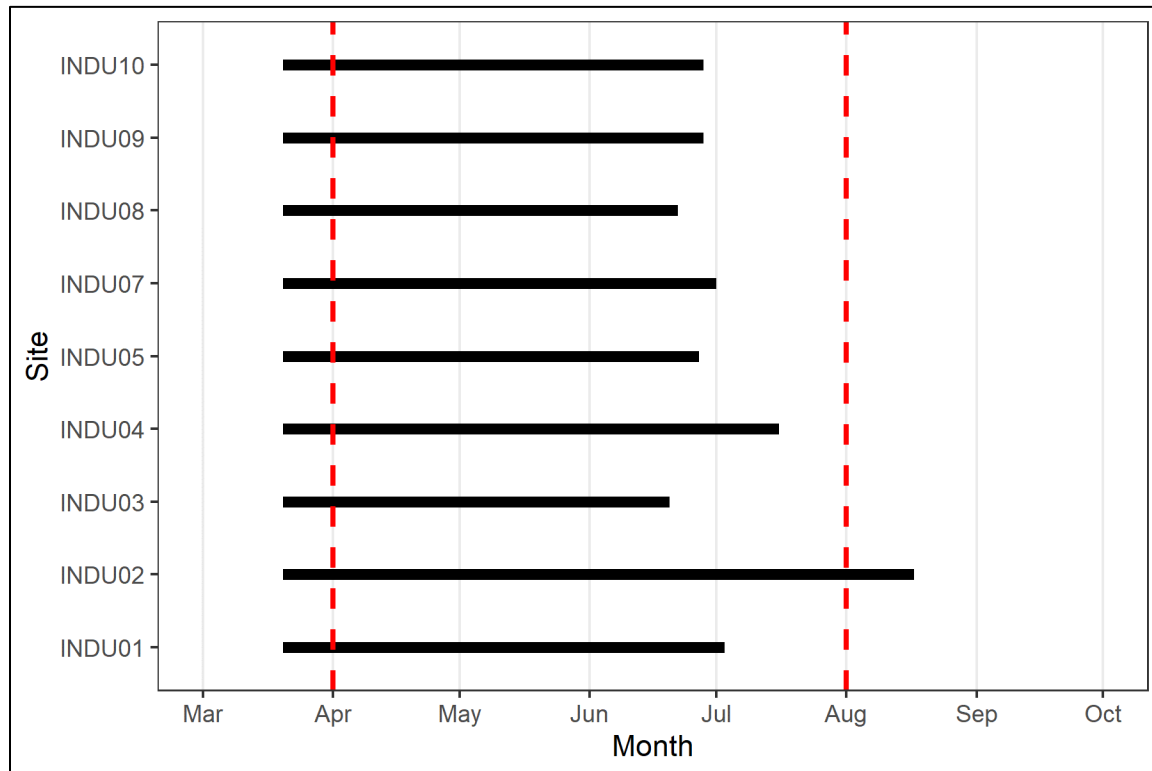


Figure 3. Successful recording periods for Indiana Dunes National Park, 2018. Red lines indicate the target sampling period. Site INDU06 was not monitored, so is not included here.

Temperature Logs

Daily maximum temperatures were exceeding the threshold of 40°F as soon as ARS were deployed in mid-March, which is unusually early (Figure 4). However, there is no evidence that frogs had started calling before units were deployed. No temperature logs were supplied for INDU02 or INDU06.

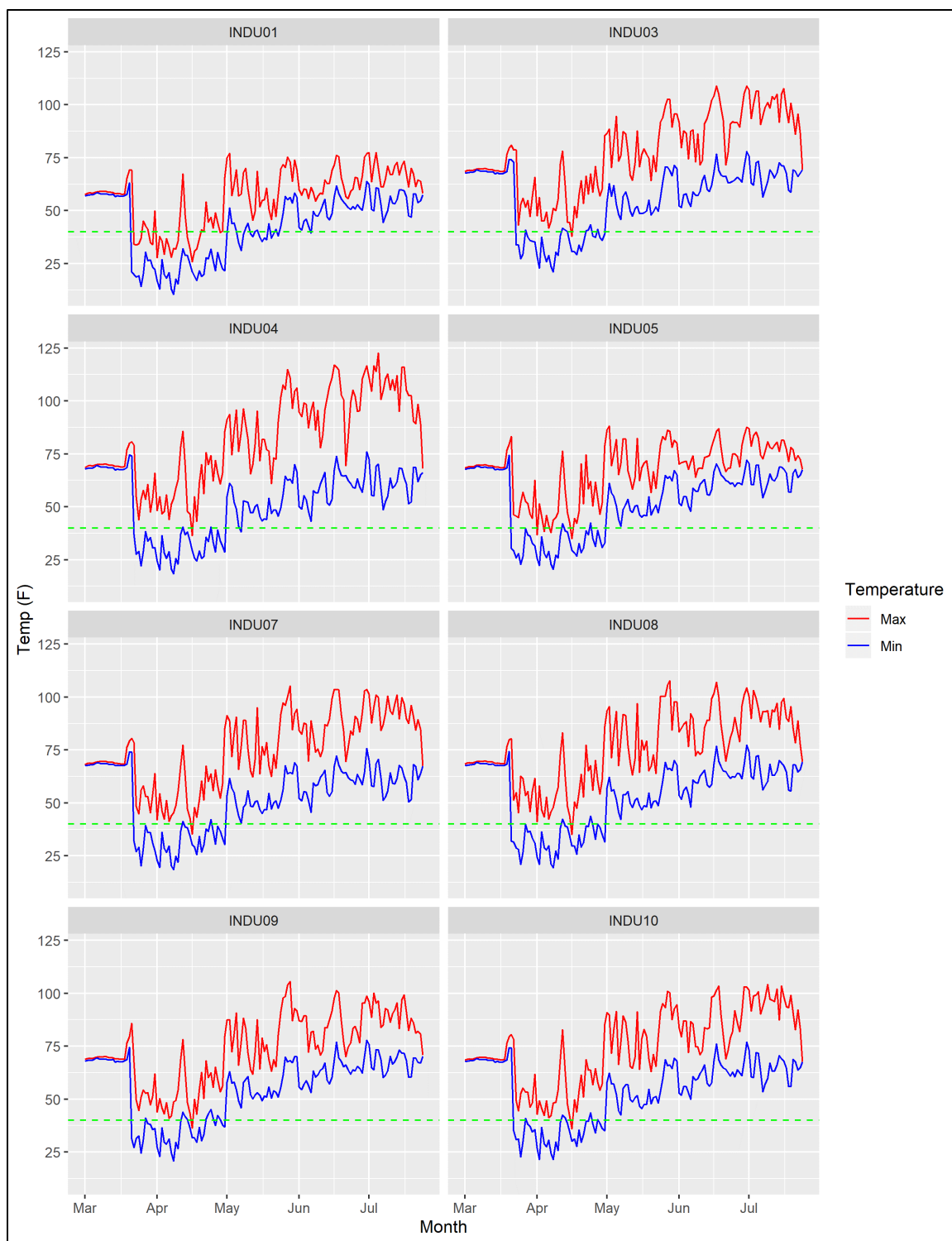


Figure 4. Temperature logs for each INDU site in 2018. The red line depicts daily maximum temperature; blue line daily minimum temperature. The green line is the 40°F minimum temperature threshold for selection of samples for manual scanning. This figure only shows data from the target sampling period (1 April through 31 July). Data prior to field deployment in mid-March represents office storage temperature.

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 and Grand Portage). Note that auto-detections do not distinguish between Gray Treefrog and Cope's Gray Treefrog, owing to the similarity of the calls of this diploid-tetraploid species pair. Manual scans do attempt to determine detections to species. For phenology we treat these as a species pair, as calling periods do not differ between species (Mossman et al. 1998, Dodd 2013).

We chose not to model the earlier calling species at this time (Boreal Chorus Frog, Northern Leopard Frog, Spring Peeper, Wood Frog) owing to often late deployment of ARS units missing their earliest calls. These species can be modeled if ARS deployment target dates improve through fall deployments and delayed starts. Calling phenology 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.

At INDU in 2018, earliest calling dates were quite consistent for Eastern American Toad across all sites occupied, except for calling beginning a few days later at INDU03 (Figure 5). For Treefrog spp. (all Gray Treefrog) calling started a few days later at INDU04 and INDU05, but was otherwise quite synchronized. Green Frog calling at sites INDU08 and INDU09 began later than other sites, and the very late calls at INDU05 were a single frog only (likely not a breeding population).

As expected from climate differences, frogs begin calling earlier at more southerly parks and later at more northern parks, with INDU start dates being the earliest (Figure 6). Late first-calling dates typically represent lone frogs at sites where no breeding population is established.

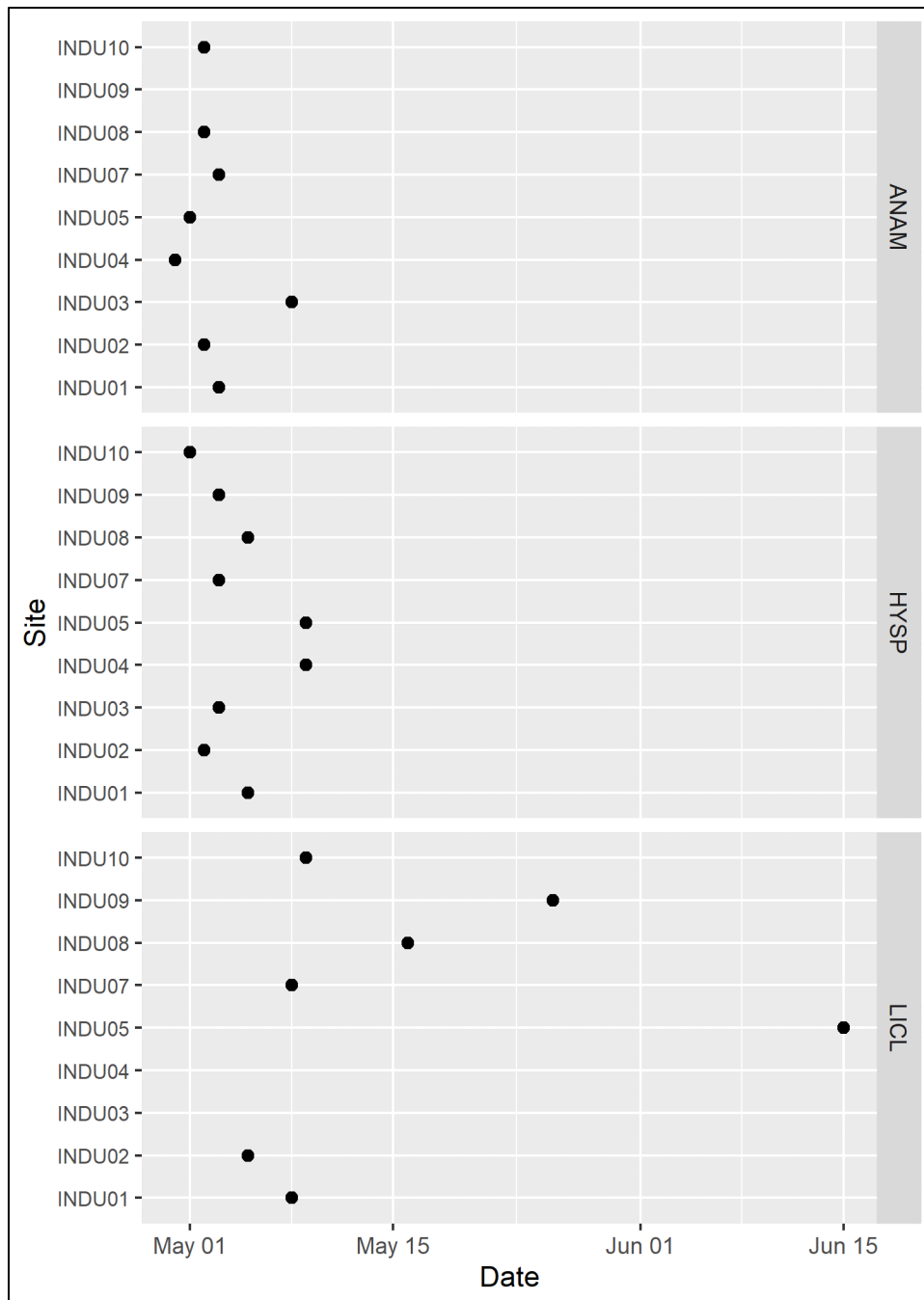


Figure 5. Dates of first confirmed detections for Eastern American Toad (ANAM), Treefrog spp. (HYSP), and Green Frog (LICL), at Indiana Dunes National Park, 2018.

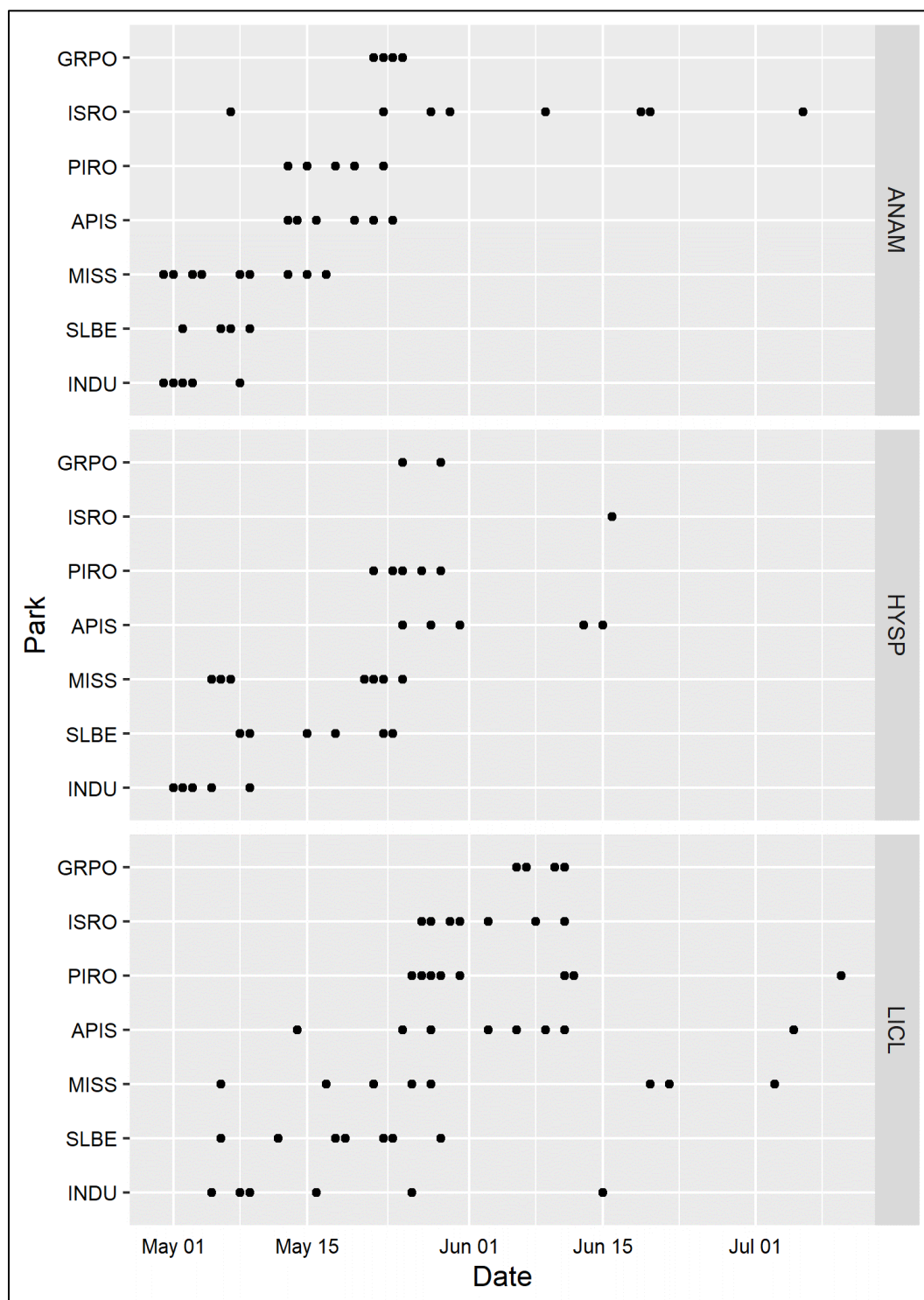


Figure 6. First detection dates of three species for all parks conducting monitoring in 2018 (parks ordered north to south). GRPO = Grand Portage, ISRO = Isle Royale, PIRO = Pictured Rocks, APIS = Apostle Islands, MISS = Mississippi River, SLBE = Sleeping Bear Dunes, INDU = Indiana Dunes. ANAM = Eastern American Toad, HYSP = Treefrog spp., LICL = Green Frog.

Call Index Values (CIV)

We also track 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 7). CIV is scored in manual scanning where Cope's Gray Treefrog and Gray Treefrog are identified to species and hence are reported on separately. For example, in 2018 at INDU02 Gray Treefrog (HYVE) had more samples with a CIV of 1 than 3, while the reverse pattern is shown for Spring Peeper (PSCR) at INDU01. 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. At INDU in 2018, the most abundant frogs by this measure were Gray Treefrog, Green Frog, and Spring Peeper. Note, however, that the relationship between this calling activity metric and actual population size varies among species, and this metric is designed to measure relative abundance within a species across years rather than to compare abundance among species.

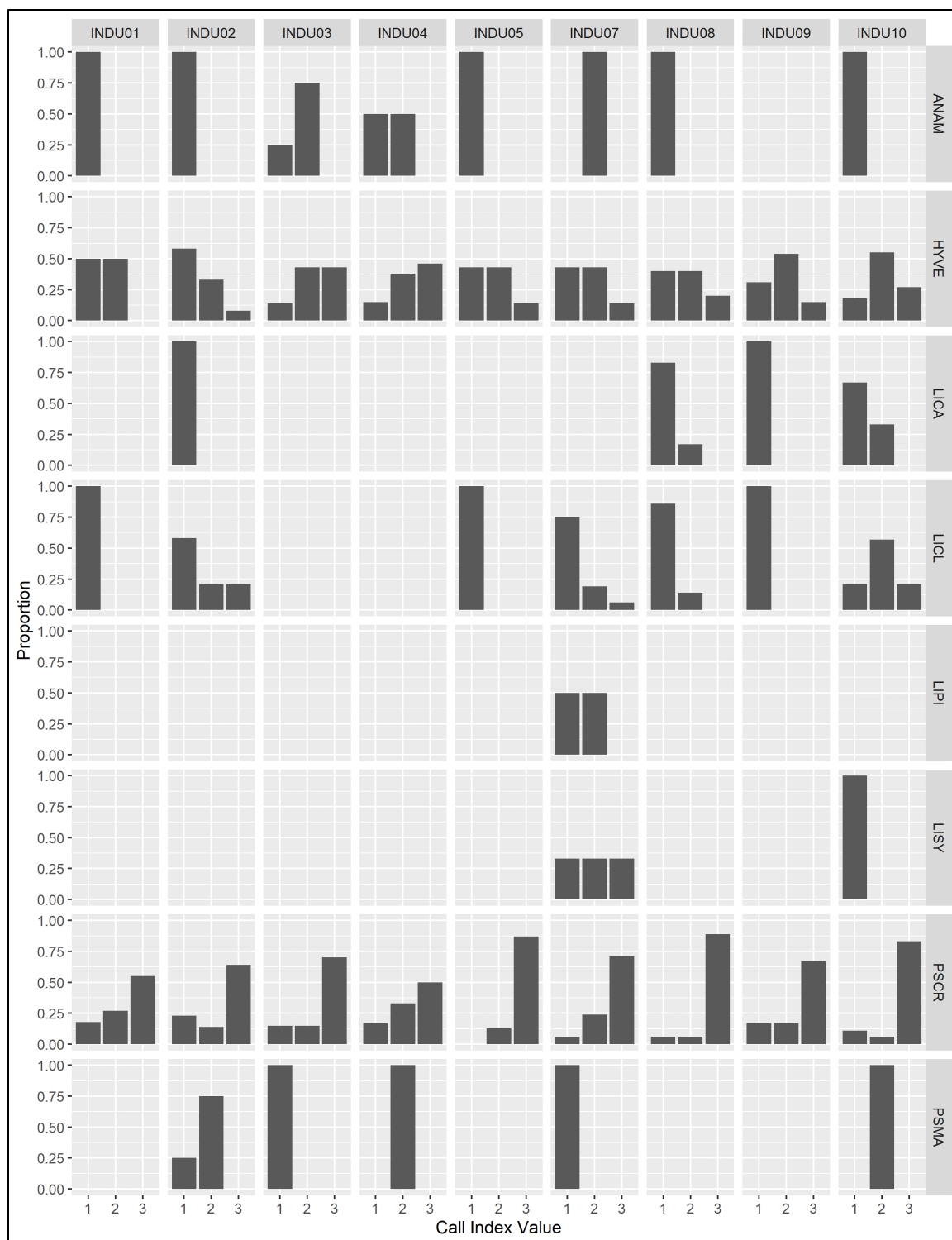


Figure 7. Call Index Value (CIV) distribution for each species at each site, Indiana Dunes National Park, 2018. Only species detected on at least one site are displayed. ANAM = Eastern American Toad, HYVE = Gray Treefrog, LICA = American Bullfrog, LICL = Green Frog, LIPI = Northern Leopard Frog, LISY = Wood Frog, PSCR = Spring Peeper, PSMA = Boreal Chorus Frog.

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 as at least two observers agree on presence or absence. We then calculated the proportion of the 300 samples where automated detection returned a species when it was not 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). For more details regarding detection error types, see Appendix B. Overall agreement rates for automated detections ranged from 0.00 to 88.74% (Table 2). For example, for Eastern American Toad (ANAM), of the 300 samples that were manually checked (actual number was 270 at INDU in 2018 due to non-deployment of INDU06), 18 were scored as occupied. Of these 18 samples, the automated method identified this species in 10 of these samples giving an overall agreement rate of 55.56%.

It is important to keep this analysis in context. While agreement rates (Table 2) for the two surveys may sometimes seem poor on the 300 samples compared, agreement on site occupancy was much better, which was the original goal for developing the automated detection algorithms. This is because the algorithms often only identify high quality recordings, which are usually found within the hundreds of samples analyzed at each site but not necessarily within the 30 samples manually scanned at each site. This was an intentional trade off to reduce the number of false positives in automated detection.

Table 2. Automated detection error rates for only samples where manual verification identified a species in the sample. ANAM = Eastern American Toad, HYSP = Treefrog spp., LICA = American Bullfrog, LICL = Green Frog, LIPI = Northern Leopard Frog, LISY = Wood Frog, PSCR = Spring Peeper, PSMA = Boreal Chorus Frog.

Species	Number of samples with species detected manually	Number of matches on automated detection	Agreement
ANAM	18	10	55.56%
HYSP	122	37	30.33%
LICA	23	7	30.43%
LICL	74	50	67.57%
LIPI	2	0	0.00%
LISY	4	3	75.00%
PSCR	151	134	88.74%
PSMA	15	6	40.00%

Figure 8 displays the automated detection rates for each species at each site in 2018. Eastern American Toad (ANAM) automated detection was confirmed at all but one site, but with most detections at INDU03, INDU04, and INDU05. Treefrog spp. (HYSP; all were Gray Treefrog) was

confirmed at all sites with the most detections at INDU07, INDU09, and INDU10. American Bullfrog (LICA) was only detected at INDU08, INDU09, and INDU10. Green Frog (LICL) was detected at all but two sites and had few detections at INDU01 and INDU06. Northern Leopard Frog (LIPI) was confirmed only at INDU 07, and Wood Frog (LISY) only at INDU07 and INDU10. Spring Peeper (PSCR) had the highest detection rates and was found at every site. Boreal Chorus Frog was detected at all sites except INDU09.

Compared to other parks, automated detection rates at INDU were relatively low for Green Frog (LICL) and Wood Frog (LISY), and it is the only park supporting American Bullfrog (LICA) (Figure 9).

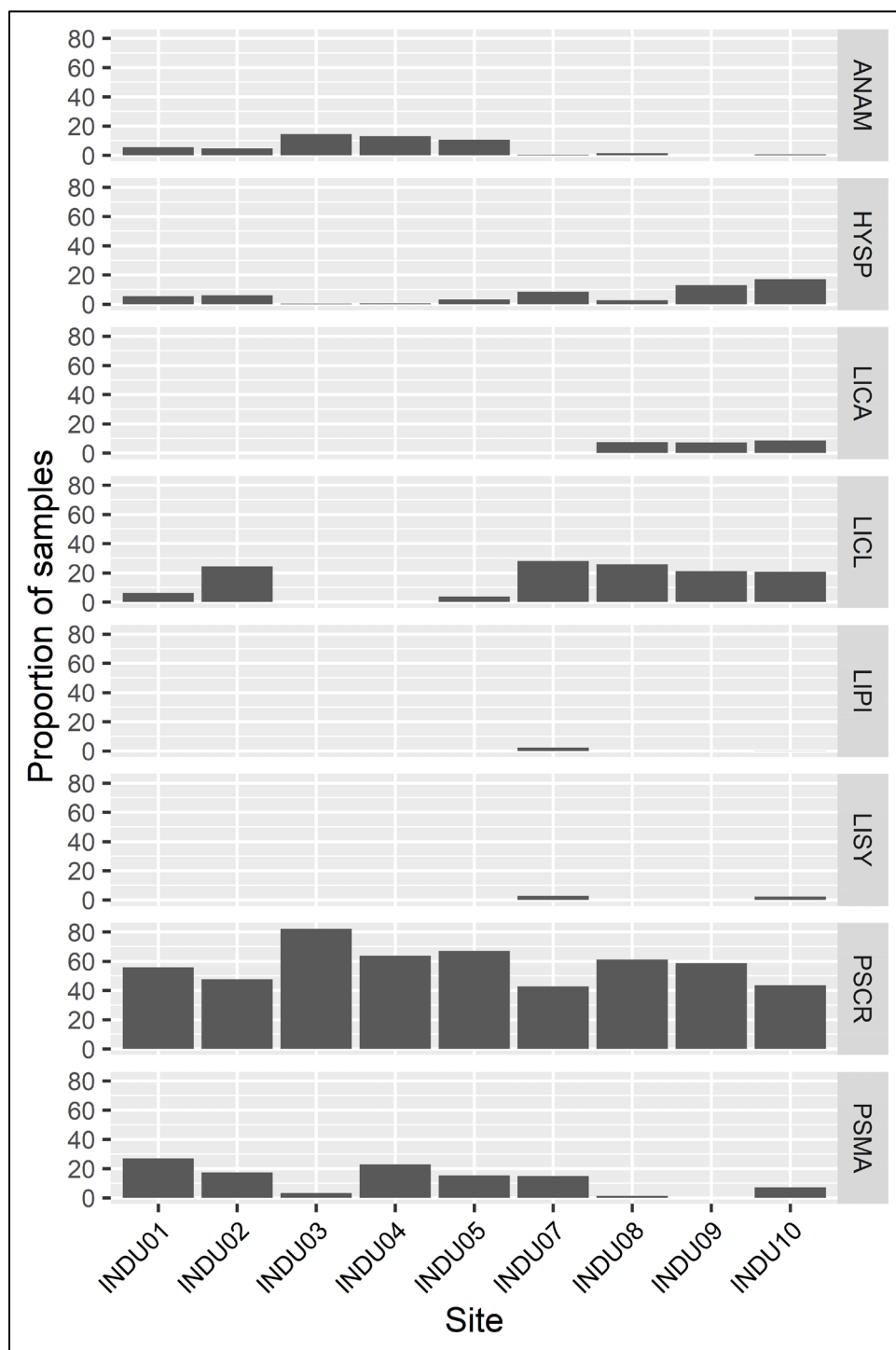


Figure 8. Percent of samples with automated detections by species at each site at Indiana Dunes National Park in 2018. From top, Eastern American Toad (ANAM), Treefrog spp. (HYSP), American Bullfrog (LICA), Green Frog (LICL), Northern Leopard Frog (LIPI), Wood Frog (LISY), Spring Peeper (PSCR), and Boreal Chorus Frog (PSMA).

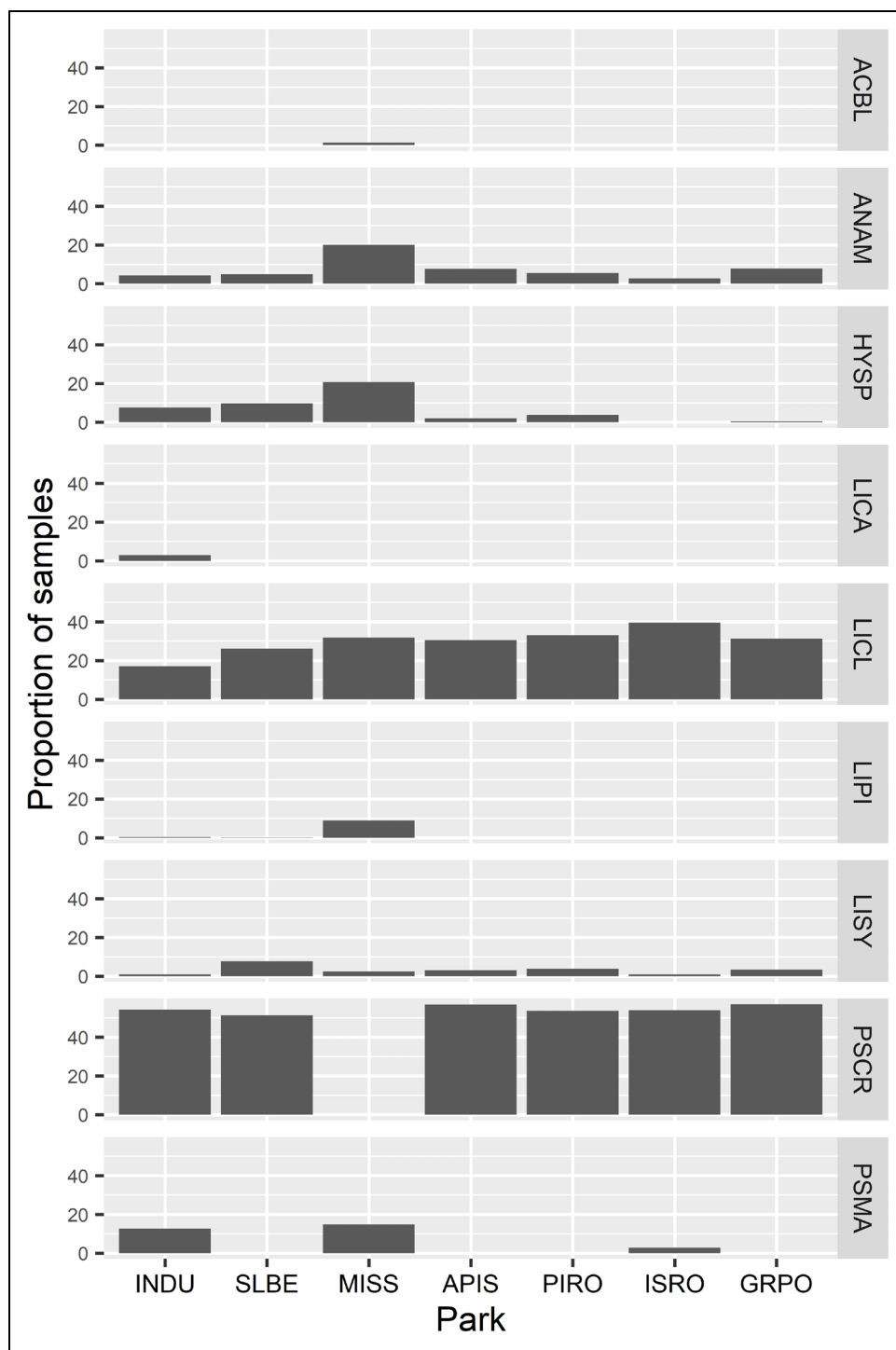


Figure 9. Percent of samples with automated detections by species across parks monitored in 2018. Parks ordered south to north: INDU=Indiana Dunes, SLBE=Sleeping Bear Dunes, MISS=Mississippi River, APIS=Apostle Islands, PIRO=Pictured Rocks, ISRO=Isle Royale, GRPO=Grand Portage. Only species detected at any park are shown. From top, Blanchard's Cricket Frog (ACBL), Eastern American Toad (ANAM), Treefrog spp. (HYSP), American Bullfrog (LICA), Green Frog (LICL), Northern Leopard Frog (LIPI), Wood Frog (LISY), Spring Peeper (PSCR), Boreal Chorus Frog (PSMA).

For site occupancy conclusions at INDU in 2018, automated results reported only one false absence compared to manual results: one LICA site (INDU02); while the manual process reported five false absences (where species presence was confirmed only by automated detection in samples not selected for manual scanning): LIPI at INDU10, LISY at INDU01; and PSMA at INDU01, INDU05, and INDU08). The error rates calculated here for automated detections are only utilized to improve the accuracy of the percent of samples with detections reported in Figure 8, a new metric developed in 2018.

Discussion

The monitoring program detected eight species of frogs and toads at INDU in 2018, with five species occurring at nearly every site: Eastern American Toad (ANAM), Treefrog spp. (HYSP; all were Gray Treefrog), Green Frog (LICL), Spring Peeper (PSCR), and Boreal Chorus Frog (PSMA) (Appendix D). American Bullfrog (LICA), Northern Leopard Frog (LIPI), and Wood Frog (LISY) were detected on less than half of the monitored sites. No detections were confirmed for the two species thought to be extirpated: Blanchard's Cricket Frog (ACBL) and Fowler's Toad (ANFO).

We expanded analyses and reporting in 2018 to address calling phenology and to provide additional metrics for tracking changes in abundance (as opposed to occupancy) across years. Abundance is tracked by assessing how the maximum call intensity changes on sites across years (see Figure 8), and by how many automated detections are reported from sites across years (see Figure 9).

The dual survey approach (manual and automated) with large sample sizes continues to return reliable results, providing an accurate 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 B.

The most difficult species to confirm are Northern Leopard Frog, American Bullfrog, and Cope's Gray Treefrog. 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 ARS locations. American Bullfrog calls are often obscured by anthropogenic noise in its low frequency band, and this more southern frog is confirmed only at INDU. 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. These difficult species are nevertheless adequately monitored by the dual survey approach but do have higher false absence rates than other species (Appendix B, Table B2).

Site INDU06 was not monitored in 2018 due to worries of vandalism, and no temperature log was supplied for INDU02 (the closest available temperature log was used for analyses). We recommend re-starting data collection at Site INDU06 to meet the program goal of 10 monitoring sites. We can assist with repositioning the ARS within the same wetland so that the likelihood of vandalism is reduced, or with finding a new monitoring site based on the program site selection criteria and site evaluation data.

All but one of the remaining ARS failed before the target end date of 1 August, presumably due to battery drains. While this did not seem to affect occupancy conclusions, it did reduce the number of detections for late-calling species and this metric may need to be transformed to a proportion of occupied samples for multi-year comparisons. Replacement of aging SM2+ ARS units in 2019 with more efficient SM4 units should resolve battery life issues moving forward.

Clipping (overwhelming of frequency bands into undifferentiated noise that cannot be resolved to species) and presumed static discharge (sharp clicks of high volume) also persist in the data and can make samples impossible to analyze when very loud Spring Peeper choruses obscure everything else. We recommend investigating possible solutions such as programming a lower gain setting or grounding ARS units.

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Appendix A. ARS Samples

No ARS programming errors were evident in 2018; all programmed samples successfully recorded on the days that the recording devices were operational (Figure A1).

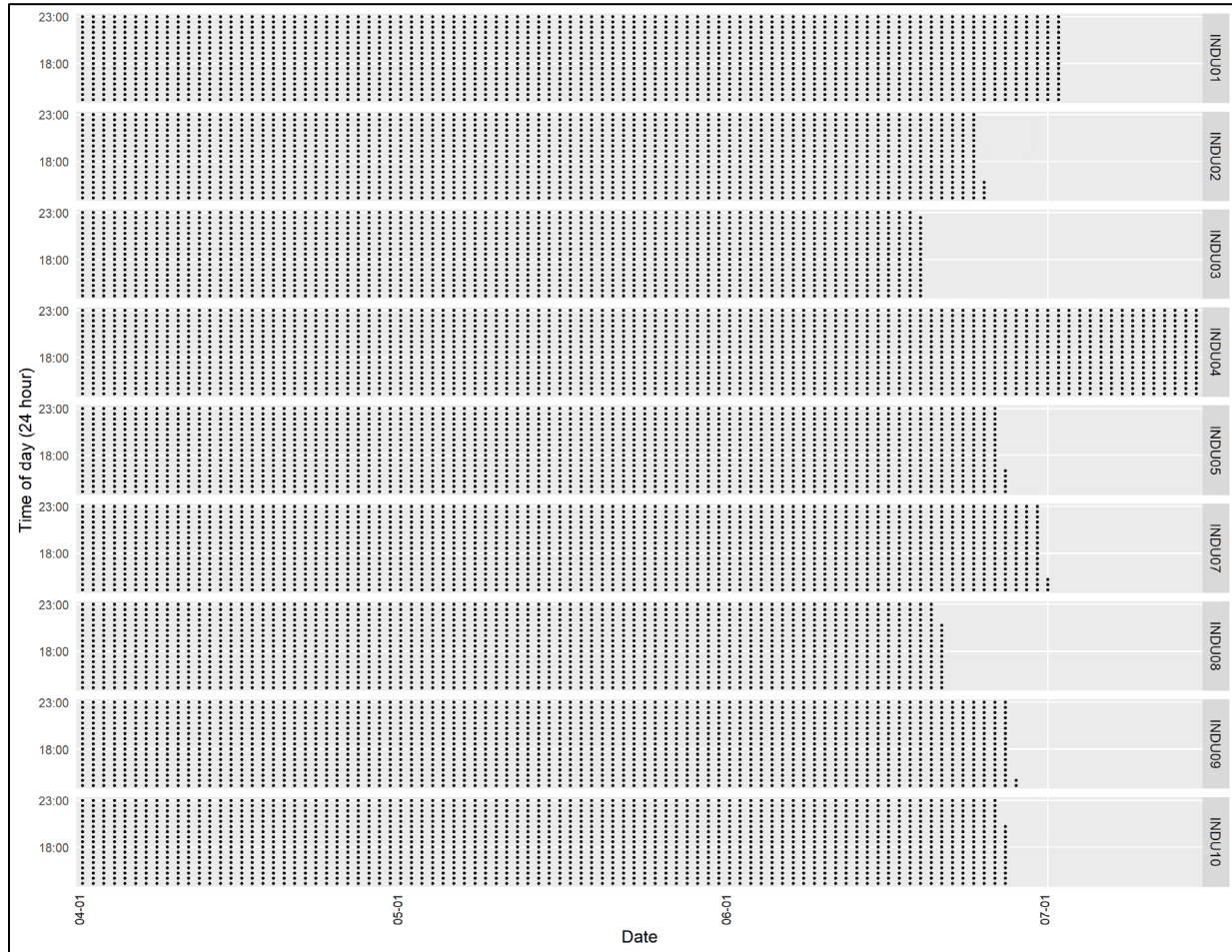


Figure A1. Sampling success for Indiana Dunes National Park during the analysis period of 1 April through 31 July, 2018. Each dot represents a recording.

Appendix B. Automated Detection Error Analysis

The number of samples from all INDU sites with any detection for each species in 2018 is presented in Table B1. For example, Eastern American Toad (ANAM) was detected in 18 of 270 samples by manual scans, with automated detections agreeing in only 10 of these and returning false absences in eight. False presences in the last row of Table B1 do not affect occupancy conclusions, but rather are used for estimating automated detection error rates. These false presences were not entered into the site occupancy record as they were all rejected by the automated detection proofing process.

Table B1. Matrix of number of samples in which species' presence from automated detection algorithms (columns) was confirmed by manual scans (rows) for 30 samples at each of 10 sites (N=270 in 2018).

Manual ID	Auto ID										
	ACBL	ANAM	ANFO	HYSP	LICA	LICL	LIPI	LISY	PSCR	PSMA	None ^a
ACBL	0 ^c	–	–	–	–	–	–	–	–	–	0
ANAM	–	10 ^c	–	–	–	–	–	–	–	–	8
ANFO	–	–	0 ^c	–	–	–	–	–	–	–	0
HYSP	–	–	–	37 ^c	–	–	–	–	–	–	85
LICA	–	–	–	–	7 ^c	–	–	–	–	–	16
LICL	–	–	–	–	–	50 ^c	–	–	–	–	24
LIPI	–	–	–	–	–	–	0 ^c	–	–	–	2
LISY	–	–	–	–	–	–	–	3 ^c	–	–	1
PSCR	–	–	–	–	–	–	–	–	134 ^c	–	17
PSMA	–	–	–	–	–	–	–	–	–	6 ^c	9
None ^b	0	8	0	0	0	4	0	0	0	19	2260 ^c

^a The 'none' column represents the number of samples with a manual detection with no automated detection.

^b The 'none' row represents the number of samples with an automated detection with no manual detection.

^c Indicates the number of samples where both methods agreed the species was present (also with a green background).

We assessed automated detection rates by correcting results from 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). Commission error rates will be utilized as correction factors when comparing the number of samples with detections at each site across years for tracking trends in abundance (the number of putative automated detections will be reduced by this amount annually). Correction factors are derived from Table B2, where error rates are calculated by comparing results from automated detections and manual scans on the same 30 samples per site.

In 2018 commission (false presence) error rates returned by the automated detection process were 0% for most species. Low commission error rates were returned for Eastern American Toad (ANAM; 3.17%) and Green Frog (LICL; 2.04%). Commission error was higher for Boreal Chorus Frog (PSMA) at 7.45%. No commission errors enter into site occupancy statistics, as they are rejected by

the proofing process. Omission (false absence) error rates were variable in 2018 with some species harder for the algorithms to detect than others. Note that as calling intensity increases (more frogs present) omission error also increases as algorithms often cannot identify individual calls in noisy choruses. In these conditions algorithms almost always detect the species at the site later in the night as calling intensity diminishes with falling temperatures; hence, large sample sizes are important. Omission error is addressed in long term trend analysis models as a false absence rate.

Table B2. Rates of commission, omission, and agreement for automated algorithm results from 30 samples proofed manually at each site (N=270 in 2018). Commission = false presence, Omission = false absence, Agree = correct result.

Species ^a	Commission ^b	Omission ^c	Agree (present) ^d	Agree (absent) ^e
ACBL	0.00	0.00	0.00	100.00
ANAM	3.17	44.44	55.56	96.83
ANFO	0.00	0.00	0.00	100.00
HYSP	0.00	69.67	30.33	100.00
LICA	0.00	69.57	30.43	100.00
LICL	2.04	32.43	67.57	97.96
LIPI	0.00	100.00	0.00	100.00
LISY	0.00	25.00	75.00	100.00
PSCR	0.00	11.26	88.74	100.00
PSMA	7.45	60.00	40.00	92.55

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

^b Commission = percent of samples with any putative automated species detection which was not confirmed by manual survey results (false presence rate).

^c Omission = percent of samples without any putative automated species detection which did have manual survey detections (false absence rate).

^d Agree (present) = percent of samples with manual detections that automated surveys also detected, i.e., agreement on species' presence.

^e Agree (absent) = percent of samples without manual detection that automated surveys agreed with.

Appendix C. Cumulative Data Collection Results.

Data collection has been consistently late across years due to the logistics of deploying equipment in early spring (Figure C1). We recommend deploying ARS several months early on a delayed start, in autumn or winter. The network office can provide the appropriate programming. This will require a battery change mid-season (ca. early to mid-June) by a technician familiar with powering down the ARS, changing batteries, re-starting the ARS, and performing a check status operation to ensure proper functioning at that time. It is always a good idea to carry spare blank SD cards when checking units in case card corruptions are encountered (check status operation returns ERROR, EMPTY, or DIRTY messages). Whenever cards are replaced, new cards should be formatted in the ARS before the programming is started, and old cards should be sent to the network office (with a completed mid-season check form) for data retrieval.

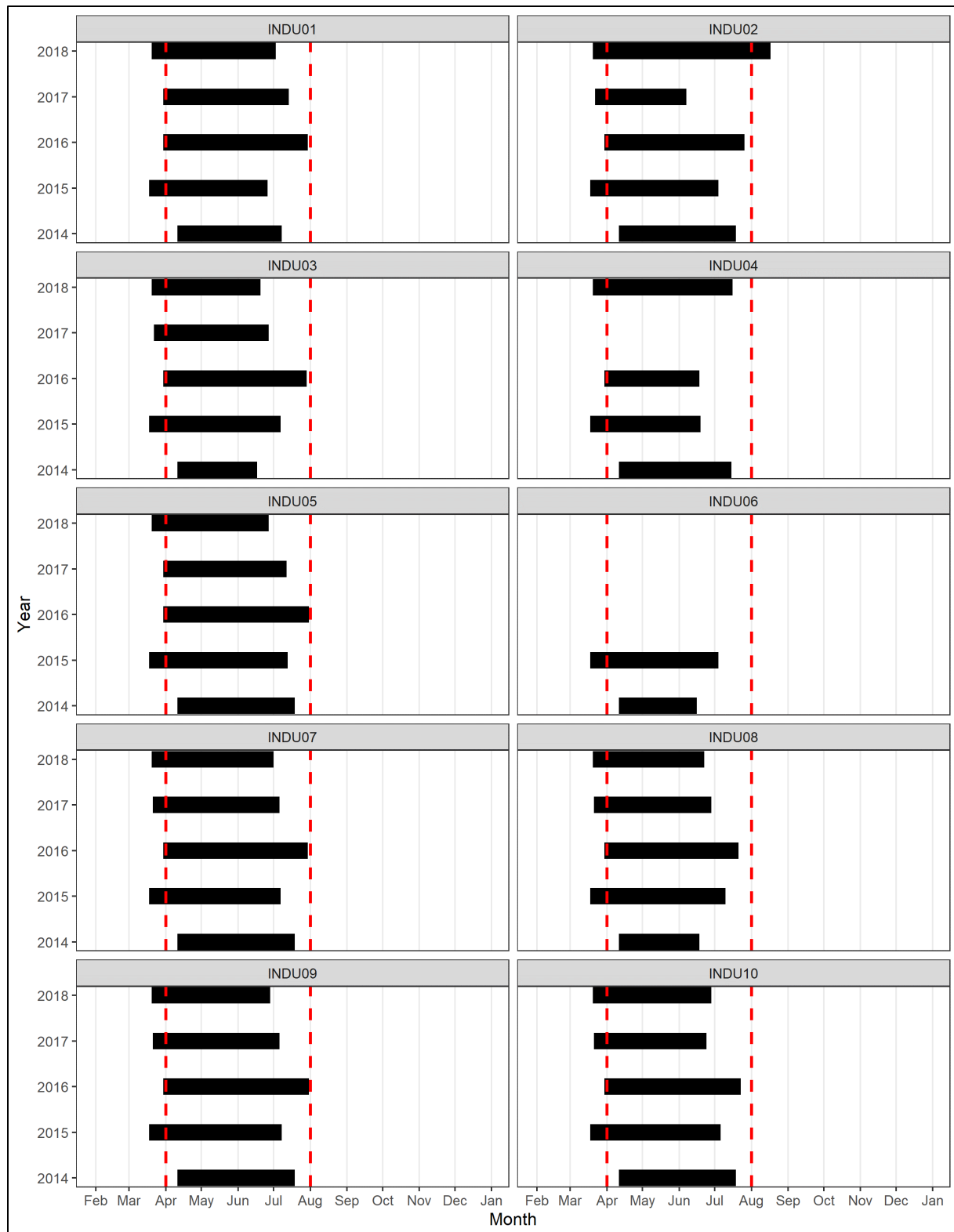


Figure C1. Successful data collection periods are shown for each site in each year, 2014–2018. Red lines indicate the start and end of the targeted calling season.

Appendix D. Cumulative Occupancy Record.

The multi-year occupancy record (Figure D1) provides preliminary site occupancy trends. 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.

Eastern American Toad (ANAM), Treefrog spp. (HYSP), Green Frog (LICL), and Spring Peeper (PSCR) were consistently present at most sites in most years. The occupancy record for rarer and/or harder to detect species is less consistent. Note that in the initial reporting years Chorus Frog spp. was denoted as Western Chorus Frog (PSTR, *Pseudacris triseriata*) based on geography, and carried thus into 2017 reporting. However, more recent range evaluation based on genetics now suggests that Chorus Frog spp. at INDU are actually Boreal Chorus Frog (PSMA, *Pseudacris maculata*; Powell et al. 2016). Therefore we have changed prior year species determinations to Boreal Chorus Frog. This determination should not be considered definitive until genetics of the local INDU populations might be completed.

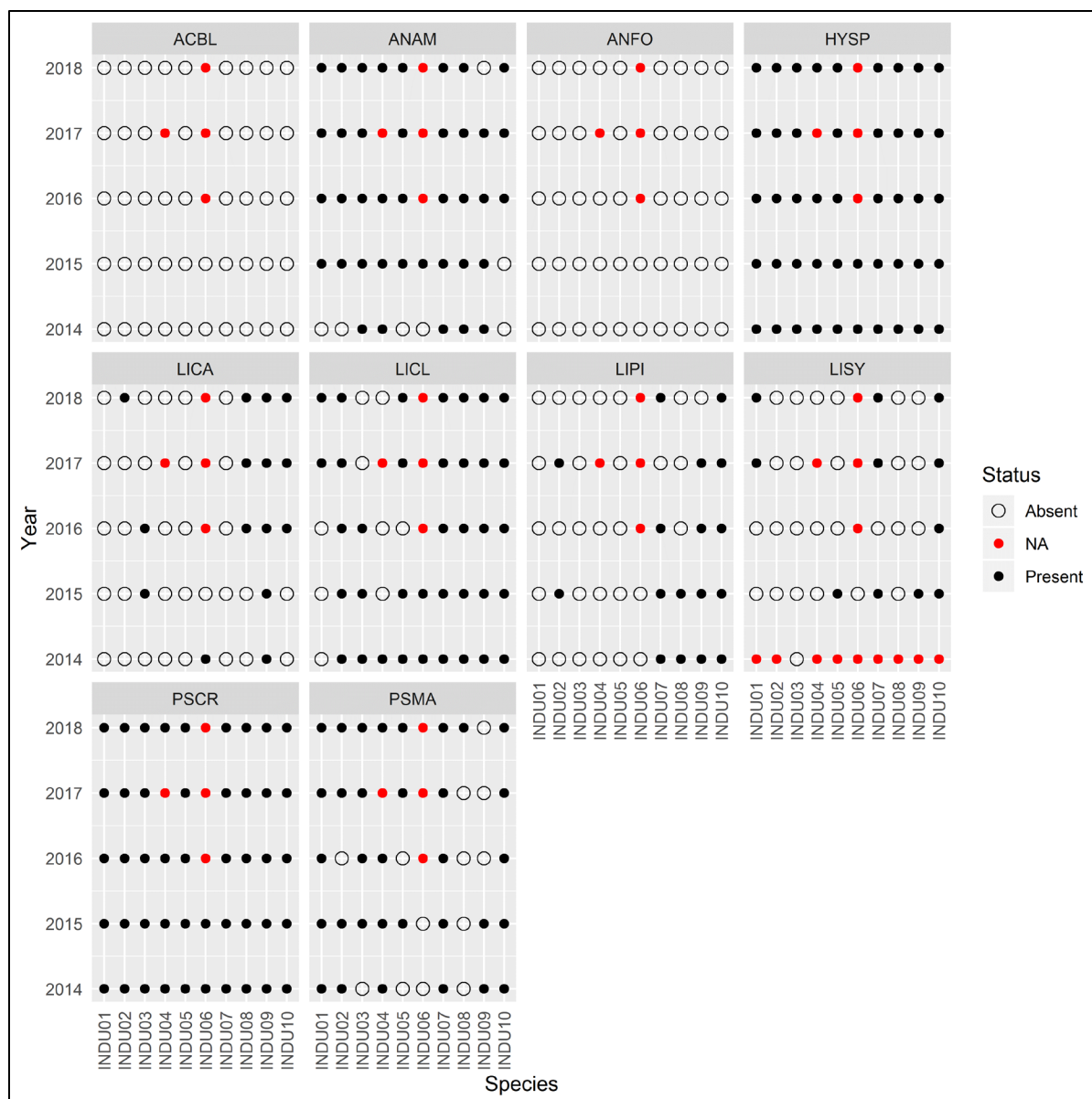


Figure D1. Cumulative occupancy record for each species and site at INDU since 2014. Black dots indicate occupancy, hollow circles indicate putative absence, red dots indicate the sampling was insufficient to draw any occupancy conclusion.

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