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Using Passive Acoustic Monitoring to Assess the Distribution of a Rare Frog in the NJ Meadowlands

Michael J. Turso[1*]

Abstract - The New Jersey Meadowlands are a diverse mosaic of tidal and freshwater habitats encompassed by an urban landscape that is home to hundreds of species across taxa throughout the year. However, among amphibians, *Rana kauffeldi* (Atlantic Coast Leopard Frog) is the last remaining frog species known to occupy freshwater habitats in the Meadowlands. No standardized surveys have been conducted on this newly described species within the district since 2013. Because of the abundance of anthropogenic noise in the area, the efficacy of acoustic recording units (ARUs) to conduct frog surveys was in question. Therefore, the distribution of Atlantic Coast Leopard Frog in the Meadowlands was assessed using ARUs. These surveys found that the species' general distribution was unchanged over the last decade. ARUs were highly effective for detecting the species despite constant background noise.

Introduction

Rana kauffeldi Feinberg (Atlantic Coast Leopard Frog) is a recently discovered frog species found in freshwater and coastal ecosystems throughout northern and central New Jersey, parts of southern New York and Connecticut, and eastern Pennsylvania, as well as coastal Delaware, Maryland, and Virginia (Feinberg et al, 2014, Schlesinger et al. 2018). As far as is known, the species is highly range-restricted and is the only frog species currently inhabiting the New Jersey Meadowlands (Kiviat 2011).

Passive surveys for calling amphibians were conducted in the Meadowlands District (Fig. 1) in April and May of 2006, well before the species was described (Kiviat 2011). These occurred at Upper Penhorn Marsh in North Bergen and at Teterboro Airport Woods in Moonachie (Kiviat 2011). Positive detections of what were assumed to be *Rana sphenocephala* (Cope) (Southern Leopard Frog) at both of those sites were yielded (Cope 1889, Kiviat 2011). After the discovery of Atlantic Coast Leopard Frog, further study revealed that the isolated Meadowlands populations were in fact this newly described species (Feinberg et al. 2014, Kiviat 2011, Newman et al. 2012). Additional surveys in 2012 and 2013 yielded positive detections of this species at both of these sites as well as in the Lower Snake Hill Marshes (Feinberg 2015, Kiviat 2012), but no standardized surveys have been conducted since then to reassess the presence/absence of this species across the Meadowlands.

Due to safety concerns, it is not feasible to conduct surveys at night in the Meadowlands except for under special, controlled circumstances. Therefore, alternative methods must be employed to understand the region's nocturnal wildlife. Passive acoustic monitoring is a relatively novel method of surveying wildlife without direct observations. Acoustic recording units (ARUs) are deployed and programmed to capture all sounds during specified time intervals. The data are then downloaded and analyzed using a variety of software. This method allows for safer and more effective nocturnal audio detections.

Reassessing the presence/absence of Atlantic Coast Leopard Frogs in the Meadowlands is critical to understanding vocal wildlife habits in the region. This information will also

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contribute to knowledge of this novel species' distribution and population trends overall. Much has changed in the Meadowlands since Spring 2012, from both an ecological and an anthropogenic standpoint. The most notable ecological change is the inundation of saltwater into freshwater sites by Hurricane Sandy in October 2012. Subsequent surveys the following Spring found Atlantic Coast Leopard Frogs at all the same sites as in 2012 (Feinberg 2015). Anthropogenic changes in the last 10 years that may have impacted this population include newly filled wetlands, increased density of homes in residential areas, and infrastructure updates. Confirming the lasting presence or absence of this species at previous study sites over a 10-year period and evaluating new sites may have major conservation and restoration implications on local scales.

The overall conservation status of this species is largely unknown; however, a 2017 assessment listed Atlantic Coast Leopard Frog as declining in New York and Connecticut and stable in New Jersey (Schlesinger et al. 2018). It is listed as 'Least Concern' by the International Union for Conservation of Nature (IUCN), but faces many threats, particularly in urbanized areas, given its specialized habitat requirements and overall small range (Schlesinger et al. 2018). The data collected during this study may be used to inform future status assessments. Therefore, the primary research objectives of this study were (1) to reassess the presence/absence of Atlantic Coast Leopard Frog at Meadowlands sites with previously documented positive detections and non-surveyed sites with suitable habitat, and (2) to determine if automated sound classification software, paired with passive acoustic monitoring, provides an effective method for surveying and detecting calling frogs in urban wetland complexes.
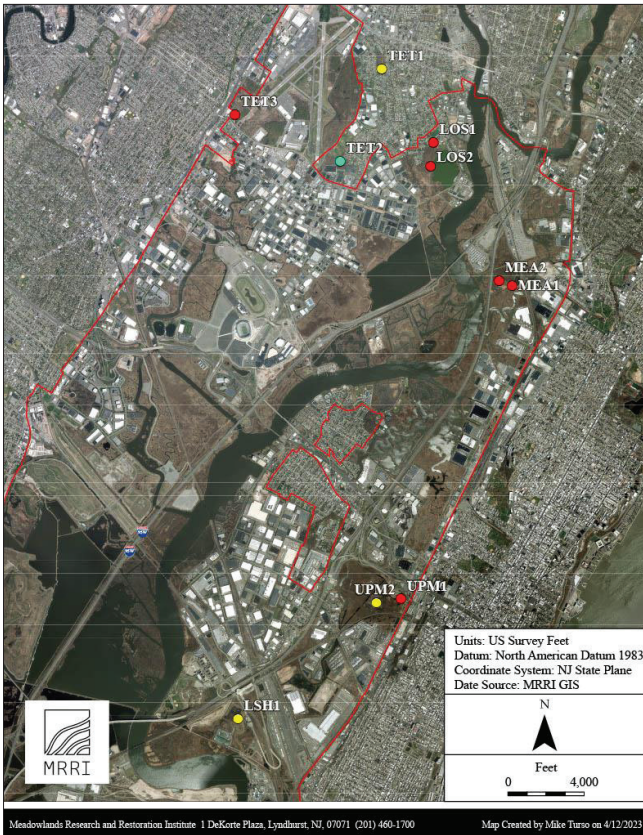

Figure 1. Map showing the locations of all ARU survey points. Red points indicate a chorus ranking of 0, yellow points indicate a chorus ranking of 1, and the green point indicates a chorus ranking of 2. The red lines show the Meadowlands District boundaries.

Methods

Nocturnal survey accessibility to previous sites has become highly difficult since 2013, due to shifting land ownership and security concerns. Therefore, to collect auditory data at night, ARUs (Wildlife Acoustics Song Meter Mini Bat with Acoustic Microphone Stub) were deployed to passively listen for calling Atlantic Coast Leopard Frogs. They were placed at 2 well-spaced points in Upper Penhorn Marsh, 1 point in Little Snake Hill Marsh, and at 3 points in the publicly accessible woods adjacent to Teterboro Airport (Fig. 1). ARUs were also deployed at 2 points in Meadowlark Marsh in Ridgefield as well as at 2 points in Losen Slote Park in Little Ferry (Fig. 1). These sites are mostly or entirely freshwater and cut off from the tide, making them strong candidates for additional Atlantic Coast Leopard Frog presence in the Meadowlands region.

ARU deployments began in early March 2023 and concluded in late April 2023. This period is generally considered Atlantic Coast Leopard Frog's peak calling season (Kiviat 2012). Three recorders were rotated across all 10 points due to resource limitations. ARUs were deployed ahead of multiple nights with temperatures above 10ºC which became increasingly common as the season progressed. Although the species is not strictly nocturnal, vocalization activity is most common in the evening and early nocturnal hours (Kiviat 2012), so each unit was programmed to record all acoustic sounds between 0 and 12 kHz from sunset until midnight. Recorders were left in their respective locations for up to a week. Data from the recorders were checked once every 1-3 days depending on accessibility to the point.

The acoustic data were sorted and analyzed using Wildlife Acoustics Kaleidoscope Pro's Cluster Analysis feature. Many Atlantic Coast Leopard Frog vocalizations were run through the program with thousands of other sounds captured in the Meadowlands. This process trained the classifier to distinguish between the distinct frog calls and the abiotic and biotic noise abundant throughout this highly urbanized area, which streamlined the process of sorting through the many bird and human sounds at the sites. The widely adopted ranking system described by Brander et al., (2007) Lepage et al., (1997), and Mossman and Hine (1984), was used to quantify the size of a calling frog chorus (Kiviat 2011). The highest rank was listed for each point.

0 = no individuals heard
1 = calls of individuals can be counted separately, with space between calls
2 = calls of individuals are distinguishable, with some calls overlapping
3 = full chorus with calls continuous, overlapping, and too numerous to be counted

If Atlantic Coast Leopard Frog was detected at any given point, that point was not surveyed again. If no vocalizations were detected at any given point over several nights with suitable conditions, that point was given a chorus ranking of 0. Data were quality checked after acoustic analysis to assess the overall efficacy of the methods in light of high levels of urban noise, and to rule out possible false positives and negatives due to such noise or other reasons. To rule out false positives, at least one file containing positive detections from each night was checked to ensure leopard frogs were indeed vocalizing. To rule out false negatives, 60 one-minute files from each site were selected at random and manually assessed to ensure no frogs were calling. The presence/absence and chorus quantification data were illustrated in ArcMap (Fig. 1) and tabulated in Microsoft Excel (Table 1).

Results

Atlantic Coast Leopard Frog vocalizations were detected at 3 out of 5 sites, and 4 out of 10 points (Fig. 1, Table 1). The ARUs detected both the characteristic "chucks" (Fig. 2a) and interspersed "growls" of chorusing individuals (Fig 2b). Abundant anthropogenic noise did not affect the auto classifier's ability to detect frog vocalizations, given that individuals were present and calling. The auto classifier resulted in many false positives, but no false negatives.

The 3 sites with vocalizing Atlantic Coast Leopard Frogs were Upper Penhorn Marsh, Teterboro Woods, and Little Snake Hill Marsh (Fig. 1, Table 1). Chorusing frogs were only detected at 1 of the 2 points at Upper Penhorn Marsh and 2 of the 3 points around Teterboro Woods (Fig. 1, Table 1). Only 1 point was surveyed at Little Snake Hill Marsh. No vocalizations were detected at either of the 2 points at Meadowlark Marsh or the 2 points at Losen Slote Park (Fig. 1, Table 1). Of all the points with positive vocalization detections, only 1 chorus was ranked as 2 and none were ranked as 3. The remaining 3 positive points were ranked as 1.

The first positive vocalization detections came on the evening of 3/17/2023 from TET2, followed by UPM2 on the evening of 3/23/2023. Conditions were suitable for vocalization activity on the majority of nights thereafter, and all other positive detections occurred between 3/24/2023 and 4/10/2023.

Discussion

Points with Atlantic Coast Leopard Frog vocalizations were clustered in 2 areas. The first cluster was in the extreme northwestern area of the Meadowlands around Teterboro Airport Woods (Fig. 1). TET2 was the only point with a chorus ranking of 2 (Fig. 1, Table 1). 2012 surveys ranked the chorus here at 1, suggesting the number of frogs at this point may have increased (Kiviat 2012), but further study is needed to quantify this. This finding could be explained by the increase in vegetation cover at this point compared to the photo provided in Kiviat 2012 (Fig. 3a). What was once a mostly open pool of water is now predominantly covered by *Phragmites australis* (Cav.) Trin. ex Steud (Common Reed) and *Typha* sp. (Cattail). This finding suggests that increased vegetation cover may support Atlantic Coast

Table 1. Chorus ranking data for each ARU survey point with their corresponding deployment and retrieval dates.

Site	Point ID	Deploy Date	Retrieve Date	Chorus Rank
Upper Penhorn Marsh	UPM1	3/16/2023	3/27/2023	0
Upper Penhorn Marsh	UPM2	3/16/2023	3/27/2023	1
Teterboro Woods Area	TET1	3/20/2023	3/23/2023	1
Teterboro Woods Area	TET2	3/16/2023	3/20/2023	2
Teterboro Woods Area	TET3	3/27/2023	4/3/2023	0
Meadowlark Marsh	MEA1	4/4/2023	4/10/2023	0
Meadowlark Marsh	MEA2	4/4/2023	4/10/2023	0
Losen Slote Park	LOS1	3/23/2023	3/27/2023	0
Losen Slote Park	LOS2	3/28/2023	4/3/2023	0
Little Snake Hill Marsh	LSH1	4/4/2023	4/10/2023	1

Leopard Frog vocalization activity, but more research on both local and regional scales is needed. The other point with positive detections in this area was TET1 (Table 1). This small forested wetland contains permanent freshwater pools fed by drainage pipes, each pool being less than 50 square meters in size (Fig. 3b). This suggests that the size of a water body is non-determinant of Atlantic Coast Leopard Frog vocalization activity, though more study is needed. No Atlantic Coast Leopard Frog vocalizations were detected at TET3, which was unexpected given detections at the other Teterboro points. This point, a mostly open pool of freshwater, is only marginally smaller than the TET2 pool, and is covered by tall deciduous trees. However, it is directly adjacent to State Route 17 which is a major highway. Close proximity to this road may discourage Atlantic Coast Leopard Frogs from using this pool for vocalizing and breeding (Bouchard et al. 2009).

The second cluster of vocalization activity was in the extreme southeastern region of the Meadowlands District (Fig. 1). 2006 surveys ranked the chorus in Upper Penhorn Marsh as 2 and found most of the vocalization activity west of the drainage ditch bisecting the marsh

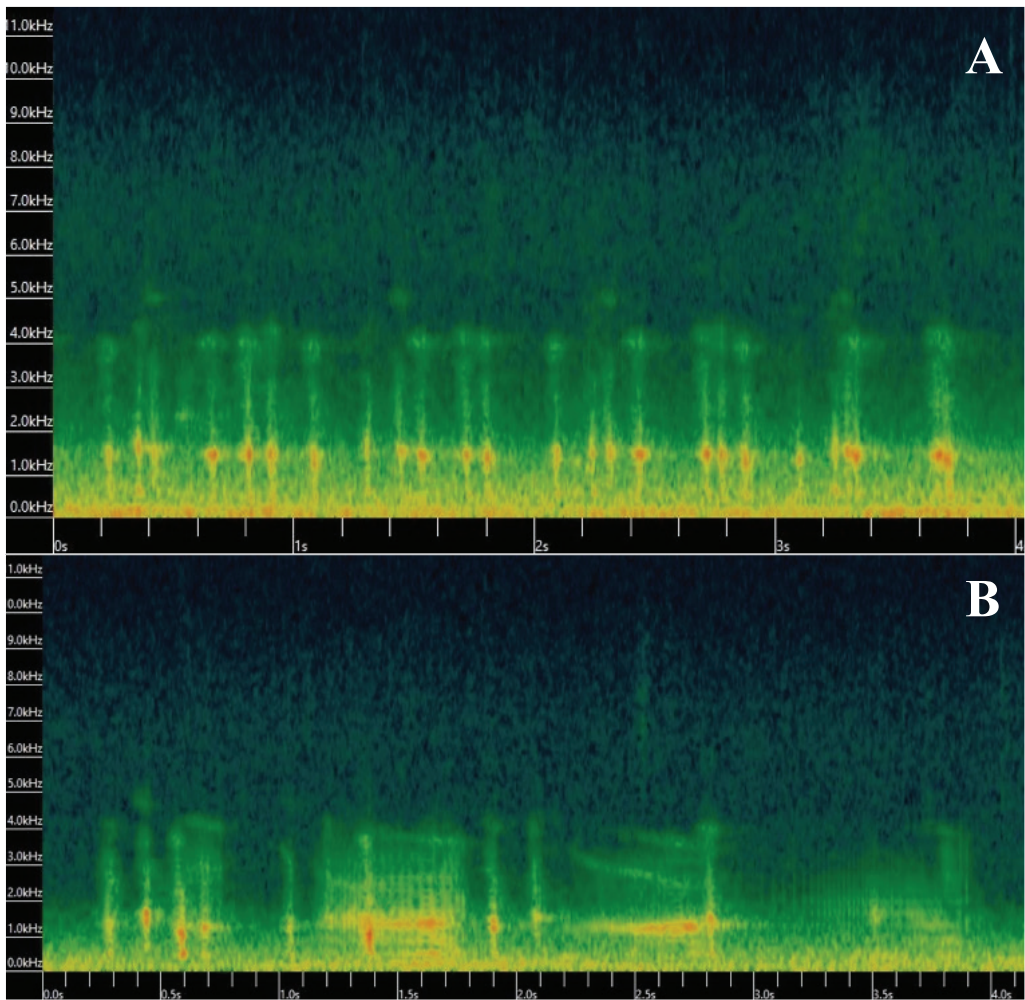Figure 2. (a) Spectrogram showing classic Atlantic Coast Leopard Frog "chucks" collected at TET2 on 3/17/2023. (b) Spectrogram showing Atlantic Coast Leopard Frog interspersed "growls" among the many short "chucks" collected from TET2 on 3/18/2023.

(Kiviat 2011). Both 2023 ARU survey points at this site were located east of the drainage ditch, and only UPM2 yielded positive detections (Fig. 1, Table 1). This large pool of freshwater is bordered almost exclusively by Common Reed. Its chorus ranking was 1, as only a few individuals were detected. Reassessing the presence/absence of Atlantic Coast Leopard Frog across the entirety of this site will be an important future project. However, reconfirming the species' continued presence 10 years after the most recent surveys suggests that the population is surviving here. The Little Snake Hill Marsh point (LSH1) also yielded positive detections with a chorus ranking of 1 (Fig. 1, Table 1). This site is loosely connected to Upper Penhorn Marsh via Penhorn Creek. Positive detections at both Upper Penhorn Marsh and Little Snake Hill Marsh suggests that these 2 populations are likely connected, but genetic analysis is needed for confirmation.

Figure 3. (a) ARU deployment point TET2. This was the only point with a chorus ranking of 2. Images from 2012 showed this pool as being mostly open water. (b) ARU deployment point TET1. Frogs were detected here with a chorus ranking of 1 despite the relatively small pool size and isolated location.

The northwestern and southeastern clusters of Atlantic Coast Leopard Frog in the Meadowlands are cut off by long stretches of suburban and urban complexes, as well as the tidal Hackensack River (Fig. 1). This fragmentation makes gene flow unlikely between these 2 populations, but genetic analysis is needed for more thorough assessment and the potential conservation implications it brings. However, TET1 is separated from the general Teterboro Airport Woods area by at least 300 meters of suburban neighborhoods, suggesting that individuals will travel short distances through residential areas to find suitable habitat. The extent to which the species uses and tolerates such areas as potential migration habitat is still unclear, and the maximum distance individuals will travel from the highest quality habitat within Teterboro Woods is also largely unknown. Additionally, the fact that frogs were detected at TET2 on 3/17/2023 but not at UPM2 until 3/23/2023 is notable, but the reason behind this finding is unclear.

The remaining two sites, Losen Slote Park and Meadowlark Marsh, did not yield positive detections despite ARU deployments over multiple nights with suitable vocalization conditions and evidence of concurrent chorus activity at other sites (Table 1). Losen Slote Park is a public access green area used moderately heavily by local residents. LOS1 is a vernal pool at the very beginning of the trailhead and is very close to an active sports field, which may discourage Atlantic Coast Leopard Frogs from vocalizing here given the abundance of loud noise in the evening hours. LOS2 is another vernal pool situated mostly in the restricted access area of the park. The lack of positive detections here was unexpected given the strong suitability of the habitat. This site is separated from Teterboro Airport Woods by over a kilometer of suburban area with several main roads. Migration between the 2 sites would be difficult, but not impossible, as leopard frogs are known to traverse large expanses to access suitable habitat (Knutson et al. 2018). More thorough analysis of both biotic and abiotic factors will be necessary to understand the absence of Atlantic Coast Leopard Frog at Losen Slote Park. The Meadowlark Marsh points, although mostly freshwater, are surrounded by either brackish water or urban complex. Therefore, the lack of positive detections here is not surprising. Additionally, the pond at MEA1 contains fish which would restrict nearly any amphibian breeding activity (Gregoire and Gunzburger 2008).

The use of ARUs to detect Atlantic Coast Leopard Frogs throughout the Meadowlands proved effective. Although all recorders detected large amounts of anthropogenic noise from highways, airports, and railroads, the gaps in between these sounds were enough for the recorders to detect frogs in good quality (Fig. 2). Nocturnal data collection is likely more effective than diurnal data collection, given lower levels of human noise and higher levels of frog activity after dark. Although the species-specific auto classifier yielded many false positives, thorough quality assessment showed no false negatives. Thus, if Atlantic Coast Leopard Frogs were vocalizing, the ARUs would have likely recorded them and the classifier identified them, albeit not necessarily correctly. This finding further suggests that building an auto classifier for low frequency frog detections is an effective method for processing large amounts of acoustic data, even in environments with considerable amounts of human noise. This can be attributed, at least in part, to the high prevalence of vocalizations when Atlantic Coast Leopard Frogs are active. It is possible that the auto classifier and subsequent quality assurance reviews may have both missed positive detections if individuals were calling infrequently. Therefore, a combination of acoustic recordings and in-person surveys may be necessary to thoroughly assess the presence/absence of cryptic species that only vocalize rarely. However, acoustic monitoring is generally a very effective and comparatively passive method of identifying highly vocal species. This finding is very important in regions like the Meadowlands where nocturnal access is generally unsafe or discouraged.

Overall, the occupancy of Atlantic Coast Leopard Frog in the Meadowlands is broadly the same as it was when 2006 and 2012 surveys were conducted (Kiviat 2011, 2012). However, several new sites with positive detections were found, including in a tiny strip of habitat surrounded by residences (TET 1), and in a recently formed pool (UPM 2) opposite where the largest chorus detected was detected in 2006 (Kiviat 2011). The most limiting factor of this study was the use of only 3 ARUs. This resource limitation forced us to be particular about where and for how long ARUs were deployed and prevented us from monitoring all locations in parallel (consistently and simultaneously) over a single period. A combination of more ARUs, as well as adjacent corresponding continuous water quality monitors, would be a more thorough method of assessing the fine-scale occupancy and water quality associations of Atlantic Coast Leopard Frog in the Meadowlands. Regardless, this study has shown that this species has persevered in Meadowlands over the 10-year period since last surveyed (Feinberg 2015). Additionally, the long-term presence of this species, despite the inundation of many of these wetland sites with saltwater by Hurricane Sandy in 2012, is notable (Feinberg 2015). This study has also shown that acoustic monitoring using auto classification software is a comparably effective tool to in-person surveys for finding frog sounds in urban sites. This study presents many possibilities for future wildlife research in the NJ Meadowlands and urban habitats as a whole. Going forward, the Meadowlands Research and Restoration Institute (MRRI) will prioritize monitoring these impressively resilient populations of Atlantic Coast Leopard Frog to assess long-term trends and ultimately develop conservation goals.

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