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Distribution and Habitat of the Undescribed Leopard Frog (*Lithobates [Rana] sp. nov.*) in the New Jersey Meadowlands, 2012

Final Report to the Hudson River Foundation
Grant # 002/12E

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Leopard frog (undescribed species), Kane Natural Area, 2008. Photo copyright 2012 Erik Kiviat.

It occurred to me that the appropriate report on an Expedited Grant would be an expedited report, and what better expedited report than one in verse? Therefore I submit the doggerel (or more properly "froggerel") below as my report on Grant 002/12E.

A new urban species of frog, you say
In glaciated lands is making its way?

How utterly rare, how fascinating,
How unlikely and how ratiocinating

Upon this palimpsest of the Metro Region
The disappearance of critters is truly legion

But here is a new one, amid reeds and roses
For a hundred years beneath biologists' noses

Frogs are dying off all over the world
But here in the City its flag unfurled

This leopard frog quietly, in an aura of mystery
Feeds, spawns, and dies – an urban life history

Mercury, chromium, PCBs, dioxins
It's well known that frogs are sensitive to toxins

One site has new radio towers and now illegal fill
For the frog larvae it's a bitter pill

Another has jet smoke and noise, and FAA wants to cut trees
Could make frogs croak and children wheeze

Biologists don't like *Phragmites* reeds
But leopard frogs find it suits their needs

Now it comes to April and March
It doesn't freeze much and it doesn't parch

The leopard frogs call around lower Secaucus
Sometimes their choruses are a bit raucous

In the Meadowlands wildlife needs the wetlands
But in northeastern New Jersey that's where the jet lands

So here ends my froggerel report
I'm sure one day there will be a retort

Astract

In 2006 I studied leopard frogs breeding in the New Jersey Meadowlands that I assumed were southern leopard frog. Early in 2012 it was made public that an undescribed species of leopard frog had been discovered at a few locations in the New York City metropolitan region. I therefore performed surveys to detect calling leopard frogs at freshwater ponds and marshes in the Meadowlands, and recorded calls to submit for species identification. I detected leopard frogs calling at one locality studied in 2006 (Moonachie) and an additional group of locations in an extensive complex of freshwater marshes (Jersey City and Secaucus). Sound recordings were confirmed by Jeremy Feinberg (Rutgers University) as the undescribed species. Water quality measurements and environmental observations suggest that the Meadowlands leopard frogs are associated with larger freshwater wetland complexes which had higher temperature, higher conductivity, and lower pH in evening measurements taken in early spring 2012. Two of the localities I studied in 2006 were inaccessible for confirmation in 2012. Meadowlands ponds and wetlands are subject to rapid anthropogenic habitat change, therefore identification of the undescribed leopard frog breeding ponds, and other species of conservation concern, are a high priority. Apparently all Meadowlands leopard frog sites were flooded by the Hurricane Sandy storm surge at the end of October 2012; consequences for the frogs are unknown.

Keywords: Leopard frog; *Lithobates*; New Jersey Meadowlands; *Rana*; urban biodiversity; wetlands.

Background and Rationale

Urban environments may support species of conservation concern despite urban stressors such as altered hydrology, loss of natural soils, and toxic contamination. Certain urban habitats even provide particular species with refuges from biological interactions such as predation, competition, herbivory, parasites, or disease. The biodiversity of cities, therefore, is of practical interest for conservation, education, and enjoyment, and as well is scientifically interesting because it can shed light on community level interactions. Studying biodiversity in cities both allows us to take advantage of opportunities to conserve those species that persist, and to learn about mistakes that can be avoided in environmental planning and nature management in regions that are still rural. A few species that are rare statewide or nationally are successful in cities; examples include the peregrine falcon nesting on tall buildings and bridges in the New York City metropolitan area, and the black redstart breeding in London, U.K.

Recently, by means of genetic techniques, the leopard frogs in the New York City region were shown to be a species distinct from the northern leopard frog (*Lithobates pipiens [Rana pipiens]*) and the southern leopard frog (*Lithobates sphenocephalus utricularius [Rana sphenocephala utricularia]*) (Foderaro 2012, Newman et al. 2012). Fortuitously, I had studied this as yet undescribed species in 2006 when I conducted frog surveys as part of biodiversity studies in the New Jersey Meadowlands. At that time I assumed, on the basis of geographic distribution, that these were southern leopard frogs (Kiviat 2011). The undescribed species (hereinafter *Lithobates sp. nov.*) so far has been confirmed at few localities and some of the populations are small. Therefore it is important to locate additional populations of this species, describe its habitats and life history, and understand its geographic range. This problem is all the more interesting because the discovery of an undescribed vertebrate in a glaciated and largely urban region is highly unusual.

I therefore set out to confirm the identity of the Meadowlands leopard frogs as the undescribed species, reconfirm the presence of this species at the sites I studied in 2006, and find additional populations in the Meadowlands region. (Historically, leopard frogs, presumably *Lithobates sp. nov.*, were collected in the Meadowlands in Ridgefield, Bergen County, and North Bergen, Hudson County as well as nearby localities outside the Meadowlands; the specimens were cited in Pace [1974]).

The fast pace of land use and habitat change due to human activities and sea level rise in the Meadowlands increases the urgency of understanding the distribution and habitat affinities of the undescribed species. Most or all of the potentially suitable freshwater breeding habitats are threatened by development, airport management, wetland mitigation activities, storage of ash from an electric generating station, and landfill remediation. It is also important to understand if there is something in the urban environment where some populations of the undescribed species occur that fosters the survival of this species. Leopard frogs, presumably the undescribed species, have not been documented on Long Island since 1995 (J. Feinberg, pers. comm.). Possibly there remains a single population on Staten Island, and one population each in Orange and Putnam counties, New York; there is also a population in the Great Swamp of New Jersey, and at least one other northern New Jersey population (*ibid.*).

In recent decades there have been unprecedented declines and extinctions of many frog species worldwide, probably due to a multiplicity of causes (Lanoo 2005), and frogs in general are considered urban-sensitive. Urbanization generally results in the loss of native herpetofaunal species and the establishment of nonnative species (Mitchell and Brown 2008). Urban factors that disfavor the native herpetofauna prominently include the loss, fragmentation, and degradation of habitats (*ibid.*). Pace (1974) called attention to the biosystematic complexity of the leopard frogs. Of nine currently known species of leopard frogs (excluding *Lithobates sp. nov.* of my report), six are reported to be declining in at least portions of their ranges, and a seventh has an extremely small range (Lannoo 2005). Four of these nine species have been described only since 1973.

Methods

I studied maps and satellite imagery, and conducted daytime reconnaissance, to locate potential leopard frog breeding habitats in the Meadowlands. In March and April 2012, the calling season, I conducted nocturnal surveys to determine the presence of calling leopard frogs, and I sound-recorded choruses for species identification. It was believed that the undescribed leopard frog could tolerate no more than about 0.5-1.0 ppt salinity and required a breeding pond with sufficient standing water into July or August to support a ca. 2.5 mo larval period (Jeremy Feinberg, pers. comm.). Because tidal waters in the Meadowlands normally exceed this level of salinity in summer, I therefore sought ponds with no tidal connections, vascular vegetation indicating fresh water, and conditions or history indicating an adequate hydroperiod. I conducted frog calling surveys from about civil twilight until midnight, because although leopard frogs sometimes call during the day, evening hours have the most dependable chorusing. I also limited surveys to evenings with air temperatures above ca. 15 C and winds of Beaufort 3 or less. I approached each pond quietly and listened for 5-10 min to determine if frogs were calling (this long listening period was necessary because of the small chorus size and intermittent calling). I then quietly measured the following water quality variables using a YSI MDS 650 meter and a YSI 6600 EDS Multi-parameter sonde (Yellow Springs Instrument Co.): water temperature, conductivity (millisiemens/cm), pH, turbidity

(NTU), and dissolved oxygen (mg/L and per cent saturation). I also collected a water sample which was stored under refrigeration. In addition to the field measurements, samples were analyzed for conductivity on a YSI EC300 in the laboratory at Cary Institute. The field measurements took another ca. 10-15 min, affording additional time to detect calling frogs. I recorded each new chorus of leopard frogs with an Olympus Linear PCM LS-10 digital audio recorder and a Sennheiser MKE 400 directional microphone, and submitted sound recordings to Jeremy Feinberg for species identification. I visited the Teterboro Southeast Pond, one of the 2006 leopard frog sites, several times during the survey period to confirm that leopard frogs were calling.

I conducted graphical and statistical analyses with Statistica version 10 (StatSoft, Tulsa, Oklahoma). I set $\alpha = 0.1$ due to small sample sizes.

Results and Discussion

In 2012 I documented leopard frogs calling at 4 sites in the Meadowlands (Table 1; I considered sites distinct if they were separated by a straight-line distance of 200 m, although frogs possibly move among such sites). One of these sites was documented in 2006 but I was unable to revisit additional sites documented that year. Documented (occupied) sites, and sites that appeared to lack calling frogs (unoccupied), are shown in tables 1-2. Frog call surveys do not detect 100% of occupied sites (Pellet and Schmidt 2005). Among other problems, traffic noise can decrease frog calling activity (Lengagne 2008) as well as affecting human ability to hear animal sounds (Breeden et al. 2008).

I obtained good sound recordings of *Lithobates sp. nov.* at two of three sites where I heard them in the Little Snake Hill Marshes (Lower Penhorn Marshes, in Secaucus and Jersey City). The recordings were confirmed by Jeremy Feinberg (pers. comm.) as this species. I also recorded leopard frogs at Teterboro Southeast Pond (Kiviat 2011), which Feinberg was able to identify despite aircraft noise from nearby Teterboro Airport.

In 2012 I collected water quality data for 3 occupied and 8 unoccupied sites (Figure 1, Table 3). Features shared by Meadowlands leopard frog sites were small pools or ponds, an extensive wetland matrix, no tidal (brackish water) connection, 100 m or farther from a garbage landfill, relatively good water quality with high evening DO, high pH, high conductivity, and low turbidity (The formerly occupied site at the Kane Natural Area was an extensive freshwater marsh with intermittent pools, and its character supports the importance of wetland extent in distinguishing occupied from unoccupied sites although I do not know where the frogs were breeding at or near Kane.)

pH and DO (ppm) were correlated in the full set of ponds (Spearman's rho = 0.736, $p = 0.00976$). Evening pH and DO values were high, probably resulting from high rates of daytime algal photosynthesis expected in eutrophic waters. Inasmuch as lower pH (within the range of values measured) was a predictor of leopard frog occupancy, it is possible that the higher pH sites were more polluted. The association of occupied ponds with extensive wetlands, either swamps or marshes, suggests that these areas provided habitats for foraging and overwintering as well as breeding. Northern leopard frogs and southern leopard frogs range far from breeding ponds in summer (Klemens 1993, Hulse et al. 2001, White and White 2002).

Figure 1. Localities for leopard frog in the New Jersey Meadowlands on a satellite image from Google Earth. North is to the right, the Hudson River at bottom. 1. Teterboro West, approximate location, 2006; 2. Teterboro Southeast, 2006 and 2012; 3. Kane Natural Area, 2008, nonbreeding individual; 4. Upper Penhorn Marsh, 2006; 5-7. Little Snake Hill marshes, 2012 (calling frogs were detected at all localities except number 3).

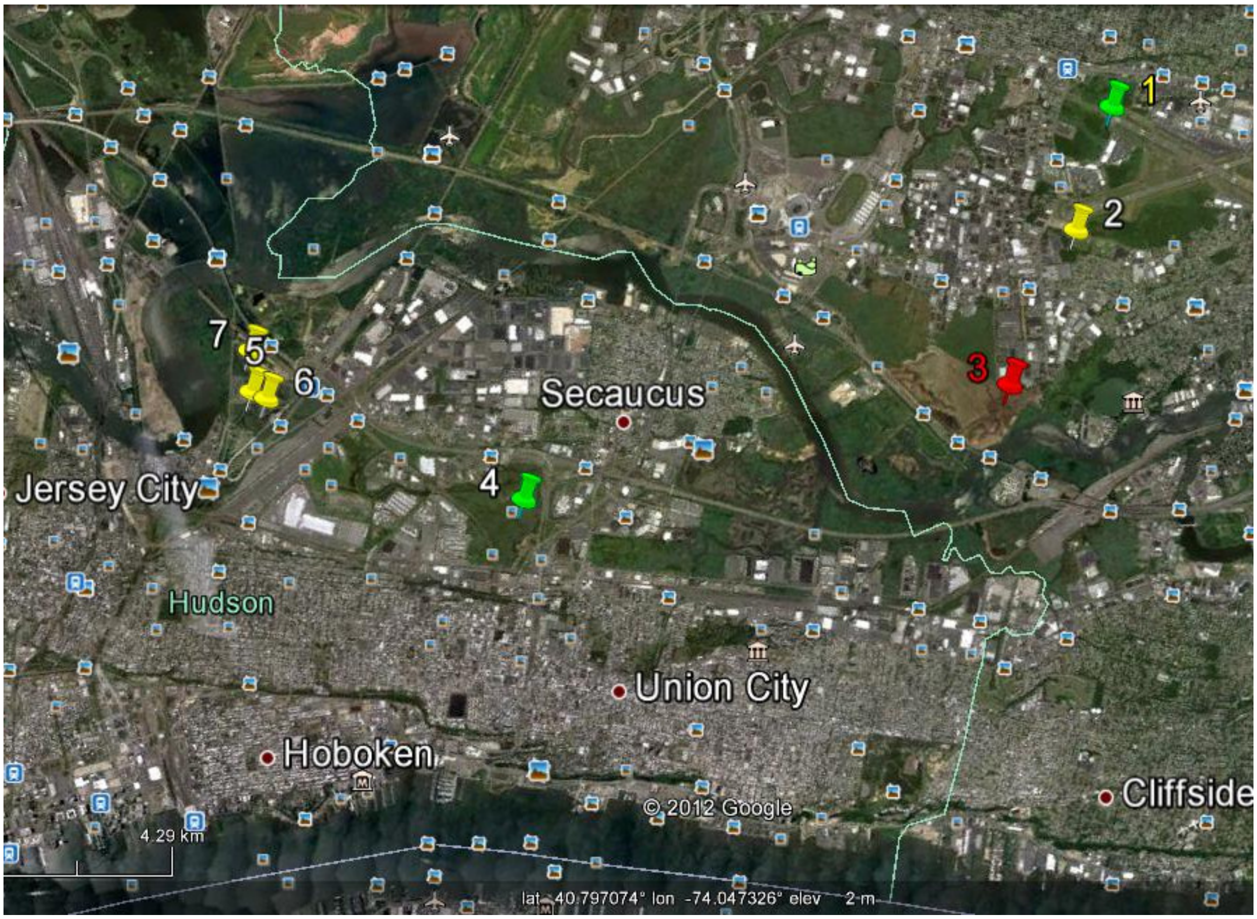

Table 1. Confirmed leopard frog calling sites in the New Jersey Meadowlands. * Heard in 2006 (see Kiviat 2011); # heard in 2012.

Site name	**Municipality**	**Habitat**	**Surroundings**	**Bottom**
Teterboro Airport west area*	Teterboro	? (No access)	Swamp, wet woods, runway area, etc.	?
Teterboro Airport Southeast Pond*#	Moonachie	Stormwater pond	Swamp, wet woods parking lot	Shallow silt above firm bottom
Upper Penhorn Marsh*	North Bergen	Flooded nontidal reed marsh (former Atlantic white cedar swamp)	Reed marsh, highway & railroad verges, developed areas	Soft organic soil
Litle Snake Hill Marsh 1	Jersey City	Flooded nontidal reed marsh (former brackish tidal marsh?)	Flooded reed marshes, developed areas	Soft organic soil?
LSH Marsh 2	Jersey City	Same as above	Same as above	Soft organic soil?
LSH Marsh 3	Secaucus	Same as above	Same as above	Soft organic soil?
Richard P. Kane Natural Area (nonbreeding individual 2008; breeding pond unidentified)	Carlstadt – South Hackensack	Reed marsh with recently breached dike	Reed marshes, clay flats, gas pipeline road on fill, ponded lower reach of stream	Soft organic soil

Table 2. Potential breeding habitats negative for frogs in 2012

Site name	Municipality	Habitat	Surroundings	Bottom
Overpeck Creek	Palisades Park & Leonia	Sheltered cove of estuarine impoundment	Inactive landfill, recreation	
1-E Landfill northeast pond	North Arlington	Stormwater pond	Landfill, dike	Shallow sediment
1-E Landfill west pond	North Arlington	Stormwater pond	Landfill, trucking	
Rail Station pond	Secaucus	Large stormwater pond	Rail station, highway, road on fill	
Turnpike pond	Secaucus	Isolated pond	Turnpike, thickets, swamp	
Pond south of Laurel Hill	Secaucus	Pond in freshwater marsh	Equipment park, freshwater marsh	
Pond between railroads	Secaucus	Pond in freshwater marsh	Railroads, freshwater marsh	
Pond SE of LSH Marsh 1	Secaucus	Pond in freshwater marsh	Fill (landfill?), freshwater marsh	
Kingsland Landfill 1	Lyndhurst	Stream impoundment	Landfill, thickets	
Kingsland Landfill 2	Lyndhurst	Stream impoundment	Landfill, thickets	
Kingsland Landfill 3	Lyndhurst	Stream impoundment	Landfill, thickets	
Kearny Marsh West (Kearny Freshwater Marsh)	Kearny	Freshwater impoundment	Railroad, highways, landfill, recreation, thickets	Soft organic soil

Table 3. Water quality data from sites (ponds) surveyed in 2012. Overpeck = Overpeck Creek; Kingsland = Kingsland Landfill; 1-E West = Pond at western foot of 1-E Landfill; Rail Station and Turnpike are the large and small ponds, respectively, adjoining the Turnpike between Laurel Hill and the Secaucus Rail Station; LSH-SW and LSH-E are the marshes southwest and east of Little Snake Hill (Lower Penhorn Marshes); Kearny is the western edge of Kearny Marsh West; Teterboro SE = Teterboro Southeast Pond. Used = leopard frogs called in 2012; Temp = water temperature; Cond-fld = conductivity, field measurement; Cond-lab = conductivity, lab measurement; Sal-lab = salinity estimated from laboratory measurement of conductivity; DO-sat = dissolved oxygen per cent saturation; DO-ppm = dissolved oxygen, parts-per-million.

	UTM	Date	Used	Large	Temp	Cond-fld	Cond-lab	Sal-lab	pH	Turbidity	DO-sat	DO-ppm
Overpeck	4524870, 584910	41015	0	1	19.7	0.820	0.760	0.4	7.30	30.2	33.6	3.01
Kingsland-1	4516137, 574706	41002	0	0	14.3	0.774	0.866	0.4	10.20	165.1	216.1	22.26
Kingsland-2	4516207, 574975	41002	0	0	13.7	0.769	0.821	0.4	7.90	11.3	107.1	10.97
Kingsland-3	4515888, 575416	41002	0	0	13.4	0.606	0.629	0.3	8.10	15.1	106.8	11.14
1-E West	4513920, 573958	41013	0	0	19.3	0.130	0.184	0.1	9.39	1.5	130.3	12.02
Rail Station	4512646, 577609	40996	0	0	12.4	1.530	1.589	0.8	9.14	24.6	109.8	11.71
Turnpike	4512527, 577535	40996	0	0	13.5	2.290	3.550	1.2	7.88	25.0	81.0	8.33
LSH-SW	4511798, 577600	41014	1	1	19.3	3.200	3.420	1.8	8.25	5.6	56.8	5.17
LSH-E	4511905, 578004	40996	1	1	15.4	3.520	3.560	1.9	7.93	68.0	66.3	6.50
Kearny*	4512744, 572963	41013	0	1	18.2	1.924	3.047	1.8	8.42	20.9	142.6	13.33
Teterboro SE	4521179, 579561	41003	1	1	16.8	0.500	0.428	0.2	7.13	4.3	113.3	10.80

*Measurements taken at boat landing, NW corner of marsh; field conductivity was 3.35 mS farther down west edge of marsh (substituting 3.35 for 1.924 made little difference in the logistic regression with two independent variables reported below.

It is important to note that the occupied sites I found in 2006 and 2012 occur in three clusters: Teterboro Airport Woods (2 or 3 breeding pools), Upper Penhorn Marsh (one large marsh with frogs calling at several locations), and Little Snake Hill - Lower Penhorn Marsh (large complex of marshes with frogs at three locations). Within any one cluster, environmental conditions may be somewhat similar, and stressors or threats are likely to be similar.

I heard leopard frogs nonsignificantly more often in pools that were part of large wetland complexes than in isolated ponds or small wetlands (Fisher exact test, $p = 0.61$). Pools in larger wetlands had nonsignificantly higher water temperatures (Figure 2) (Mann-Whitney $U = 4.0$, exact $p = 0.52$).

Mann Whitney U tests comparing water quality variables in occupied and unoccupied ponds were not significant for pH, conductivity, salinity, turbidity, or dissolved oxygen, considered as separate variables.

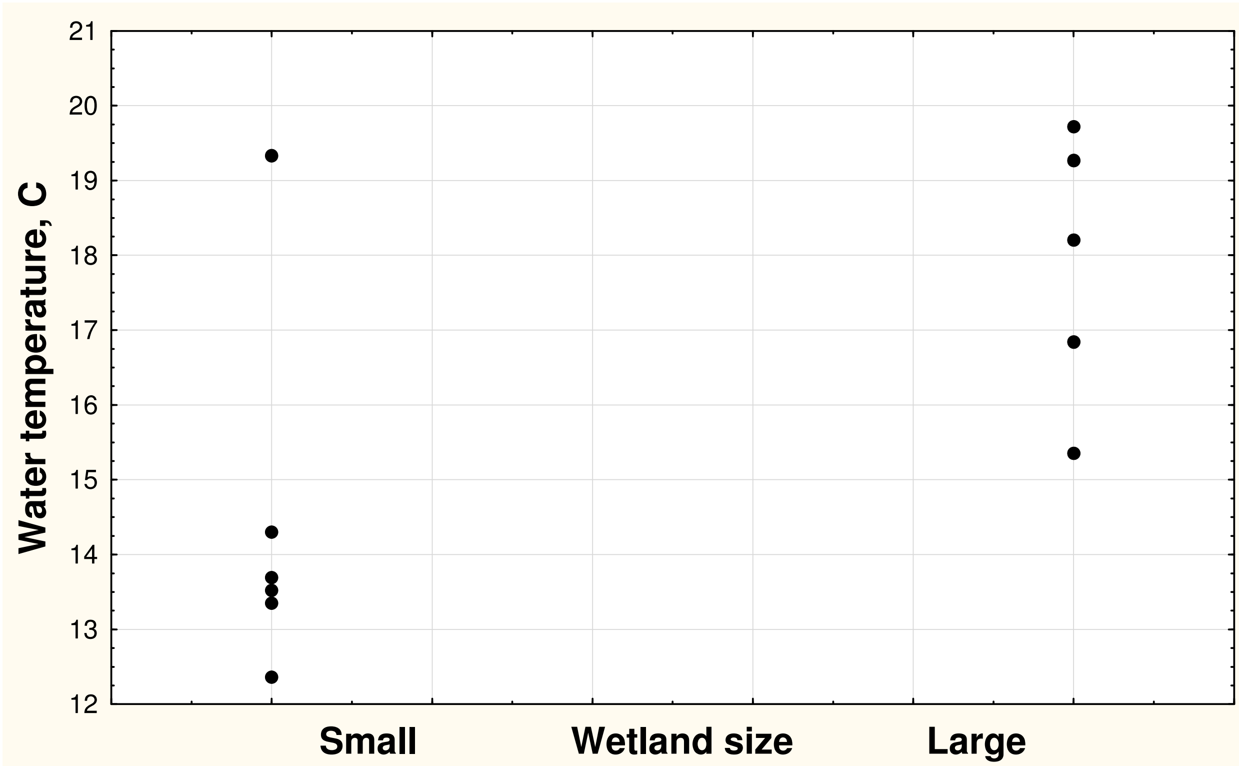

Figure 2. Scatterplot showing that water temperatures were higher in pools that were part of larger wetlands (with the exception of one high temperature in a small wetland). Temperatures were recorded during evening hours in early spring at the times of leopard frog surveys.

Simple logistic regression (one continuous independent water quality variable and one binary dependent variable which was used-nonused or occupied – unoccupied) was not significant for any single water quality variable. Multiple logistic regressions (two or three continuous water quality variables and the one binary dependent variable) were significant with two combinations of variables. Regression was significant with pH and conductivity (field) ($p = 0.00819$; Figure 3) or pH, conductivity (field), and turbidity ($p = 0.00488$). In these equations, lower pH was the strongest predictor, with higher conductivity a strong second, and lower turbidity a very weak third. Sites were selected to avoid highly brackish water, and the 1.9 ppt (estimated) salinity at one of the two lower Penhorn sites may well be the maximum tolerated. Karraker et al. (2008) found that 3.0 mS (millisiemens) conductivity reduced survival of spotted salamanders (*Ambystoma maculatum*) and wood frogs (*Lithobates sylvaticus*) in pools near roads in northern New York. Two of the leopard frog breeding pools in the Meadowlands had conductivity 3.4 and 3.6 mS; possibly less of this was due to sodium chloride and more to other dissolved mineral substances, or *Lithobates sp. nov.* is more tolerant of salt than spotted salamanders and wood frogs.

The small number of samples (11 sites) suggests caution in interpretating the logistic regressions. Moreover, Keating and Cherry (2004) questioned whether logistic regression should be used in habitat selection studies. I therefore regard the analysis presented here as exploratory.

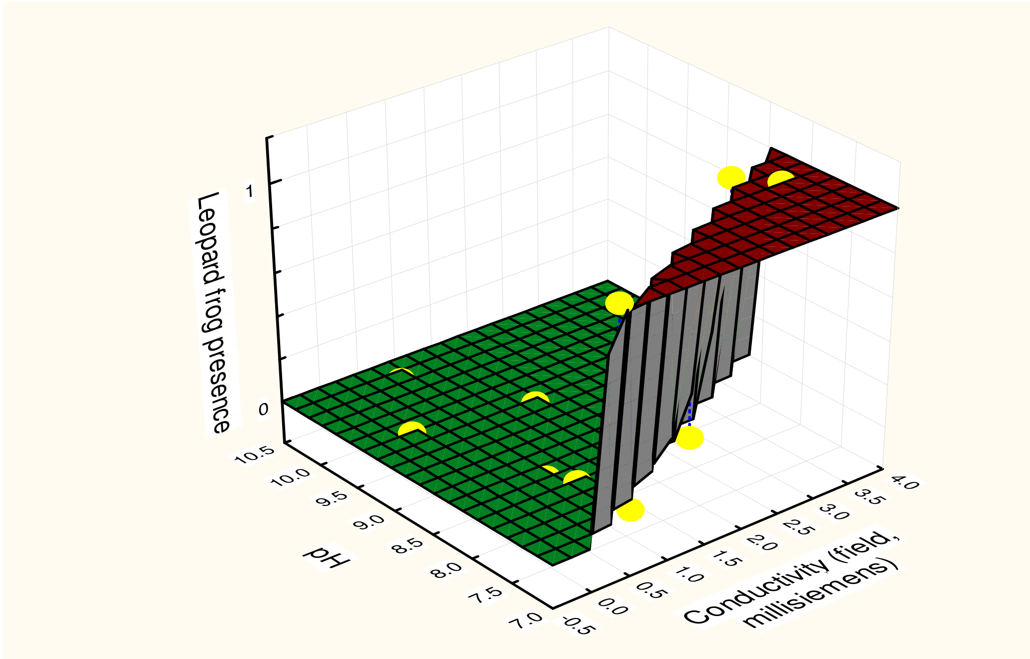

Figure 3. Graph of the multiple logistic regression of leopard frog presence-absence on pH and conductivity. The upper (brown) plane represents 3 sites where the frogs occurred, and the lower (green) plane represents 8 sites where frogs were not heard. The surface overall indicates that the frogs were found at relatively low pH and high conductivity (within the ranges of these variables in the habitats studied, see Table 3).

One could argue that the two calling sites where I measured water quality in the Little Snake Hill Marshes were pseudoreplicates inasmuch as they were part of the same freshwater marsh complex. However, this complex is fragmented by roads, railroads, artificial levees along the channel of Penhorn Creek, and other human-created features. Turbidity and DO were substantially different between these ponds (Table 3). I was unable to reach the third calling site within these marshes to measure water quality.

Ponds with better water quality (as measured) may have lower levels of certain materials known to be toxic to frogs, such as nitrogen compounds, metals, and pesticides (Bridges and Semlitsch 2005). The general absence of frogs from potential habitat adjoining or on top of either inactive or capped garbage landfills also suggests that certain ponds might have been polluted with substances to which frogs are sensitive.

Water quality values, marsh extent, and interspersion of reedbeds (*Phragmites australis*) and pools at Kearny Marsh West would seem suitable for leopard frogs, but I did not hear any there. There are a landfill and sediment contamination in that marsh. It is possible that leopard frogs calling well out in this large marsh would not be audible from the marsh edge. Jeremy Feinberg (pers. comm.)

believes that *Lithobates sp. nov.* choruses are audible only 50 m away under conditions of low environmental noise, although this seems conservative to me.

I did not hear or see any other frog species in either the occupied or unoccupied ponds in 2006-2012. (In spring 2006, I heard one American toad [*Anaxyrus americanus*] calling near Laurel Hill, possibly from one of the two ponds, Rail Station and Turnpike ponds, between Laurel Hill and the Secaucus train station where I surveyed for leopard frogs in 2012 with negative results.) Several other frog species have been found in the Meadowlands during that period, and as many as 11 species have been reported historically, although some of these species were not well documented (Kiviat 2011). Now, however, frogs of any species appear to be scarce. The absence or scarcity of other frogs may reduce predatory or competitive pressure on the leopard frogs. Potential predators of adult or larval frogs that occur in the Meadowlands include dragonflies, snapping turtle, garter snake, least bittern, black-crowned night-heron, great egret, mallard, common grackle, and raccoon. It was not possible to determine if these or other species were preying on leopard frog adults or larvae, or if levels of predation were less or greater in the Meadowlands than in rural habitats. It is clear, however, that species richness in any higher taxon is less in the Meadowlands than in surrounding rural regions, although the Meadowlands support many species and in some cases high densities of animals. Two predators of other species of leopard frogs, bullfrog (*Lithobates catesbeianus*; Hammerson 1982) and northern water snake (*Nerodia sipedon*; Robertson and Weatherhead 1992), are very rare in the Meadowlands (Kiviat, pers. obs.).

No data are available on parasites or pathogens in frogs in the Meadowlands. It would be interesting to examine prevalence of known anuran pathogens such as the fungus *Batrachochytrium dendrobatidis* (Bd), *Ranavirus*, and the bacterium *Aeromonas*. The urban environment and prevalent industrial contamination in the Meadowlands might reduce the immune competence of frogs and predispose them to infections (or, alternatively, urban-industrial conditions might inhibit the parasites).

Lithobates sp. nov., the undescribed species of leopard frog, appears to be persisting at certain sites, and in the Meadowlands in general. However, due to rapid and unpredictable environmental changes, all the sites where this species occurs in the Meadowlands are under a high level of threat. Teterboro Southeast Pond adjoins a truck parking lot and part of the adjacent swamp forest is slated to be cleared because of its proximity to the end of the main runway at Teterboro Airport. This pond is also treated with mosquito pesticides (2010) and it is possible that changes in materials or doses will threaten the frogs in the future. The Upper Penhorn Creek Marsh, since my 2006 study, has had a cluster of four radio broadcast antennas with ancillary facilities installed (2009) where leopard frogs called in 2006, and the north end of this marsh was being filled (in 2011 or 2012) apparently without a permit. The Kane Natural Area in Carlstadt and South Hackensack, where I have not heard frogs but where I photographed a leopard frog in 2008, has been extensively altered first by failure of the dike that excluded brackish water from the Hackensack River estuary, and then in 2010 by installation of a ca. 80 ha wetland mitigation bank. The breeding site of leopard frogs at Kane is unknown and may or may not still be suitable. The Teterboro Airport West Ponds, inside the secure area, were not accessible to me in 2006 or 2012. The airport seems to be undergoing further development of facilities. Finally, the Little Snake Hill (Lower Penhorn) Marshes do not seem to be under immediate threat of alteration but are surrounded by intensive transportation and industrial land uses including a coal ash storage site on the south side of Little Snake Hill, and the Malanka Landfill on the west side of the marshes is undergoing remediation. Apparently the leopard frog breeding pools were flooded by brackish water in the storm surge associated with

Hurricane Sandy at the end of October 2012 (USGS 2012). Brackish flooding might kill adult frogs or make pools unsuitable for breeding the following season. However, if part of the region's response to the threat of damaging storm surges is to remove some of the industrial, commercial, residential, or transportation structures from low-lying coastal areas, creation of habitats for the leopard frog could be incorporated into the resulting greenspaces.

Although not directly related to questions about leopard frogs in the Meadowlands, the northernmost population of *Lithobates sp. nov.* in the Hudson Valley is also of conservation interest. In spring 2012 Jason Tesauro and I observed and recorded northern leopard frogs (*Rana pipiens*, sound recording confirmed by Jeremy Feinberg) calling in a supratidal pool adjoining the railroad at Hudson South Bay (Columbia County, New York). Twice in spring 2012 I visited a supratidal pool at Rokeby Farm in Barrytown (Dutchess County, New York) where I had seen, heard, and collected leopard frogs in the 1980s (Klemens et al. 1987), but I was unable to find leopard frogs there in 2012.

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Jeremy Feinberg (Rutgers University) discussed leopard frogs, showed me an occupied reference site for *Lithobates sp. nov.* in New York, and identified to species my audio recordings of leopard frog calls. Dan Becker and Chris Graham assisted in the field. Francisco Artigas, Brett Bragin, Joe Grzyb, and Christine Hobble of the Meadowlands Environmental Research Institute, New Jersey Meadowlands Commission, provided information and logistical support, and loaned and calibrated the water quality instrument. Dwane Decker, Bard College Biology Program, loaned and instructed me in the use of the audio recording equipment. Stuart Findlay and Angela Cross made the laboratory measurements of conductivity at the Cary Institute for Ecosystem Studies. Jason Tesauro assisted in the field at Hudson, New York. Leopard frog surveys in 2012 were supported by an Expedited Grant from the Hudson River Research Fund of the Hudson River Foundation. The Bay and Paul Foundations have since provided a small grant partly for continued surveys in spring 2013. This is a Bard College Field Station – Hudsonia Contribution.

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