

Amphibian Monitoring in the Great Lakes Inventory and Monitoring Network: 2016 Annual Report

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The National Park Service Great Lakes Inventory and Monitoring Network (Network) began implementing an amphibian monitoring protocol at national park units across the Great Lakes region based on automated acoustic monitoring in 2013 (Casper and Beever 2013). The Network developed a prioritized list of indicators, termed 'Vital Signs,' for monitoring long-term ecosystem health in nine Network units in the Great Lakes ecoregion (Route 2004). This amphibian monitoring protocol is one of several protocols that the Network intends to implement under the umbrella of an overall monitoring plan (Route and Elias 2007). In 2013 three parks participated by selecting ten sites and deploying Automated Recording Systems (ARS) at each site per the approved protocol (Casper and Beever 2013): Indiana Dunes National Park (INDU), Pictured Rocks National Lakeshore (PIRO), and Sleeping Bear Dunes National Lakeshore (SLBE). In 2014 two additional parks participated with ten sites each: Apostle Islands National Lakeshore (APIS), and Mississippi National River and Recreation Area (MISS). In 2015 two additional parks participated with ten sites at Isle Royale National Park (ISRO), and six sites at Grand Portage National Monument (GRPO). This report summarizes 2016 results for the program. In addition, the protocol was revised in 2016 and Version 2.0 is now available from the Network office (Casper *et al.* 2016).

Highlights: Wood Frog was documented from one site at MISS. Prior to 2016 this species was only assumed present, without confirmed documentation. It is very rare at MISS and often disappears from urban settings.

1. Methods

Digital acoustic data, data forms, and photographs were archived at each Park and at the Network office (ca. 1.3 TB).

1.1 Sampling Strategy

Site selection, equipment, programming, and study design are detailed in Casper *et al.* (2016). In 2016, 66 ARS were deployed, ten at each Park except six at GRPO. All Parks duplicated 2015 deployments. Equipment and data retrieval were handled by Park and Network staff.

1.2 Recognizer Development

To date we have developed ten recognizers utilizing species recordings obtained from ARS deployed on this and other western Great Lakes area projects. This process and results are described in (Casper *et al.* 2016).

1.3 Data Analysis

Data contained on SD cards from each ARS unit were delivered to the investigators and examined for completeness, including identifying "empty" files indicating equipment failures (see Casper *et al.* 2016 for procedures). Digital audio recordings are site, time, and date stamped within file names. For each site we received varying numbers of samples (a sample is a 5-minute digital audio recording), along with a *.TXT file containing date and time stamped internal temperature logger data. External air temperature logger data were also usually available as *.HOBO files, which were exported to Excel format and merged with recognizer output results on matching date/time stamps. We performed automated analyses of all post-sunset samples from each site, from the date of ARS deployment through July 31 (per Casper *et al.* 2016). Automated analyses utilized recognizers for 12 species: Blanchard's Cricket Frog (*Acris blanchardi*), Spring Peeper (*Pseudacris crucifer*), Chorus Frogs (*Pseudacris maculata* and *P. triseriata* combined), Treefrog (*Hyla chrysoscelis* and *H. versicolor* combined), American Toad (*Anaxyrus americanus*), Northern Leopard Frog (*Lithobates pipiens*), Pickerel Frog (*Lithobates palustris*), Green Frog (*Lithobates clamitans*), American Bullfrog (*Lithobates catesbeianus*), and Wood Frog (*Lithobates sylvaticus*). Recognizer specifications and sample pre- and post- processing filtering routines are detailed in Casper *et al.* (2016) and summarized in Table 1.

We then subset 30 samples from each site for manual analyses (per Casper *et al.* 2016), which served to detect the remaining two species: Fowler's Toad (*Anaxyrus fowleri*), and Mink Frog (*Lithobates septentrionalis*), and to differentiate between Cope's (*Hyla chrysoscelis*) and Gray (*H. versicolor*) Treefrogs. Chorus Frog species assignments were determined by geography, as these species cannot be separated by call, but are not sympatric. Manual scan samples were limited to those between the date of the first Spring Peeper calling and July 31, and to those samples with air temperatures at or above 40°F.

2. Results

2.1 Recognizer File Development

Table 1 provides current recognizer parameters. In 2016-17 recognizers were developed for Fowler's Toad (ANFO) and Pickerel Frog (LIPAA) and tested on data from four non-Network sites and three non-Network sites, respectively, from which training data were obtained. The recognizers were also tested on 2015 INDU and SLBE data, but neither species was detected. The false positive rate for ANFO ranged from 0 to 0.12 with no additional filtering required when only samples between the first and last detections were considered. The false positive rate for LIPAA was 0.57 when only samples between the first and last detections at each site were considered. This rate was reduced to values as low as 0.08 by filtering for parameters such as quality and score. More testing on data that contains Pickerel Frog calls is recommended for determining the best filtering strategy for this recognizer.

Mink Frog recognizer development remains problematic due to overlap of acoustic characteristics with Green Frog and background noise such as rain. Currently Mink Frogs are detected reliably only in manual scans, and we recommend pursuing machine learning techniques for automated recognition of this species.

2.2 Data Analysis

Data collection results are presented in SOP 7 Form 1. All Parks deployed ten units except GRPO with six units. Deployment dates and data collection success varied by park, with critical variables summarized in Table 2.

Table 2: Data Collection Summary

Park	Sampling Start	Equipment Issues*	Air Loggers	Photos
APIS	April 14	APIS04, APIS11	All sites	All sites
GRPO	May 18-19	GRPO06	All sites	None
INDU	March 29	INDU03, INDU06	9 sites	9 sites
ISRO	May 27 - June 16	None	None	None
MISS	March 29 - April 6	MISS03, MISS04, MISS06, MISS10	All sites	All sites
PIRO	April 19-26	PIRO01, PIRO07, PIRO08, PIRO10	None	None
SLBE	March 18 - April 13	SLBE04	All sites	All sites

* - missing or empty files indicating equipment problems, including one channel non-functioning (thorough testing recommended after reviewing Form 1 notes)

Auto-detection results are provided in SOP 7 Form 2. First and last verified detections for each species, and counts of auto-detections and samples, are provided for each site.

Manual scanning results for 30 samples at each site are provided in SOP 7 Form 3, with notes on uncertainties and equipment issues. At least one instance of each species at each site was verified by a second observer.

Occupancy results are provided in SOP 7 Form 4. These data summarize site occupancy for each species, and compare results of automated vs. manual acoustic surveys. Twenty species/site occupancy determinations were made only by manual surveys, vs. 31 species/site occupancy determinations obtained only by automated surveys (16 of which were American Toad). Remaining site occupancy determinations were concordant between both survey methods.

Blanchard's Cricket Frog (*Acris blanchardi*): In 2016 Blanchard's Cricket Frog was detected at only one site, by both methods (MISS07). MISS however has confirmed other non-Network sites occupied by this species through an independent study. They were present historically at INDU but have not been detected there on this study.

Eastern American Toad (*Anaxyrus americanus*): For Eastern American Toad, in 2016 automated surveys returned false negatives on only one site, whereas manual surveys returned false negatives on 16 sites. This is mainly due to the infrequent calling of this species, where the 30 samples selected for manual surveys often by chance do not include samples with calling toads.

Fowler's Toad (*Anaxyrus fowleri*): This species was not detected by either method and appears to be absent from all monitored sites. Only two parks have potential for this species occurrence (INDU and SLBE).

Cope's Gray Treefrog (*Hyla chrysoscelis*): The Treefrog recognizer does not distinguish between *Hyla chrysoscelis* and *H. versicolor*. However, manual proofing of automated scans does distinguish these species. In 2016 there were no automated detections of Cope's Gray Treefrog (in the samples proofed), but manual surveys detected this species at three MISS sites. Of those three sites, the automated survey also detected Treefrog spp. at one of them (MISS01), but in a different site sample (both species were considered present at this site in manual surveys, and later determined to be present in other auto-detected samples as well). By chance, all automated detections of the species complex at MISS01 were in samples that were not selected for manual scanning. Manual detections at MISS09 and MISS10 were sites where automated surveys missed the species complex entirely. At these sites the calls were faint, distant, and better heard/visible on channel 2 (automated surveys were performed on channel 1). In sum, the automated scans returned false negatives at three sites, two through non-detection (MISS09, MISS10), and one through human error (failed to distinguish two species calling together at MISS01 last detection sample).

Gray Treefrog (*Hyla versicolor*): The Treefrog recognizer does not distinguish between *Hyla chrysoscelis* and *H. versicolor*. However, manual proofing of automated scans does distinguish these species, as do manual surveys. In 2016 this species was detected only by manual surveys on four sites (GRPO03, GRPO04, MISS02, PIRO10), and only by automated surveys on two sites (MISS06, PIRO06). At the four sites where this species was detected only manually, all calls were faint and often best heard/seen on channel 2 (right side of ARS). At MISS06 a single frog

called a single night (not a night selected for manual scanning), and at PIRO06 all automated detections were from samples not selected for manual scanning. In sum, manual surveys returned false negatives at two sites (MISS06, PIRO06), and automated surveys returned false negatives at four sites (GRPO03, GRPO04, MISS02, PIRO10). The two methods agreed on the remaining sites, with occupancy detected at 39 sites by both methods.

American Bullfrog (*Lithobates catesbeianus*): In 2016 American Bullfrog was detected at only four sites (INDU03, INDU08, INDU09, INDU10), by both survey types. It is considered absent from all other parks except possibly APIS and SLBE.

Green Frog (*Lithobates clamitans*): In 2016 Green Frog was detected by both survey types at 48 sites. An additional site (GRPO05) was confirmed only through manual surveys, and three additional sites only by automated surveys (GRPO04, MISS05, SLBE04). In sum, manual surveys returned false negatives at three sites (GRPO04, MISS05, SLBE04), and automated surveys returned false negatives at one site (GRPO05).

Pickerel Frog (*Lithobates palustris*): This species was not detected by either method and appears to be absent from all monitored sites. Only five parks have potential for this species (APIS, INDU, MISS, PIRO, SLBE) based on its known range (Powell et al. 2016), however, it is very unlikely to occur at four of these due to range limits and habitat suitability (APIS, INDU, MISS, PIRO). We recommend additional survey effort at SLBE to obtain better confidence in presence/absence in this park, by visual shoreline searches and roaming call surveys (Casper & Anton 2009).

Northern Leopard Frog (*Lithobates pipiens*): In 2016 Northern Leopard Frog was detected by both survey types at only seven sites, all at MISS (MISS01, MISS03, MISS04, MISS05, MISS06, MISS08, MISS09). An additional site (MISS07) was confirmed only through manual surveys, and three additional sites only by automated surveys (INDU07, INDU09, INDU10). In sum, manual surveys returned false negatives at three sites (INDU07, INDU09, INDU10), and automated surveys returned false negatives at one site (MISS07). ISRO sites should be treated as not surveyed, as ARS units were deployed after the breeding season ended. This species appears to be poorly detected by this ARS protocol, as it is known to be present at all parks except ISRO (Casper 2008). It has a quiet call which carries poorly, and calls infrequently and for short durations. Hence it may be present in many monitored wetlands but go undetected because calls are beyond the range of the microphones, or are masked by noise (i.e., traffic, trains, planes, thunder, rain, other frog choruses, etc.).

Mink Frog (*Lithobates septentrionalis*): In 2016 Mink Frog was detected by manual surveys at only two sites (GRPO01, ISRO03). A recognizer for automated surveys for this species has not been developed. Its quiet call is very difficult to distinguish from Green Frog and from background noises such as rain.

Wood Frog (*Lithobates sylvaticus*): In 2016 Wood Frog was detected by both survey types at 14 sites in three parks (APIS, PIRO, SLBE). An additional two sites were confirmed by automated surveys only (INDU10, PIRO06; which samples were not manually scanned), and three more sites were confirmed only through manual surveys (MISS05, PIRO04, PIRO08). In sum, manual surveys returned false negatives at two sites (INDU10, PIRO06), and automated surveys returned false negatives at three sites (MISS05, PIRO04, PIRO08). ISRO sites should be treated as not surveyed, as ARS units were deployed after the breeding season ended. The early and episodic breeding of this species makes early deployment of ARS important for survey success.

Spring Peeper (*Pseudacris crucifer*): In 2016 Spring Peeper was detected by both survey types at 54 sites, including sites at all parks except MISS. One additional site was confirmed by automated surveys only (SLBE08; at which site one frog was calling very faint). In sum, manual surveys returned a single false negative (SLBE08), and automated surveys returned no known false negatives.

Chorus Frogs: The Chorus Frog recognizer does not distinguish between Boreal Chorus Frog (*Pseudacris maculata*) and Western Chorus Frog (*P. triseriata*). However, these species are not sympatric and are assigned to species by geography (Powell et al. 2016), with *P. triseriata* at INDU and SLBE, and remaining parks assigned to *P. maculata*. At PIRO, species assignment is problematic, with the park in a range gap, and would need to be resolved if this species is ever detected there. ISRO sites should be treated as not surveyed in 2016, as ARS units were deployed after the breeding season ended. In 2016, Boreal Chorus Frog was detected only by manual surveys at five sites in MISS (3, 5, 6, 7, and 8). Boreal Chorus Frog calls are often drowned out by Spring Peeper, so false negative rates may be higher than is realized. In 2016, Western Chorus Frog was detected by automated surveys at five sites in INDU (1, 3, 4, 7, and 10), one of which (INDU04) also had a manual detection. Manual surveys therefore returned false negatives at four sites, demonstrating the value of the large sample sizes in automated scanning.

3. Discussion

While we obtained good results from testing the new Pickerel Frog and Fowler's Toad recognizers on non-Network sites, they cannot be further evaluated at this time owing to no Network sites having recorded these species. We recommend that survey effort for these species be escalated in INDU and SLBE, through human visual and auditory surveys at multiple sites with repeated visits, and potentially with additional acoustic automated surveys, to discover occupied sites. If occupied sites are found, they may be considered for supplemental monitoring with additional ARS where feasible. Beach pan sites (West beach) are known to have Fowler's Toad at INDU (personal communication Mark Roth, 2017), but deploying an ARS there would be problematic due to high visitor use and the difficulty of hiding and securing ARS in open dune habitat. This site may therefore be appropriate to monitor through a Citizen Science program.

Discordance between survey method results (Form 4, automated vs. manual) is mostly attributable to weak signals (distant calls) and obscuring noise (both natural and anthropogenic), and sometimes by the manual survey having access to the second channel where confirmations may be easier (automated surveys only scan one channel). These factors, and in some cases the rareness of species calling, continue to introduce false negatives into the data set, which can be quantified in periodic occupancy modeling. We believe that false positives for site occupancy are negligible after proofing, and would be entirely due to human error, which is rare given the two observer concurrence requirement. The most difficult to confirm species are Mink Frog and Cope's Gray Treefrog. Mink Frog calls are quiet, often obscured by noise or the calls of Green Frog, and often hard to distinguish from truncated Green Frog calls and natural or electronic interference sounds. Cope's Gray Treefrog calls can be distinguished from Gray Treefrog calls by pulse rates (Jaslow & Vogt 1977), but we find that this is not always possible unless a very clear recording is obtained with little background noise. In these cases we still must rely on qualitative call interpretation. We therefore make two recommendations. First, pool Treefrog data and analyze trends as a species complex, without determining species at sites. Second, follow-up on all Mink Frog and Cope's Gray Treefrog detections with in-hand confirmation through field surveys, to provide final quality assurance.

Data collection issues in 2016 were minimal (Forms 1, 4). We did not receive temperature logs or photos from ISRO or PIRO. Logistical problems were limited to ISRO, where all Song Meters were deployed too late for adequate sampling of early callers (Wood Frog, Boreal Chorus Frog, and Northern Leopard Frog). We recommend that ISRO switch to a permanent deployment strategy, where ARS are left in place year-round. Batteries should be changed in the fall (September/October), at which time data cards are retrieved and swapped with new cards, containing programming for a delayed start to an appropriate late April or early May start date. Then a second visit will be required in June or July to change batteries again (testing should determine when, consult with the Network). The fall data retrieval will also need to supply data to the Network in a timely manner in order for winter data analysis to be completed.

Blank files (which record a file the same size as good recordings but without sound) were found in no discernible pattern. We suspect these are due to microphone failure, and continue to recommend that microphones be tested each year before deployment and replaced as needed, and that two microphones continue to be attached to each unit to provide a backup channel. Protecting microphones with hardware cloth cages is recommended at sites where animal damage is occurring. We also continue to recommend tracking microphones and recording microphone numbers on the deployment form. This allows for tracking recording failures against individual microphones. Corresponding labels should be added to the ARS housing at the microphone ports to make it easy to record the correct port (Channel 1, Channel 2) when deploying equipment.

From Forms 1 and 3, equipment problems were noted at the following sites, and thorough

testing of this equipment is recommended (both channels; see notes on Forms when trouble shooting). Note that some problems such as missing or empty files may be caused by motherboard or memory problems, or power interruptions.

Equipment problems noted at: APIS04, APIS11, GRPO06, INDU01, INDU03, INDU05, INDU06, INDU07, ISRO02, ISRO03, ISRO05, ISRO06, ISRO07, ISRO09, MISS03, MISS04, MISS06, MISS10, PIRO01, PIRO04, PIRO05, PIRO07, PIRO08, PIRO09, PIRO10, SLBE04.

Table 3 summarizes species status by park. No new species records were added in 2016, but Wood Frog was a notable find at MISS, the first detection for this study and the first verification at the park.

4. Literature Cited

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5. Tables

Table 1:	Recognizer Parameters
Table 2:	Data Collection Summary
Table 3:	Species Confirmed by Park

6. Appendices

2016 SOP 7 Form 1 - Data collection
2016 SOP 7 Form 2 - Auto-detection verifications
2016 SOP 7 Form 3 - Manual detections
2016 SOP 7 Form 4 - Occupancy Record

Table 1: Recognizer Parameters

Parameters	Cricket Frog	Spring Peeper	Treefrogs	Am. Toad	Fowler's Toad	American Bullfrog	Green Frog	Pickereel Frog	Northern Leopard Frog	Wood Frog	Chorus Frogs
Sample Rate (Hz)	16000	16000	16000	16000	8000	4000	8000	8000	8000	8000	8000
FFT Size	256	256	256	128	256	256	256	64	256	256	256
FFT Overlap	1/2	1/2	7/8	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
Frequency Minimum	31	40	11	12	51	12	9	64	16	18	103
Frequency Range	45	16	36	8	25	27	94	15	41	60	128
Background Filter	1s	1s	1s	1s	1s	1s	1s	1s	1s	1s	1s
Maximum Syllable (ms)	48	336	600	1008	383	1088	16	16	240	80	528
Maximum Gap (ms)	200	144	920	156	657	1088	224	600	288	848	368
Maximum Song (ms)	8648	400	2288	6844	4356	25824	832	108	25840	2816	22704
Dynamic Range (dB)	20	25	20	15	20	20	20	13480	21	20	20
Maximum Complexity	32	44	43	32	32	32	32	32	32	32	30
Maximum Resolution	6	27	9	6	6	9	6	6	6	9	4
Cross Training	85.32 ± 4.75%	78.17 ± 9.37%	74.15 ± 4.38%	77.48 ± 5.03%	71.09 ± 6.49%	66.79 ± 4.19%	76.24 ± 6.42%	77.14 ± 10.81%	74.54 ± 4.24%	68.70 ± 5.84%	77.35 ± 6.37%
Total Training	87.16 ± 4.13%	83.58 ± 8.22%	74.06 ± 4.83%	77.39 ± 4.17%	73.32 ± 3.91%	70.85 ± 4.19%	75.88 ± 5.67%	76.88 ± 9.15%	75.88 ± 2.34%	72.88 ± 4.76%	78.53 ± 5.51%

Table 1: Recognizer Parameters

Parameters	Cricket Frog	Spring Peeper	Treefrogs	Am. Toad	Fowler's Toad	American Bullfrog	Green Frog	Pickereel Frog	Northern Leopard Frog	Wood Frog	Chorus Frogs
Training Files	2 files; 7 annotations	2 files; 30 annotations	4 files; 38 annotations	3 files; 17 annotations	3 files; 15 annotations	6 files; 23 annotations	3 files; 63 annotations	3 files; 12 annotations	5 files; 21 annotations	3 files; 14 annotations	4 files; 19 annotations
Annotations	A series of 4 to 7 clicks between 2500 & 4000 Hz	A single peep between 2000 & 4000 Hz	A 0.2 to 0.7 sec trill between 600 & 3000 Hz	A 5 to 9 sec trill between 1600 & 2250 Hz	A 0.5 to 3 sec buzzy whine between 1600 & 2300 Hz	3 to 6 syllables (strums) between 200 & 600 Hz	A 1 - 1.4 sec single syllable ('gung') between 300 - 2000 Hz	A 0.7 to 1 sec snore between 700 & 2500 Hz	A 1.5 to 3.5 sec series of knocks between 500 & 1600 Hz	2 to 3 single chirps between 500 & 2500 Hz	A 0.7 - 1.2 sec ascending trill between 3200 & 4000 Hz
Post-Processing	None	None	Count individual syllables in call to distinguish between species*	Excel Filter: Dur> 5 sec	None	Excel Filter: Dur>4.5 sec, Score>55	Excel Filter: Quality>30, Score>60	Excel Filter: Score>60	None	None	Ascertain species by location; Boreal Chorus Frog - Excel Filter: Score>65

*- HYCH: 41-71 syllables/sec; HYVE: 14 - 29 syllables/sec

Table 3: Species Confirmed by Park (P = Present, A = Absent)*

Species	Recognizer File Complete?	Recognizer in Progress?	Comments	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
American Toad	Yes	NA	Complete	P	P	P	P	P	P	P	P	P
Fowler's Toad	Yes	NA	Complete	A	A	P	A	A	A	A	A	A
Blanchard's Cricket Frog	Yes	NA	Complete	A	A	P	A	P ¹	A	A	A	A
Cope's Gray Treefrog	Yes	NA	Treefrog recognizer does not distinguish between species	P ²	A	P	A	P	A	P	A	A
Gray Treefrog	Yes	NA	Treefrog recognizer does not distinguish between species	P	P	P	P	P	P	P	P	P
Spring Peeper	Yes	NA	Complete	P	P	P	P	P ³	P	P	P	P
Western Chorus Frog	Yes	NA	Chorus Frog recognizer does not distinguish between species	A	A	P	A	A	A ⁴	A	P	A
Boreal Chorus Frog	Yes	NA	Chorus Frog recognizer does not distinguish between species	P ³	P	A	P	P	A ⁴	P	A	P
American Bullfrog	Yes	NA	Complete	A ⁵	A	P	A	A ⁵	A ⁵	P	P	A
Green Frog	Yes	NA	Complete	P	P	P	P	P	P	P	P	P
Mink Frog	No	No	Cannot be developed due to software limitations.	P	P	A	P	A	P ⁵	P	A	A
Pickerel Frog	Yes	NA	Complete	A	A	A ³	A	A	A	P	P	A
Northern Leopard Frog	Yes	NA	Complete	P	P	P	A	P	P	P	P	P
Wood Frog	Yes	NA	Complete	P	P	P	P	P	P	P	P	P

* - Note that all species are surveyed for in manual scans, but automated analyses are restricted to parks within a species potential range.

1 - Species confirmed within park in 2015.

2 - Acoustic voucher now available from APIS10.

3 - Apparently extirpated from park, but include in analyses in case it reappears.

4 - Records from park are rejected, without vouchers (Casper et al. 2015).

5 - Records from park are questionable, without vouchers.