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Summary of Amphibian Community Monitoring at Congaree National Park, 2010

Natural Resource Report NPS/SECN/NRDS—2011/167

ON THE COVER
Ambystoma opacum (marbled salamander)
Photograph by SECN staff.

Summary of Amphibian Community Monitoring at Congaree National Park, 2010

Natural Resource Data Series NPS/SECN/NRDS—2011/167

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The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data were collected and analyzed using established methods based on peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the Southeast Coast Network (http://science.nature.nps.gov/im/units/secn) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm).

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Executive Summary

This report summarizes data collected with the Draft SECN Amphibian Community Monitoring Protocol (Byrne et al., *in preparation*) at Congaree National Park in 2010.

1. Data were collected at 31 spatially-balanced random locations at the Park with two techniques: automated recording devices and visual-encounter surveys.

2. Sampling activities occurred at the Park from 4/10/2010 to 4/27/2010, and again from 6/15/2010 to 7/2/2010.

3. We detected 1,132 amphibians, half of which were larva, in 24 species, genera, or order, and 58 reptiles and reptile signs in 18 species, genera, order, or sign.

4. Monitoring efforts resulted in the addition of six new species/sub-species to the Park's official species list: two amphibians, *Eurycea quadridigitata* (dwarf salamander) and *Rana clamitans clamitans* (bronze frog), and four reptiles, *Elaphe obsoleta obsoleta* (black rat snake), *Elaphe alleghaniensis* (Eastern rat snake or yellow rat snake), *Nerodia erythrogaster erythrogaster* (red-bellied water snake), and *Trachemys scripta scripta* (yellow-bellied slider).

5. No non-native amphibians or reptiles were detected.

6. The ARDs detected fewer species than expected, likely due to atypical weather conditions, so supplemental ARD monitoring will occur at 12 locations in 2011 and the full monitoring protocol will be implemented in 2013.

7. Observed amphibian-species richness is 19, and despite the ARDs not performing as well as expected, an evaluation of sampling effort relative to the number of species detected indicated that the sample adequately characterized species richness. Amphibian diversity is considered high at the Park.

8. Cope's gray treefrog, marbled salamander, and Southern leopard frog were the most widely distributed amphibians detected.

9. Five-lined skink, green anole, and Dekay's brown snake were the most widely distributed reptiles detected.

10. The full dataset, and associated metadata, can be acquired from the data store at http://science.nature.nps.gov/nrdata/

Introduction

Overview

Amphibian populations have exhibited declines in North America and many other areas around the world. Several factors are attributable to population declines and localized extinctions. Among these factors are disease and anthropogenic stressors such as habitat loss and degradation, non-native predators, acid precipitation, altered hydrology and hydroperiod, ultraviolet radiation, and chemical contaminants (Collins and Storfer 2003). Although diseases and parasites naturally occur in amphibian populations, the effects of these influences can be exacerbated when combined with other anthropogenic stressors.

Amphibians have complex life cycles, where the immature phase often consists of an aquatic larval stage, followed by a post-metamorphic adult terrestrial stage. Slight alterations in the aquatic or terrestrial communities upon which amphibians are dependent can have substantial impacts on the survival, reproduction, and persistence of a species. Given their habitat requirements, anatomy, and physiology, amphibians are considered good indicators of ecological condition.

The southeastern U.S. is host to one of the most diverse amphibian communities in the world. With an estimated 140 amphibian species, more than half of which are salamanders, the Southeast accounts for about half of the total number of amphibians in the U.S (Echternacht & Harris 1993, Petranka 1998). The Southeast Coast Network (SECN) has 61 known amphibian species; 26 in Caudata (salamanders, newts, amphiumas, sirens), and 35 in Anura (frogs and toads; Appendix A).

Given their known population declines, sensitivity to anthropogenic stressors, and the diversity of amphibians in the southeastern U.S., amphibian communities are a priority for SECN monitoring efforts.

The National Park Service Omnibus Management Act of 1998, and other reinforcing policies and regulations, require park managers "to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources" (Title II, Sec. 204). The amphibian-community monitoring data summarized herein is a tool to assist park managers in fulfilling this mandate.

This report summarizes data collected under the draft SECN Amphibian Community Monitoring Protocol (Byrne et al., *in preparation*).

Objective

- Determine trends in amphibian-species occupancy, distribution, diversity, and community composition in SECN parks.

Methods

Study Area

Congaree National Park (CONG) is located in central South Carolina approximately 30 km southeast of the capital city of Columbia (Figure 1). The 10,845-ha (26,800 ac) park is bordered to the south by the Congaree River and the Wateree River to the east. The Park consists of the largest contiguous old-growth bottomland-hardwood forest remaining in the United States. As such, it consists of a variety of aquatic and terrestrial community types, and, correspondingly, hosts a phenomenal diversity of flora and fauna. Because the Park is predominantly a floodplain, the vegetation communities are primarily driven by hydrologic process (i.e., hydroperiod) and soil type, and range from bald cypress (*Taxodium distichum*)- and water/swamp tupelo (*Nyssa aquatica*/*biflora*)-dominated communities to loblolly pine and longleaf pine (*Pinus taeda* and *P. palustris*) communities, and old pine plantations, that occur along the northern edge of the Park. The majority of the Park's vegetation communities, however, have a strong component of sugarberry (*Celtis laevigata*), sweetgum (*Liquidambar styraciflua*), and laurel oak (*Quercus laurifolia*) (American Geographic Data, Inc. 2001).

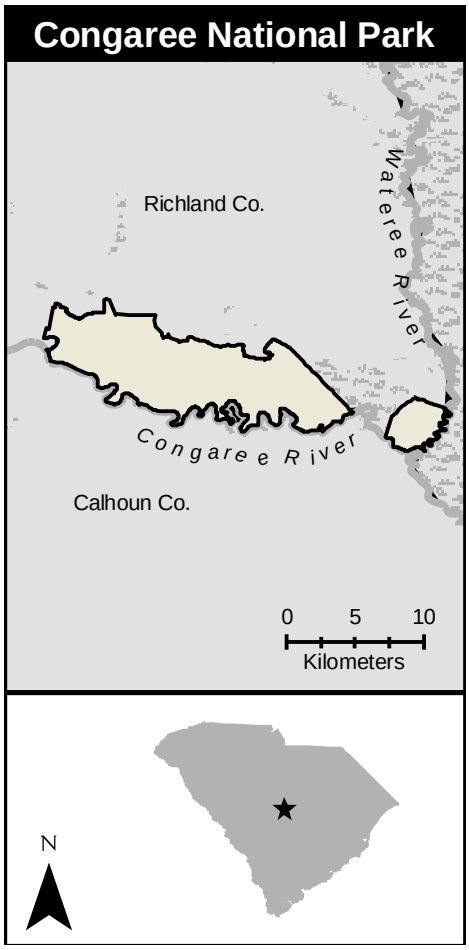

Figure 1. Location of Congaree National Park.

Due to the unique properties of the Park, it has been designated an International Biosphere Reserve, National Natural Landmark, Globally Important Bird Area, and also includes a 6,075-ha (15,010 ac) congressionally-designated Wilderness Area. Further, the Park is renowned for its numerous national- and state-champion trees.

Given the location of CONG within the watershed, the park is subject to a variety of aquatic-based stressors (i.e., pollutants) from upstream sources. Further, an unmanaged feral hog population (*Sus scrofa*) occurs at the Park and causes widespread rooting and herbivory damage. The Park has an active fire-management program to restore and maintain the upland communities (i.e., those dominated by *Pinus* spp.).

CONG has 32 known amphibian species and 37 known reptiles (Table A-1); which includes two amphibians and four reptiles added to the Park's official species list as a result of the 2010 monitoring efforts summarized herein. The amphibians consist of 23 species in Anura (frogs and toads) and nine species in Caudata (e.g., salamanders, newts, amphiumas, sirens). The reptiles consist of one species of Crocodilia, 28 species in Squamata (e.g., lizards, snakes, geckos, and skinks), and eight species in Testudines (turtles and tortoises).

Sampling Design

A detailed explanation of the sampling design and site selection can be found in the SECN Draft Amphibian Monitoring Protocol (Byrne et al., *in preparation*) and sample site selection SOP (Byrne 2009). In summary, to allow for park-wide inference, the Park's administrative boundary was used as the sampling frame. The sampling frame was divided into a systematic 0.5-ha grid; the center point of each grid cell served as the potential sampling site. A spatially-balanced sample was drawn from this grid using the Reversed Randomized Quadrant-Recursive Raster (RRQRR) algorithm (Theobald et al. 2007). Alternate points were used when selection criteria (i.e., including safety and access issues) were not met. A sample size of 30 was chosen after consideration of the Park's size, hypothesized variability, and logistical issues regarding travel time and conducting monitoring activities in five to six park units per year. Data were also collected at one additional sampling location due to favorable access conditions. Sampling locations are presented in Figure 2.

Sampling Methodology

Two sampling techniques are used as part of SECN amphibian monitoring; a combination of active and passive sampling techniques. The active technique is a time- and area-constrained medium-intensity visual encounter survey (VES) that incorporates dip-net techniques in sampling locations with aquatic communities. All species or species sign detected by sight or sound are recorded as part of the VESs. The passive technique is an automated-recording device (ARD) programmed to record one minute every ten minutes from dusk to dawn once every three days. Use of multiple techniques, as a "toolbox" approach (Olson et al. 1997), is generally agreed to be the most effective means to monitor amphibian communities (Hutchens and DePerno 2009). These sampling techniques are described in detail in Byrne (2007a) and Byrne (2007b).

ARDs were deployed from 4/10/2010 to 4/27/2010. A total of 9,408 minutes were recorded by all of the devices deployed the Park. VESs were conducted from 6/15/2010 to 7/2/2010. The ARD malfunctioned and did not record data at three sampling locations (13, 28, and A6).

Data Analysis

Because this is the first year of this protocol's implementation at the Park, only the status of the elements presented in the aforementioned monitoring objective are presented; except occupancy. The data in this report are summarized and presented in three general categories: diversity, composition, and distribution. Sampling locations are presented in Figure 2, labeled locations are presented in Appendix B, and species detected at each location are presented in Appendix C.

Despite a well-trained and dedicated field crew, complete identification of all individuals encountered was not always possible due to the quick and evasive nature of many species. Species were, however, identified to the most refined taxonomic level possible. Two factors are the most common challenges, animal-escape behavior and variability in identifying characteristics within some genera. For example, while the surveyors are approaching a small pool surrounded by dense vegetation, they catch brief glimpses of and hear several frogs dive into the pool prior to completing a full visual inspection of the individuals necessary for identification. Although the majority of these species could most likely be indentified to the genus or family level (i.e., Unknown *Rana* or Ranidae in this instance) based upon knowledge of the site and the local fauna, a conservative estimation is used and these species are identified to

Order as “Unknown Anuran”. Examples of very similar characteristics within genera where ranges their known ranges overlap are *Acris gryllus* / *A. crepitans* and many *Desmognathus* species. While reliable identification can be obtained for most of the species through physical characteristics or range discrimination, pooling to genus or group ensures consistency and does not adversely affect our knowledge of the site as these species are very likely to play a very similar role in the ecosystem.

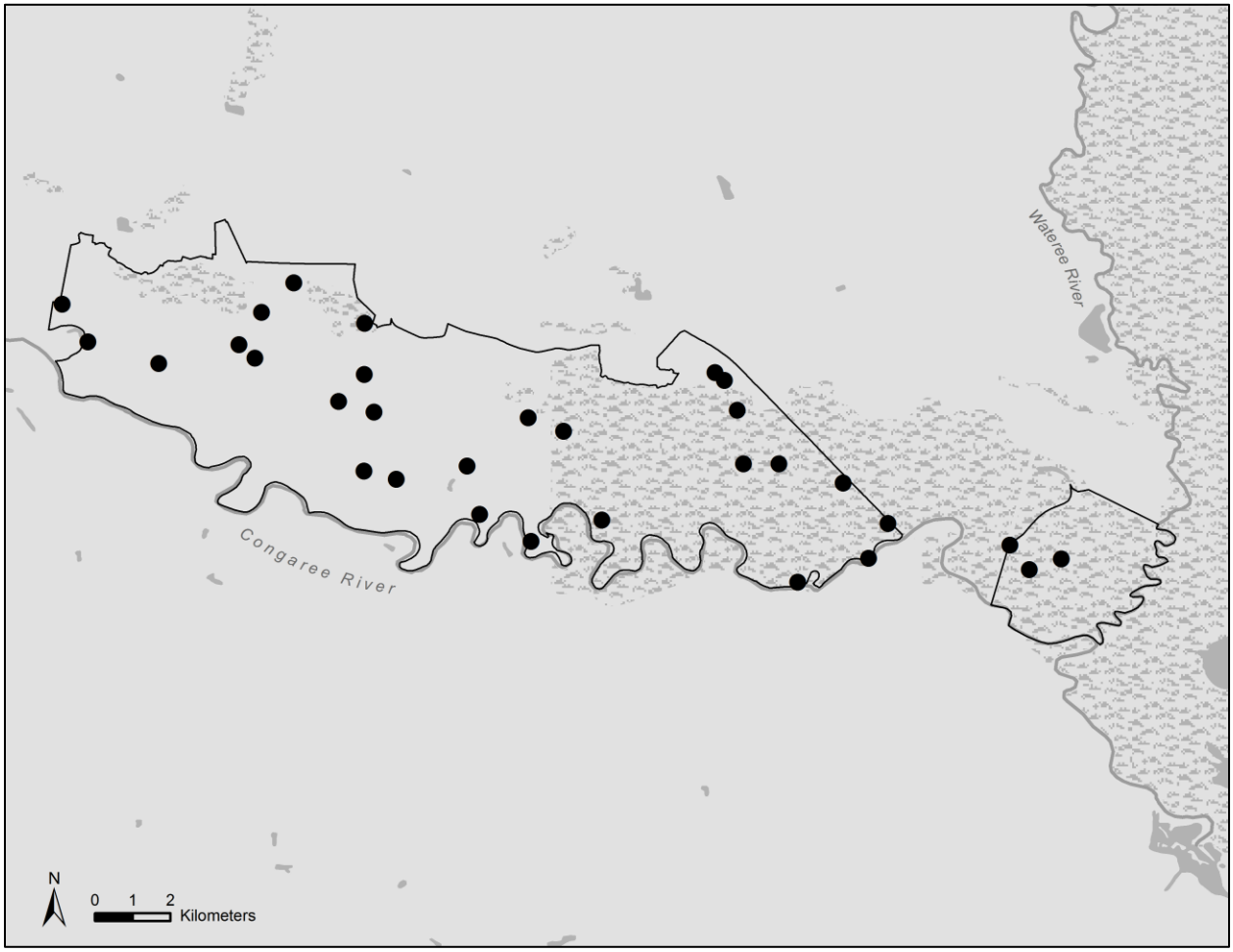

Figure 2. Spatially-balanced random sampling locations at CONG, 2010.

indentified to the genus or family level (i.e., Unknown *Rana* or Ranidae in this instance) based upon knowledge of the site and the local fauna, a conservative estimation is used and these species are identified to Order as “Unknown Anuran”. Examples of very similar characteristics within genera where ranges their known ranges overlap are *Acris gryllus* / *A. crepitans* and many *Desmognathus* species. While reliable identification can be obtained for most of the species through physical characteristics or range discrimination, pooling to genus or group ensures consistency and does not adversely affect our knowledge of the site as these species are very likely to play a very similar role in the ecosystem.

Although the primary purpose for implementing the aforementioned monitoring techniques as part of SECN monitoring efforts was to detect amphibians, reptiles were also encountered. It is

important to note that VESs and ARDs are not effective tools to survey for many reptile species, nor was the intent of VES implementation to target reptiles, but all reptile, and reptile sign detections are presented.

Diversity

Diversity is defined as "the variety and abundance of species in a defined unit of study" (Magurran 2004, p. 8). Diversity is a community property that is related to trophic structure, productivity, stability, (McIntosh 1967, McNaughton 1977), immigration / emigration (Colwell and Lees 2000), and ecological condition (i.e., ecological integrity as defined by Karr and Chu [1995]). Species diversity consists of two components: the number of species (species richness) and the relative abundance of those species (species evenness / dominance) within a defined community (Margalef 1958, Lloyd and Ghelardi 1964, Pielou 1966). Species diversity is often communicated in the form of diversity indices. The term community refers to the assemblage of species populations that occur together in space and time (Begon et al. 1986), and we consider the Park as a whole community as per the conceptual ecological models presented in our monitoring plan (see Chapter 2 in DeVivo et al. 2008).

Because diversity indices respond differently to various mechanisms that influence community change, several indices must be used to adequately characterize diversity in SECN parks (Haedrick 1975, Boyle et al. 1984). After careful appraisal of advantages and disadvantages of the many diversity indices, a suite of alpha diversity indices were selected to summarize these data (Table 1), where alpha diversity is the diversity of species within a defined area, community, or ecosystem (Whittaker 1972).

Species diversity estimates are based only on amphibian observations identified to the species level, as they were the primary target of this monitoring effort. Non-native amphibians were not included in diversity estimates. As previously mentioned, the methodologies used for amphibians are inadequate for the reptile community; therefore, diversity indices generated for reptiles would be biased and were not calculated.

Composition

Measures of community composition are often good indicators of abiotic variability, disturbance, or other stressors. Summaries related to sample composition include the total number of individuals and species detected, and proportional abundances of each species in the overall sample. For all species detected, a naïve estimate of occupancy is calculated as the proportion of sites where the species was detected at least once and unadjusted for probability of detection. All non-native species detections were pooled to calculate the proportion of sites where at least one non-native species was detected. Future data analyses will include estimates of occupancy adjusted for probability of detection (MacKenzie et al. 2002) and taking into account environmental covariates known to influence the probability of detection of amphibians (e.g., rainfall and temperature). Summaries of composition are presented for all amphibians, reptiles, and reptile sign (e.g., snake skin) detected.

Distribution

The distribution of species on park lands is integral to informed management. Further, changes in species distributions over time provides useful information regarding possible unseen influences that alter wildlife-habitat use and may be indicative of other issues. This section

presents maps of all sampling locations where each amphibian, reptile, and reptile sign was detected.

Table 1. Diversity indices used, corresponding symbol, community attribute the index reflects, the range of index values, and notes on each index.

Index	Symbol	Community Attribute	Index Citation	Notes
Native Spp. Richness	S_{obs}	Richness	n/a	Value is a positive integer that indicates the number of native species in the sample. Intuitive. Good discriminant ability if sampling effort is comparable; sensitive to sample size, the occurrence of rare species, or those with low detectability; does not account for relative abundances.
Chao 1	**Chao1**	Richness	Chao (1984) Chao (1987)	Values indicate an estimate of species richness; abundance-based estimate; works well with dataset containing several infrequent observations[a].
Chao 2	**Chao2**	Richness	Chao (1984) Chao (1987)	Values indicate an estimate of total species richness (including species not present in the sample); incidence-based estimate; works well with dataset containing several infrequent observations[a].
Abundance-based Coverage	**ACE**	Richness	Chao and Lee (1992) Chazdon et al. (1998)	Values indicate an estimate of species richness; abundance-based estimate.
Incidence-based Coverage	**ICE**	Richness	Lee and Chao (1994) Chazdon et al. (1998)	Values indicate an estimate of total species richness (including species not present in the sample); incidence-based estimate.
Jackknife 1	**Jack1**	Richness	Burnham and Overton (1978) Burnham and Overton (1979) Heltshe and Forrester (1983)	Values indicate an estimate of total species richness (including species not present in the sample); incidence-based estimate; The higher the value the higher the species richness. This procedure requires no assumptions regarding the data distribution.
Jackknife 2	**Jack2**	Richness	Smith and van Belle (1984)	Values indicate an estimate of species richness; incidence-based estimate.
Bootstrap	**Boot**	Richness	Smith and van Belle (1984)	Values indicate an estimate of species richness; incidence-based estimate.

Table 1. (Continued)

Index	Symbol	Community Attribute	Index Citation	Notes
Fisher's α	**α**	Richness	Fisher et al. (1943)	Value is a positive integer and indicates a relative estimate of species richness; good discriminant ability, low sensitivity to sample size, and robust to deviations in the assumed distribution [b, c, d, e]; abundance-based estimate.
Q Statistic	**Q**	Richness	Kempton and Taylor (1976) Kempton and Taylor (1978)	Value is a positive integer and indicates a relative estimate of species richness. Good discriminant ability and low bias with small samples[f], model fit is irrelevant to index performance[g]; value is not weighted towards abundant or rare species; abundance-based estimate.
Smith and Wilson	$\mathbf{E_{var}}$	Evenness	Smith and Wilson (1996)	Values range from 0 (no evenness) to 1 (perfectly even and all species exists in relatively equal abundance); weighs common species more heavily than rare species (desirable in certain cases).
Smith and Wilson 1/D	$\mathbf{E_{1/D}}$	Evenness	Smith and Wilson (1996) Simpson (1949)	Values range from 0 (no evenness) to 1 (perfectly even and all species exists in relatively equal abundance); weighs rare and abundant species equally (desirable in certain cases).
Camargo	**E'**	Evenness	Camargo (1992)	Values range from 0 (no evenness) to 1 (perfectly even and all species exists in relatively equal abundance); performs well estimating intermediate values of evenness than the other indices; weighs rare and abundant species equally (desirable in certain cases).
Gini	$\mathbf{E_G}$	Evenness	Gini (1912)	Values range from 0 (no evenness) to 1 (perfectly even and all species exists in relatively equal abundance); Good discriminant ability and low sensitivity to sample size[h].
Berger-Parker	$\mathbf{D_{BP}}$	Dominance	Berger and Parker (1970)	Values range from 0 (no single-species dominance) to 1 (sample is strongly dominated by a single species); describes the proportional dominance of the single most abundant species; low sensitivity to sample size but poor discriminant ability[i] – not used for across year or site comparisons.

[a] (Chao 1984), [b](Kempton 2002), [c](Kempton and Taylor 1974), [d](Hayek and Buzas 1997), [e](Wolda 1983), [f](Kempton and Wedderburn 1978), [g](Magurran 1988), [h](Lexerød and Eid 2006), [i](Magurran 2004)

Results

Diversity

Diversity indices calculated for these data were selected to reflect community composition (i.e., number of species) and structure (i.e., number of individuals), which include species richness and evenness estimates (Table 2). Confidence intervals for each diversity index were estimated with a bootstrap procedure. A brief explanation of interpreting the value is presented in Table 2.

Rank-abundance plots, frequency distributions, and other descriptive approaches were used to explore the abundance distributions and patterns in the dataset, and evaluate the utility of select indices and abundance equitability among species. The data are best fit by a log-normal abundance model; χ^2=1.6084, df=3, p=0.6575. The dispersion (i.e., the variance / mean) also suggest that species are not aggregated and occur randomly at the Park.

The species accumulation curve generated from the data asymptotes at approximately 28 samples (i.e., less than the total number of samples collected), validating the sample size as effective in characterizing amphibian diversity at the Park.

Observed species richness (i.e., S_{obs}) was 19 (95% CI: 14.98, 22.22), including two new amphibian species added to the species list as a result of the monitoring results presented herein, *Eurycea quadridigitata* (dwarf salamander) and *Rana clamitans clamitans* (bronze frog). Several species-richness estimators are relatively consistent with one another (Table 2). Because of the uncertainty associated with the Chao estimators (as indicated by the high confidence intervals) due to the characteristics of the dataset, the ACE, ICE, Jack1, Jack2, and Boot richness estimators are likely better estimates of true species richness. Not surprisingly, diversity indices suggest high amphibian-species diversity at the Park (α=4.10, Q=3.29;Table 2). The sample was not dominated by any one particular species; however four species composed approximately 75% of the sample (Figure 3). The approximately-equal relative abundances of several species explain the different performance of the evenness/dominance indices (i.e., E' and D_{BP} suggest high evenness and E_{var}, $E_{1/D}$, and E_G suggest medium evenness. Because 2010 monitoring efforts were the first for this vital sign, these values will serve as a baseline to which to compare when the Park is sampled again.

Composition

Amphibians

We detected 1,132 amphibians in 24 species, genera, or order. The majority (53%) of the overall sample consisted of unidentified larvae (unidentifiable due to the distance of the tadpoles from observers). This component of the sample, however, was not included in Figure 3 in order to better depict the structure of the components of the sample that were further indentified. Approximately 75% of the sample was composed of four species [in order of relative abundance, Cope's gray treefrog (*Hyla chrysoscelis*) larval and post-metamorphic, marbled salamander (*Ambystoma opacum*), *Desmognathus* sp. (dusky salamander), and Southern leopard frog (*Rana sphenocephala*);(Figure 3)]. Occupancy provides insight into the distribution of species across the park and whether a species is commonly or uncommonly encountered; however, this is strongly influenced by a species' detectability (which will be accounted for in future analyses) as more-easily detected species may be more frequently encountered (and vice versa). Cope's gray

treefrog (0.71), marbled salamander (0.64), Southern leopard frog (0.59), and Southern toad (*Bufo terrestris*) (0.45) had the highest rates of occupancy (Table 3). No non-native species were detected.

Table 2. Amphibian alpha-diversity estimates at CONG, 2010.

Index	Symbol	Value	Lower 95% CI	Upper 95% CI	Value Interpretation
Native Spp. Richness	S_{obs}	19.00	14.98	22.22	Number of native species detected
Chao 1	**Chao1**	23.69	19.31	55.87	Estimated true species richness (high CI)
Chao 2	**Chao2**	24.94	19.73	54.94	Estimated true species richness (high CI)
Abundance-based Coverage	**ACE**	23.15	17.52	28.78	Estimated true species richness
Incidence-based Coverage	**ICE**	24.43	18.55	30.31	Estimated true species richness
Jackknife 1	**Jack1**	24.50	17.76	31.24	Estimated true species richness
Jackknife 2	**Jack2**	26.75	21.01	32.49	Estimated true species richness
Bootstrap	**Boot**	21.35	19.02	23.68	Estimated true species richness
Fisher's α	**α**	4.10	3.81	4.39	Baseline value, suggests high diversity
Q Statistic	**Q**	3.29	2.58	4.24	Baseline value, suggests high diversity
Smith and Wilson	E_{var}	0.46	0.32	0.51	Species occur in several relative abundances –medium evenness
Smith and Wilson 1/D	$E_{1/D}$	0.49	0.44	0.54	Species occur in several relative abundances –medium evenness
Camargo	**E'**	0.98	0.92	1.00	Species occur in fairly equal relative abundances – high evenness
Gini	E_G	0.47	0.33	0.61	Species occur in several relative abundances –medium evenness
Berger-Parker	D_{BP}	0.19	0.17	0.23	Sample is not dominated by a single species – high evenness

Reptiles

We detected 58 reptiles and reptile signs in 18 species, genera, order, or sign. Four species were additions to the Park's species list: *Elaphe obsoleta obsoleta* (black rat snake), *Elaphe alleghaniensis* (Eastern rat snake, yellow rat snake), red-bellied water snake (*Nerodia erythrogaster erythrogaster*), and *Trachemys scripta scripta* (yellow-bellied slider). Four species composed half of the sample (Figure 4), five-lined skink (*Eumeces fasciatus/inexpectatus*) Dekay's brown snake (*Storeria dekayi*), green anole (*Anolis carolinensis*), and cottonmouth (*Agkistrodon piscivorus*). Five-lined skink (0.23), green anole (0.19), and Dekay's brown snake (0.16) had the highest rates of occupancy (Table 4). No non-native species were detected.

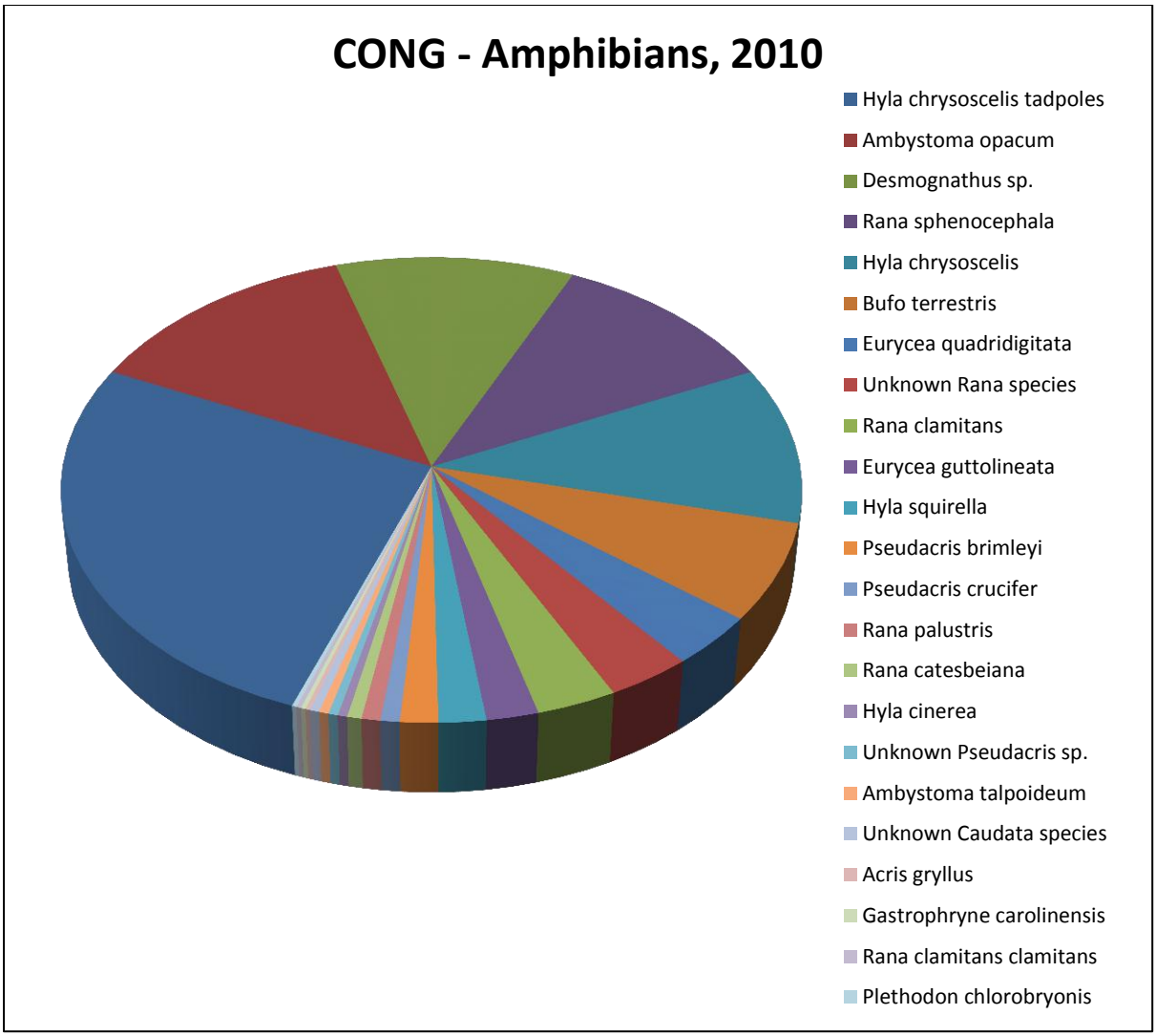

Figure 3. Proportions of amphibian species at CONG, 2010.

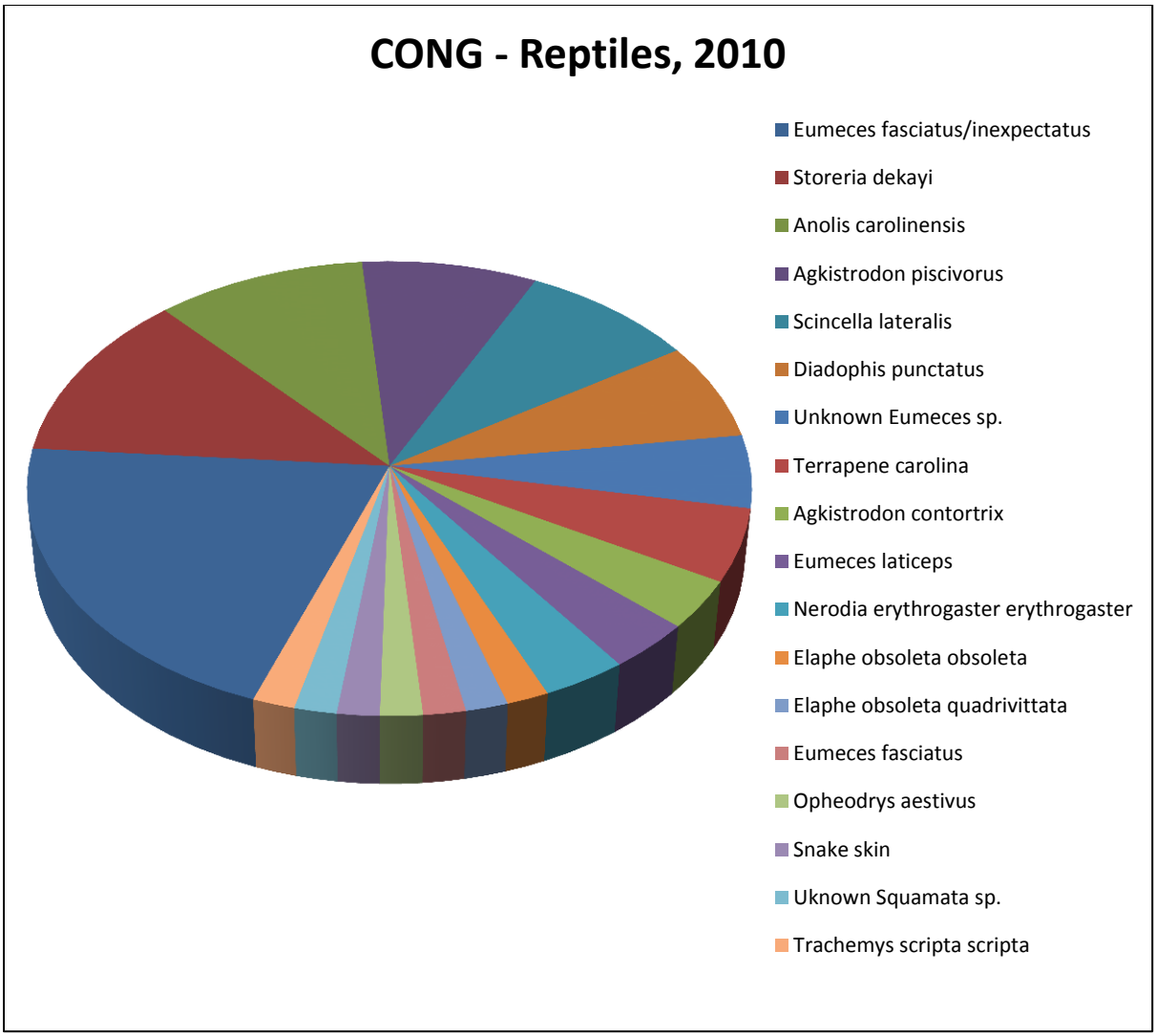

Figure 4. Proportion of reptile species and reptile signs at CONG, 2010.

Table 3. Naïve occupancy estimates (proportion of sites where the species was detected) for amphibians at CONG, 2010.

Scientific Name	Common Name	Naïve occupancy
Hyla chrysoscelis	Cope's Gray Treefrog	0.74
Ambystoma opacum	Marbled Salamander	0.61
Rana sphenocephala	Southern Leopard Frog	0.58
Bufo terrestris	Southern Toad	0.45
Unk. *Rana* sp.	NA	0.26
Eurycea quadridigitata	Dwarf Salamander	0.19
Rana clamitans	Green Frog	0.19
Desmognathus sp.	Dusky Salamander	0.16
Hyla squirella	Squirrel Treefrog	0.16
Hyla chrysoscelis tadpoles	Cope's Gray Treefrog tadpoles	0.10
Pseudacris crucifer	Spring Peeper	0.10
Eurycea guttolineata	Three-lined Salamander	0.06
Hyla cinerea	Green Treefrog	0.06
Rana catesbeiana	Bullfrog	0.06
Rana palustris	Pickerel Frog	0.06
Unk. *Caudata* sp.	NA	0.06
Acris gryllus	Southern Cricket Frog	0.03
Ambystoma talpoideum	Mole Salamander	0.03
Gastrophryne carolinensis	Eastern Narrow-mouthed Toad	0.03
Plethodon chlorobryonis	Atlantic Coast Slimy Salamander	0.03
Pseudacris brimleyi	Brimley's chorus frog	0.03
Rana clamitans clamitans	Bronze Frog	0.03
Unk. *Pseudacris* sp.	NA	0.03

Table 4. Naïve occupancy estimates (proportion of sites where the species was detected) for reptiles and reptile sign at CONG, 2010.

Scientific Name	Common Name	Naïve occupancy
Eumeces fasciatus/inexpectatus	Five-lined Skink	0.23
Anolis carolinensis	Green Anole	0.19
Storeria dekayi	Dekay's Brown Snake	0.16
Diadophis punctatus	Ring-necked Snake	0.13
Agkistrodon piscivorus	Cottonmouth	0.10
Terrapene carolina	Eastern Box Turtle	0.10
Agkistrodon contortrix	Copperhead	0.06
Eumeces laticeps	Broad-headed Skink	0.06
Nerodia erythrogaster erythrogaster	Red-bellied Water Snake	0.06
Scincella lateralis	Ground Skink	0.06
Unk.*Eumeces* sp.	NA	0.06
Elaphe obsoleta obsoleta	Black Rat Snake	0.03
Elaphe obsoleta quadrivittata	Yellow Rat Snake	0.03
Eumeces fasciatus	Five-lined Skink	0.03
Opheodrys aestivus	Rough Green Snake	0.03
Snake skin	NA	0.03
Trachemys scripta scripta	Yellow-bellied Slider	0.03

Distribution

Figures 5–44 are distribution maps for all species and species-sign that were detected during surveys. The locations of the detections, as well as the locations where the species or species sign was not detected are presented.

Amphibians

Cope's gray treefrog occurred at nearly three-quarters of all sampling locations (Figure 8). Marbled salamander (Figure 21) and Southern leopard frog (Figure 19) occurred at well over half of the sampling locations while Southern toad occurred at just under half. Sampling location #5 was the only location where no amphibians or reptiles were detected.

Reptiles

Five-lined skink was the most widely distributed species (Figure 32), followed by green anole (Figure 28), and Dekay's brown snake (Figure 40).

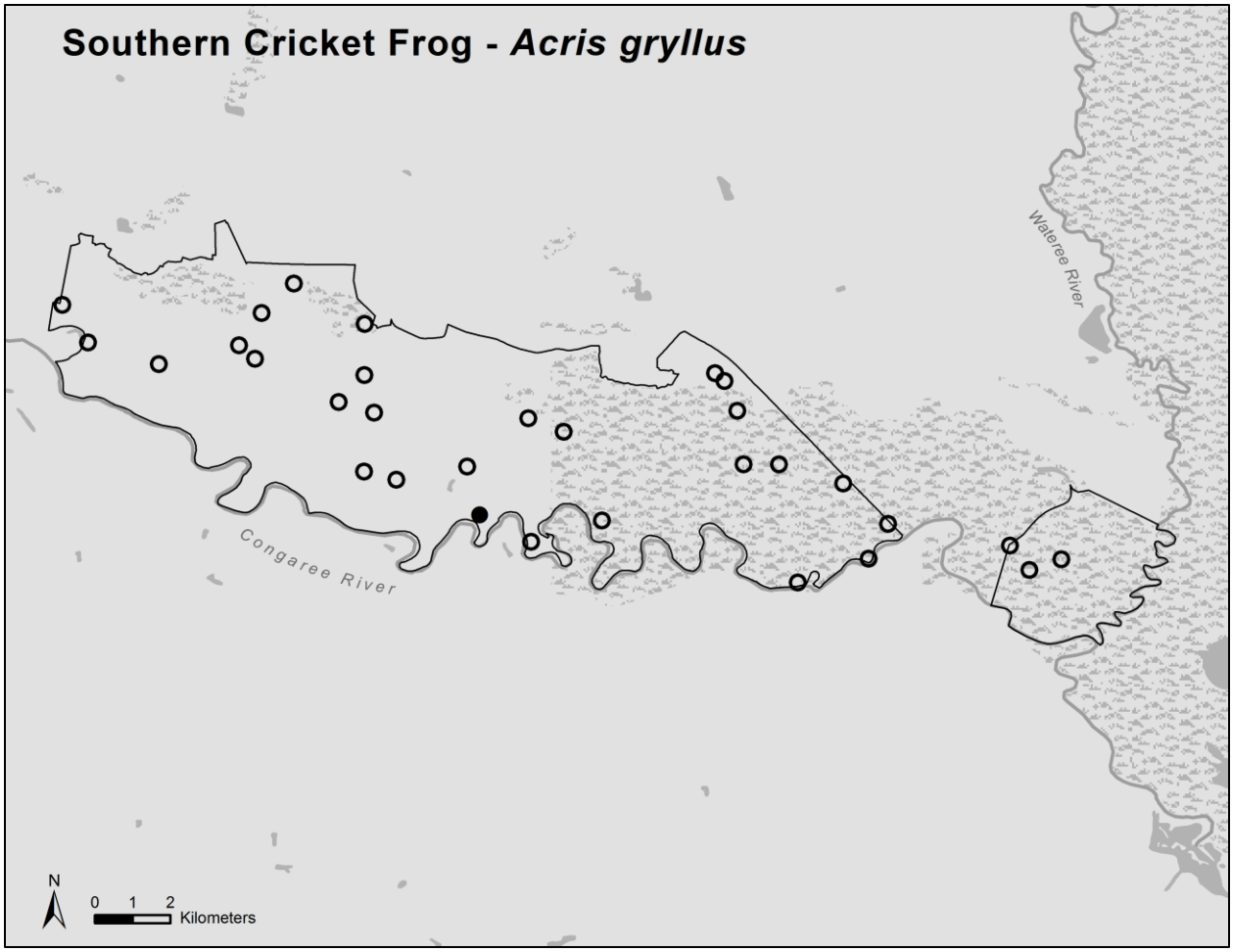

Figure 5. Sampling locations where Southern cricket frog (*Acris gryllus*) was detected at CONG, 2010. ● = detected, ○ = not detected.

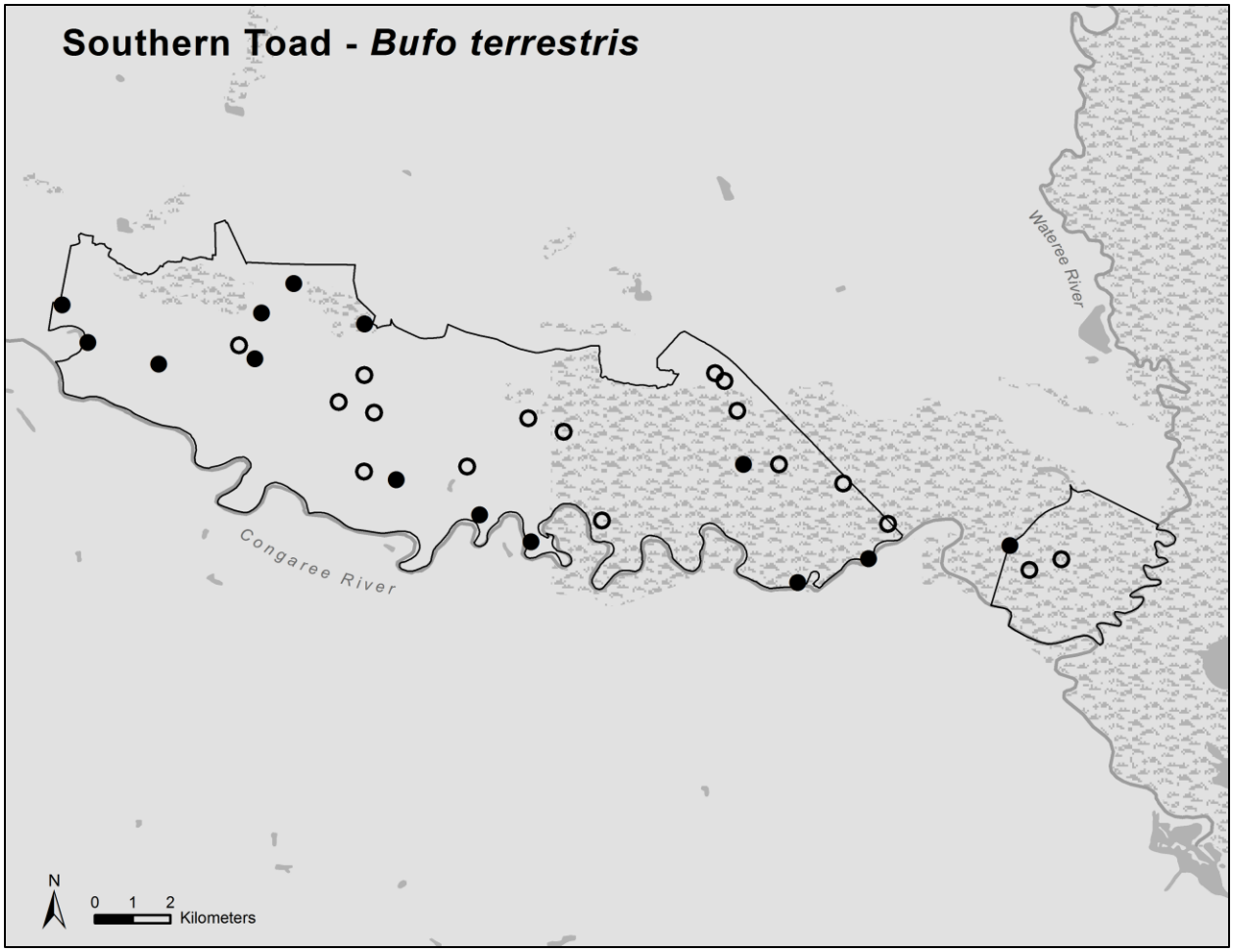

Figure 6. Sampling locations where Southern toad (*Bufo terrestris*) was detected at CONG, 2010.
● = detected, ○ = not detected.

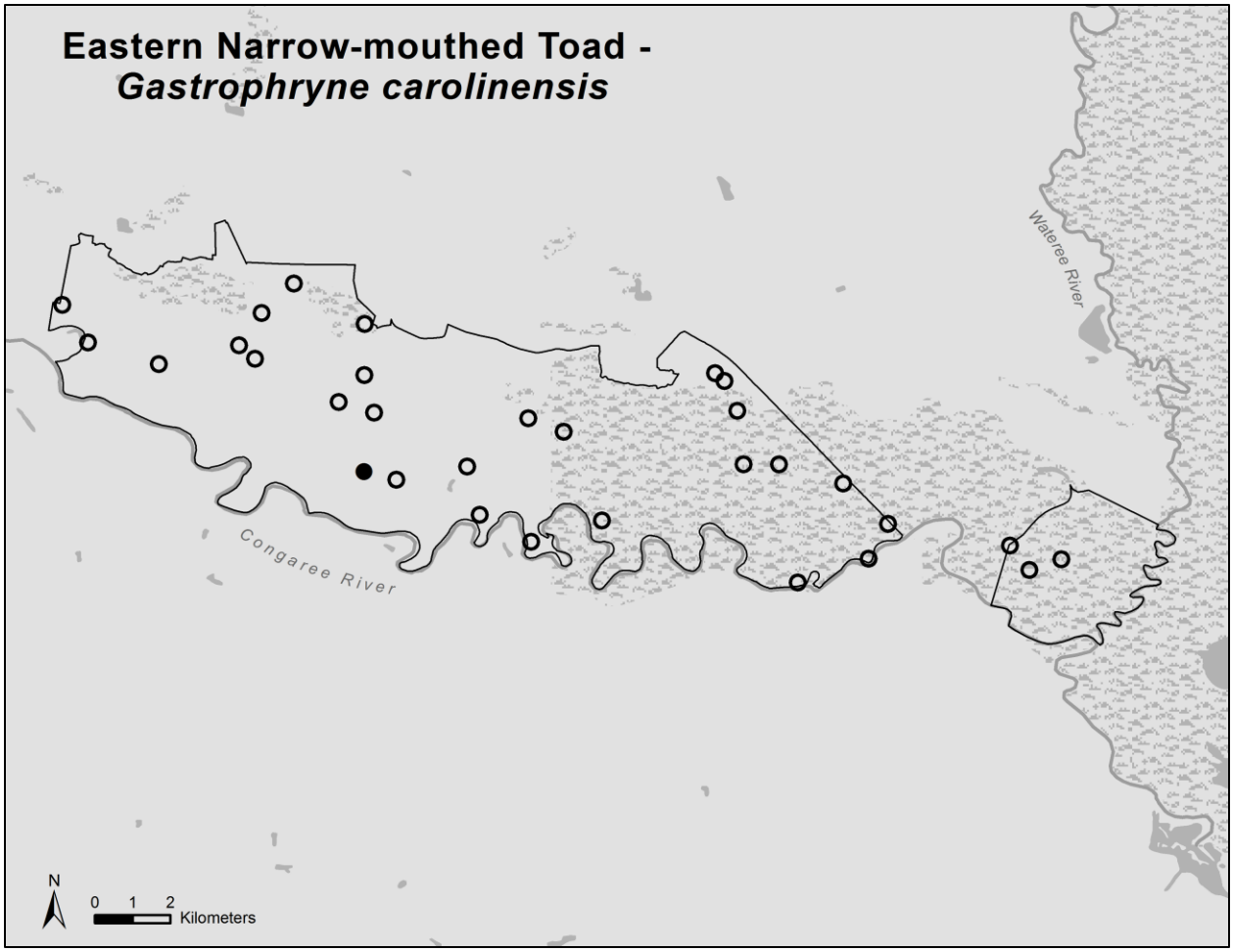

Figure 7. Sampling locations where eastern narrow-mouthed toad (*Gastrophryne carolinensis*) was detected at CONG, 2010. ● = detected, ○ = not detected.

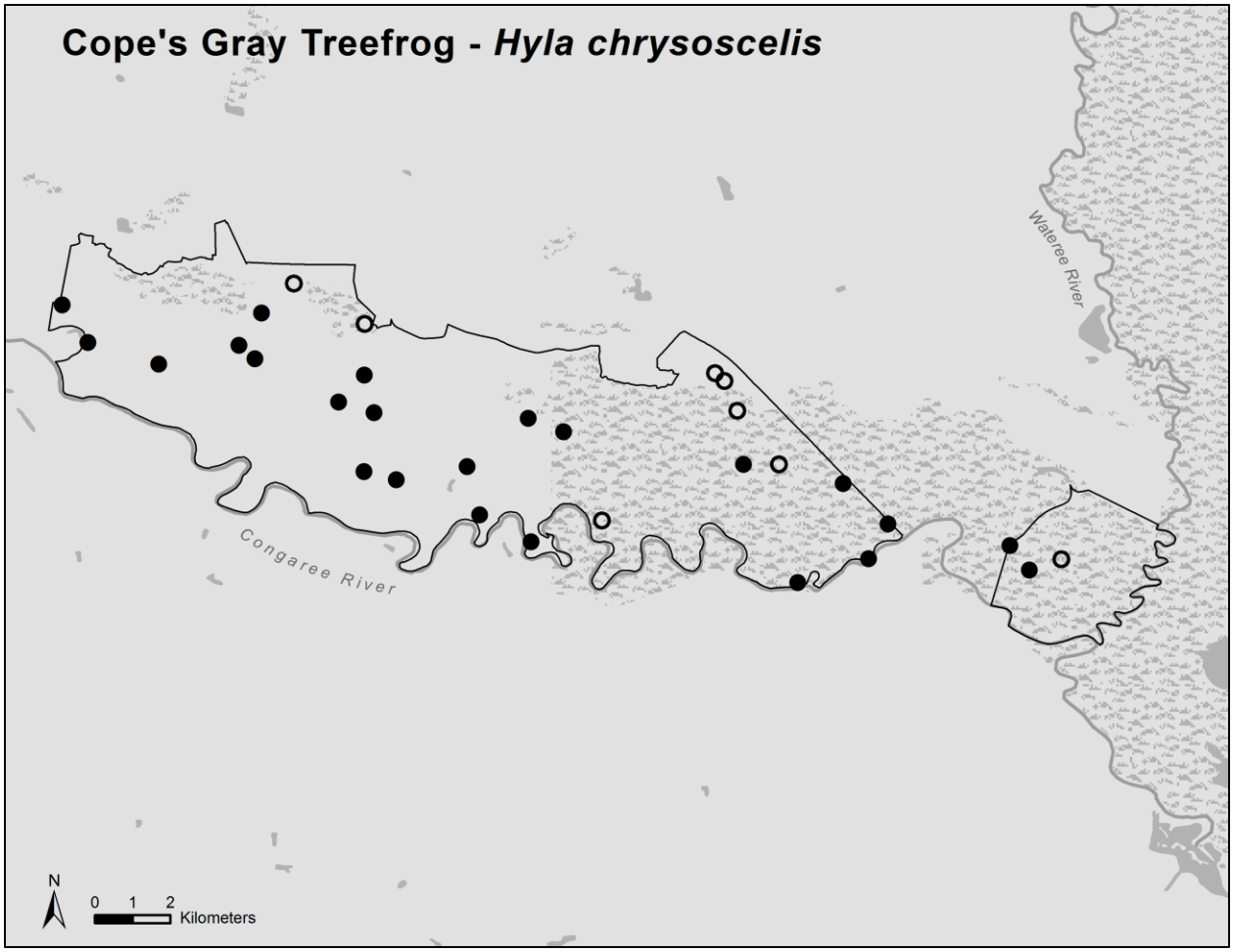

Figure 8. Sampling locations where Cope's gray treefrog (*Hyla chrysoscelis*) was detected at CONG, 2010. ● = detected, ○ = not detected.

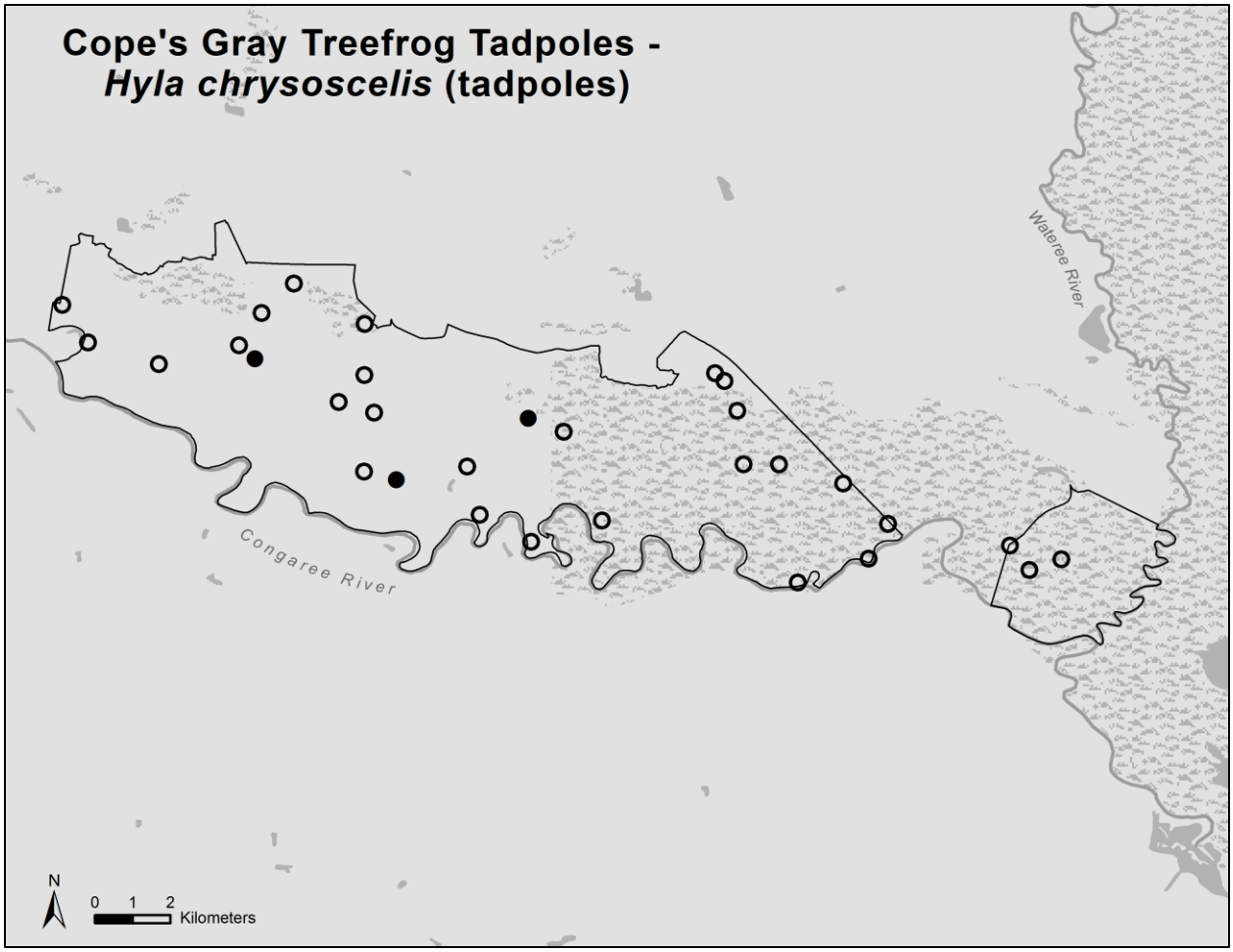

Figure 9. Sampling locations where Cope's gray treefrog tadpoles were detected at CONG, 2010.
● = detected, ○ = not detected.

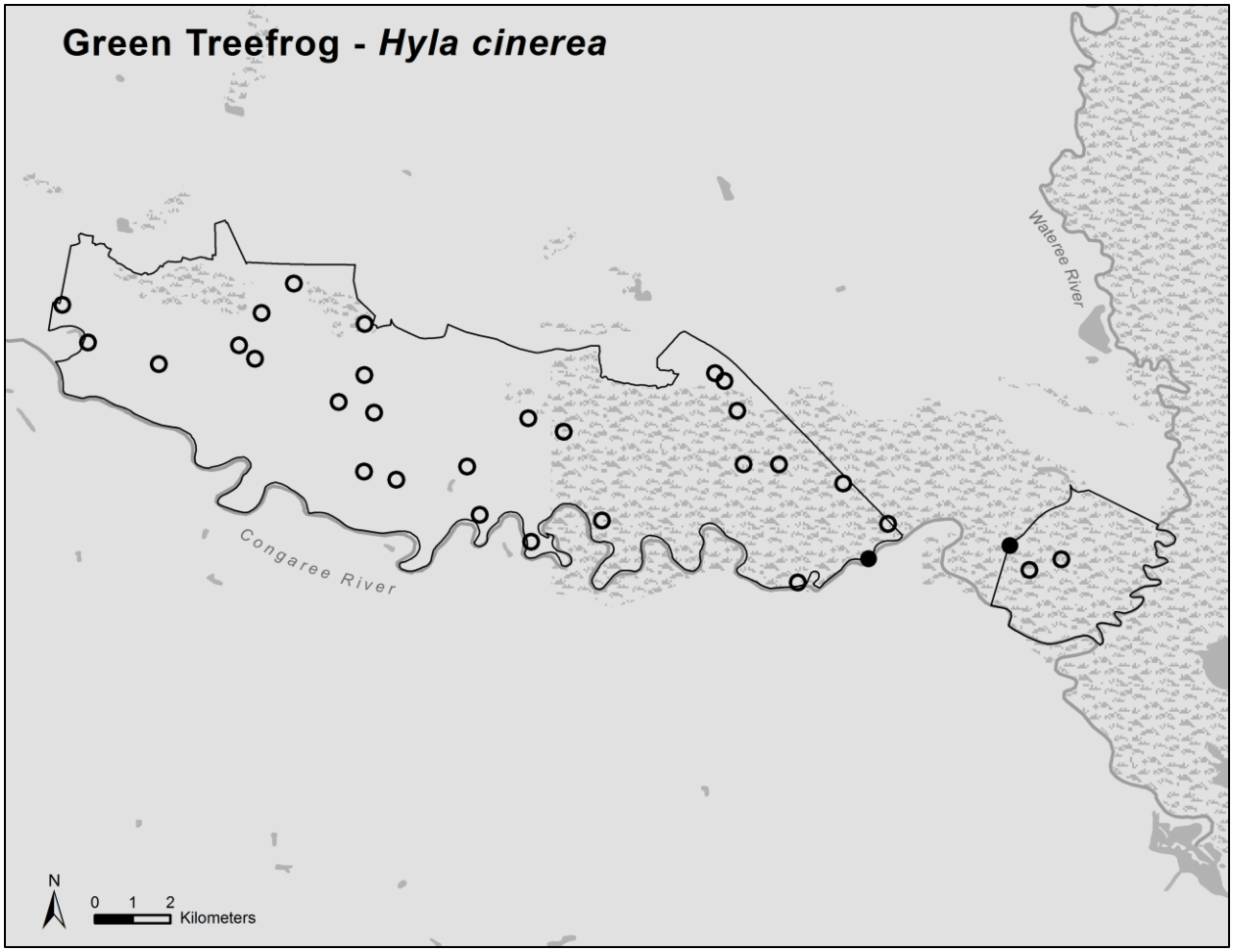

Figure 10. Sampling locations where green treefrog (*Hyla cinerea*) was detected at CONG, 2010. ● = detected, ○ = not detected.

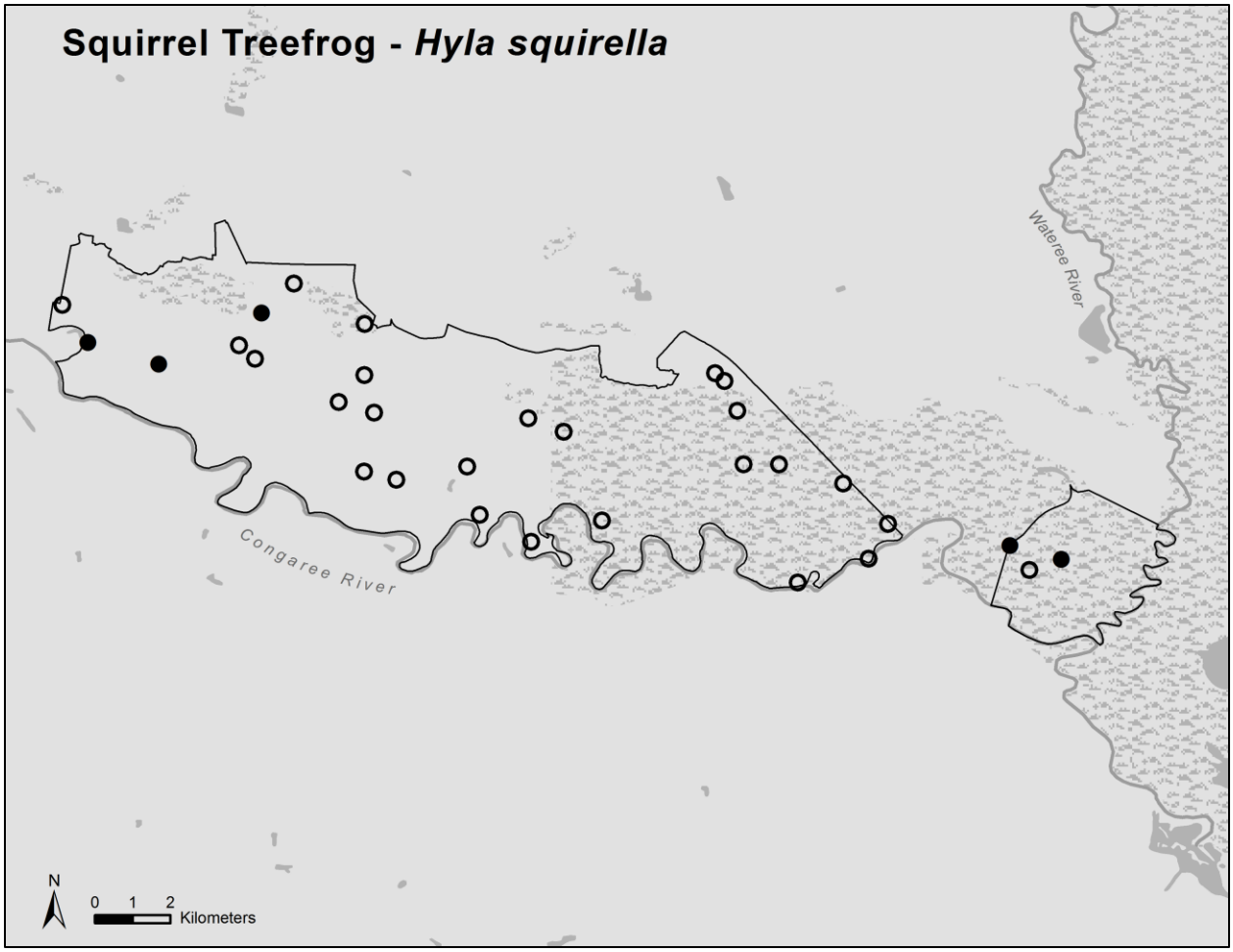

Figure 11. Sampling locations where squirrel treefrog (*Hyla squirella*) was detected at CONG, 2010. ● = detected, ○ = not detected.

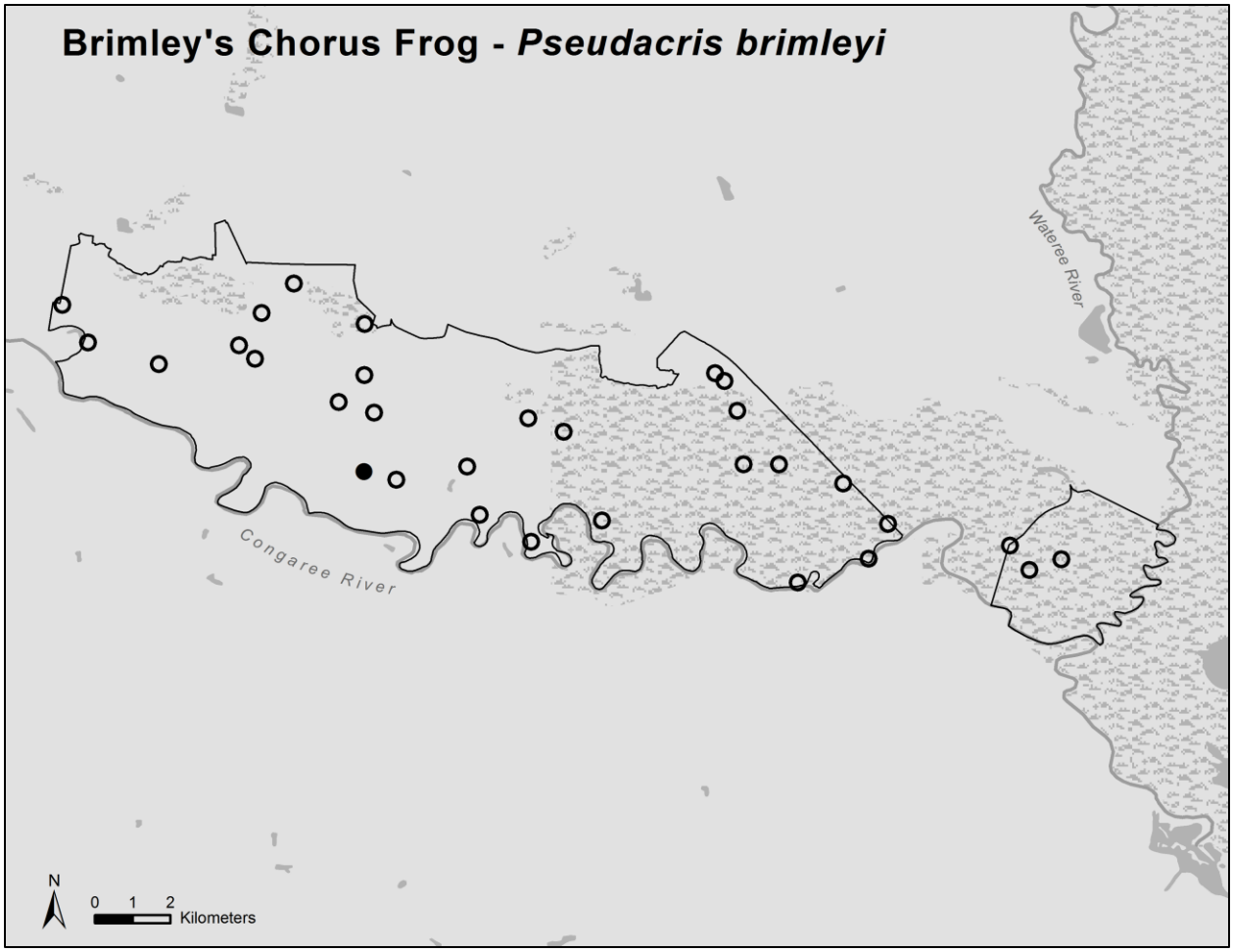

Figure 12. Sampling locations where Brimley's chorus frog (*Pseudacris brimleyi*) was detected at CONG, 2010. ● = detected, ○ = not detected.

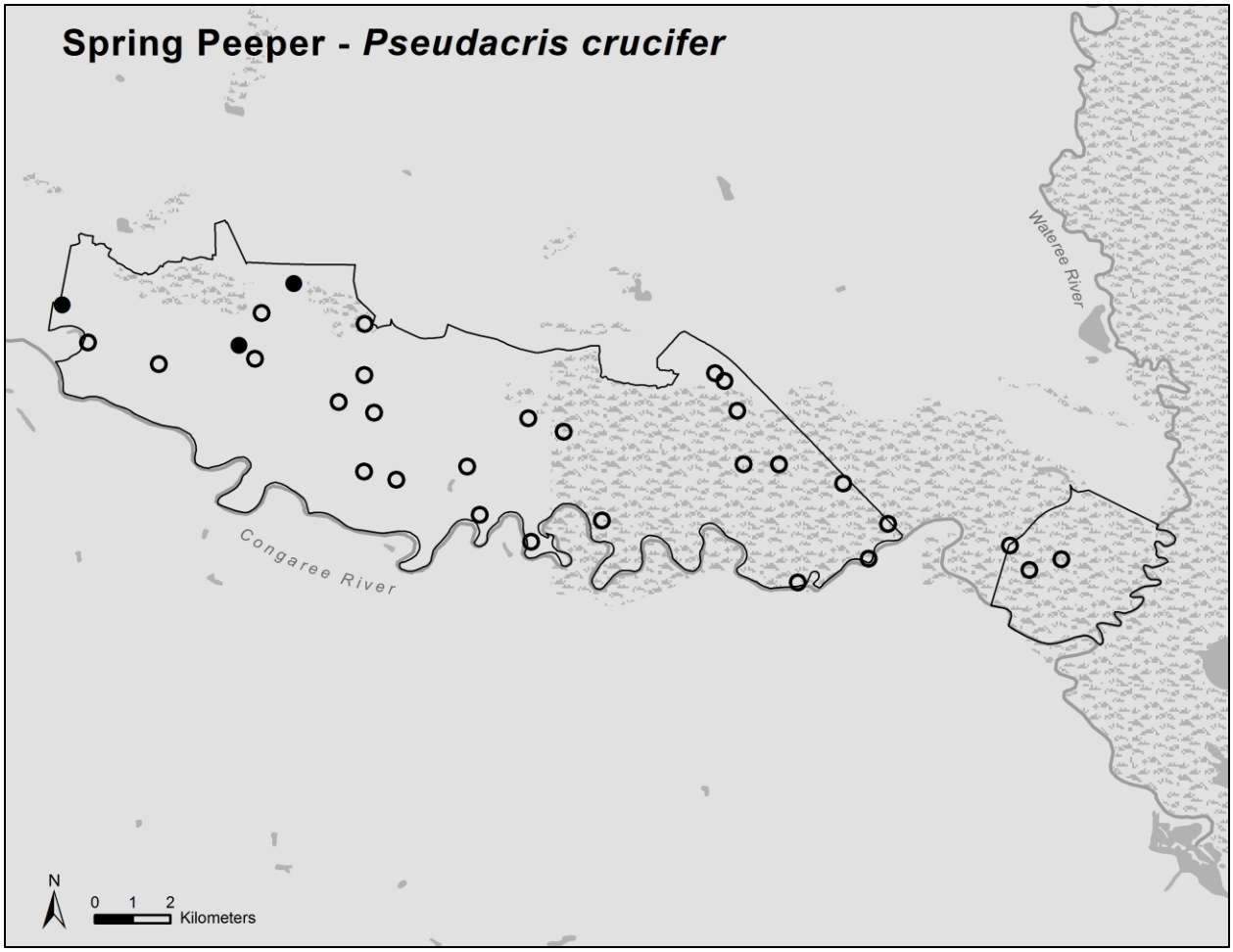

Figure 13. Sampling locations where Spring peeper (*Pseudacris crucifer*) was detected at CONG, 2010. ● = detected, ○ = not detected.

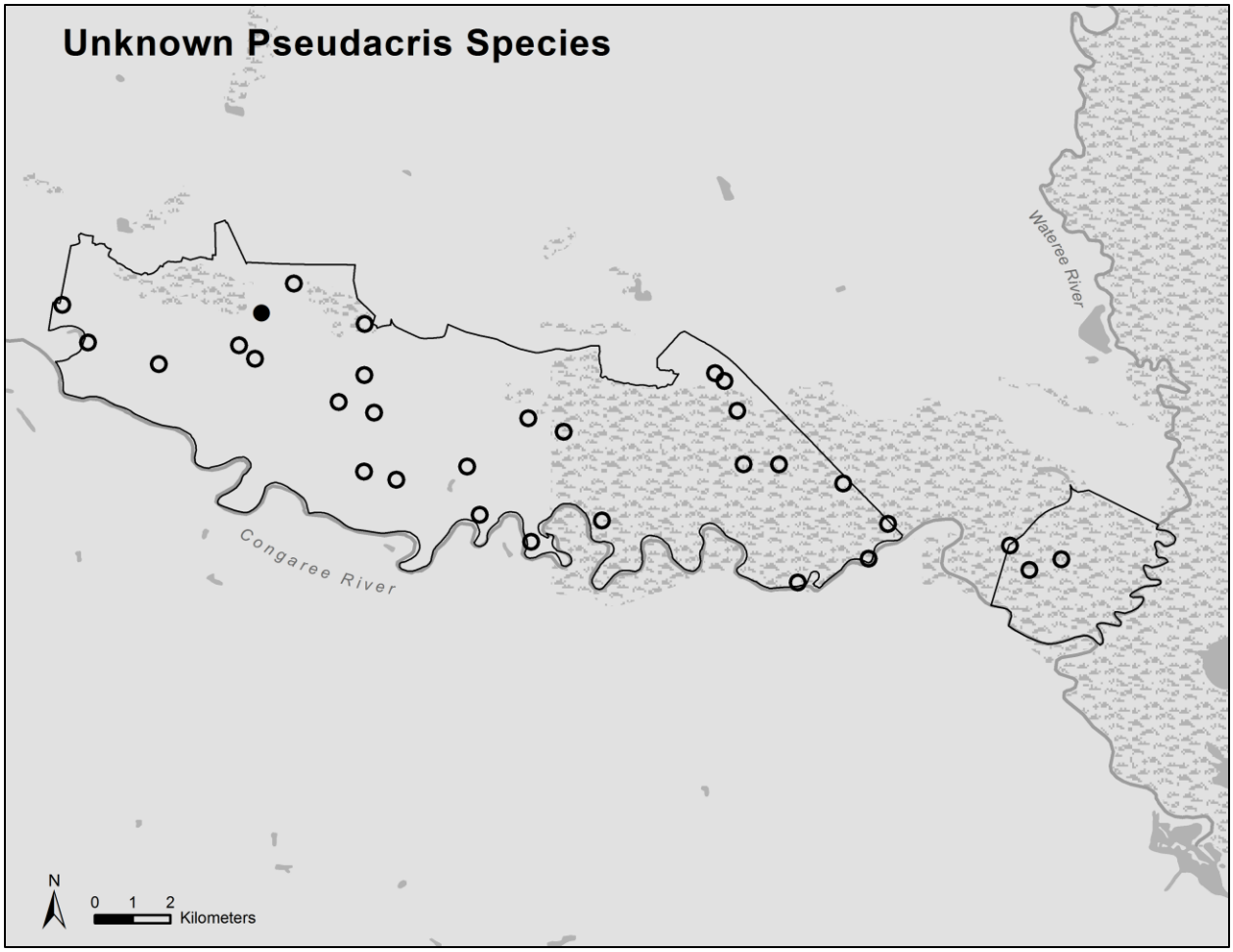

Figure 14. Sampling locations where unknown *Pseudacris* sp. was detected at CONG, 2010.
● = detected, ○ = not detected.

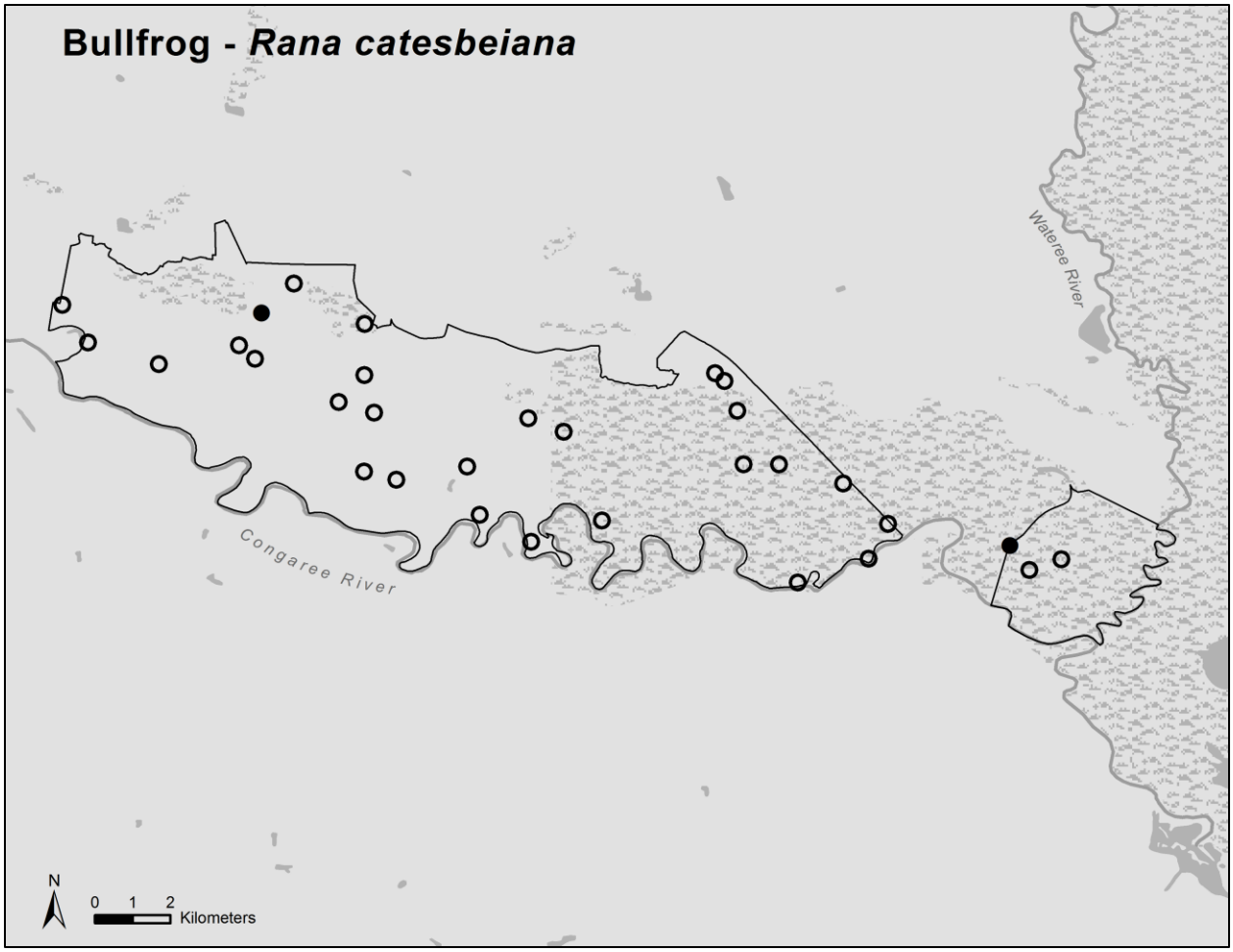

Figure 15. Sampling locations where bullfrog (*Rana catesbeiana*) was detected at CONG, 2010. ● = detected, ○ = not detected.

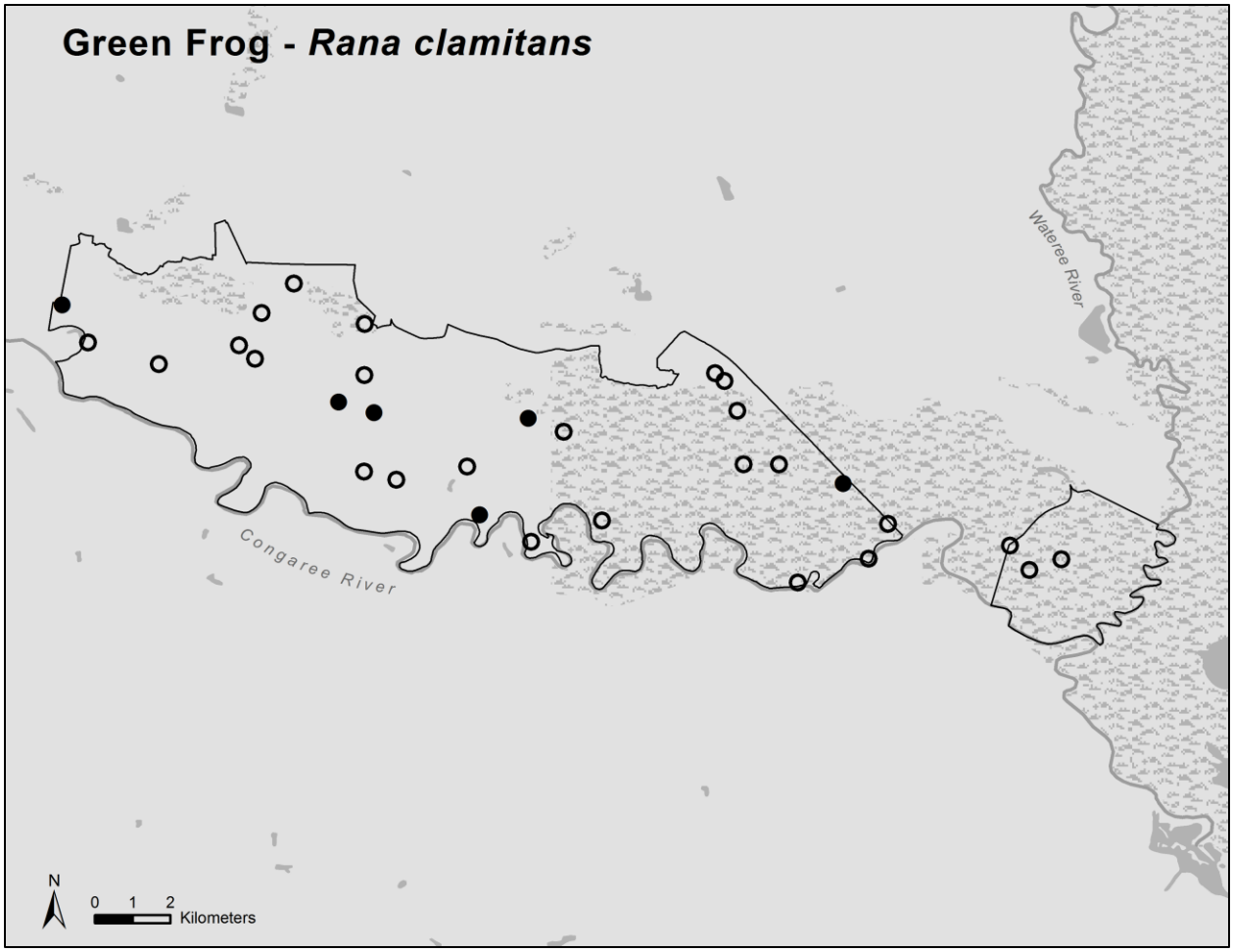

Figure 16. Sampling locations where green frog (*Rana clamitans*) was detected at CONG, 2010.
● = detected, ○ = not detected.

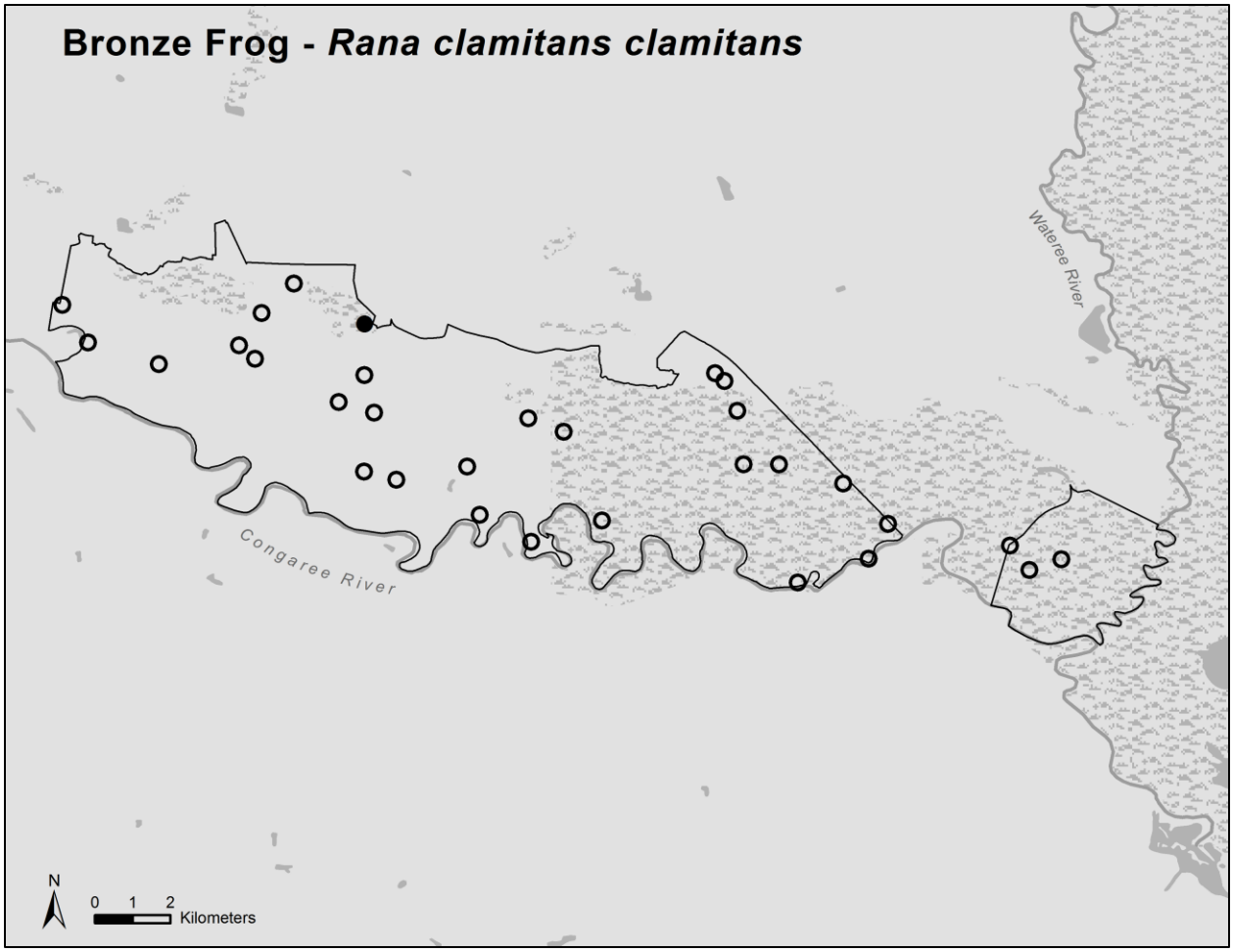

Figure 17. Sampling locations where bronze frog (*Rana clamitans clamitans*) was detected at CONG, 2010. ● = detected, ○ = not detected.

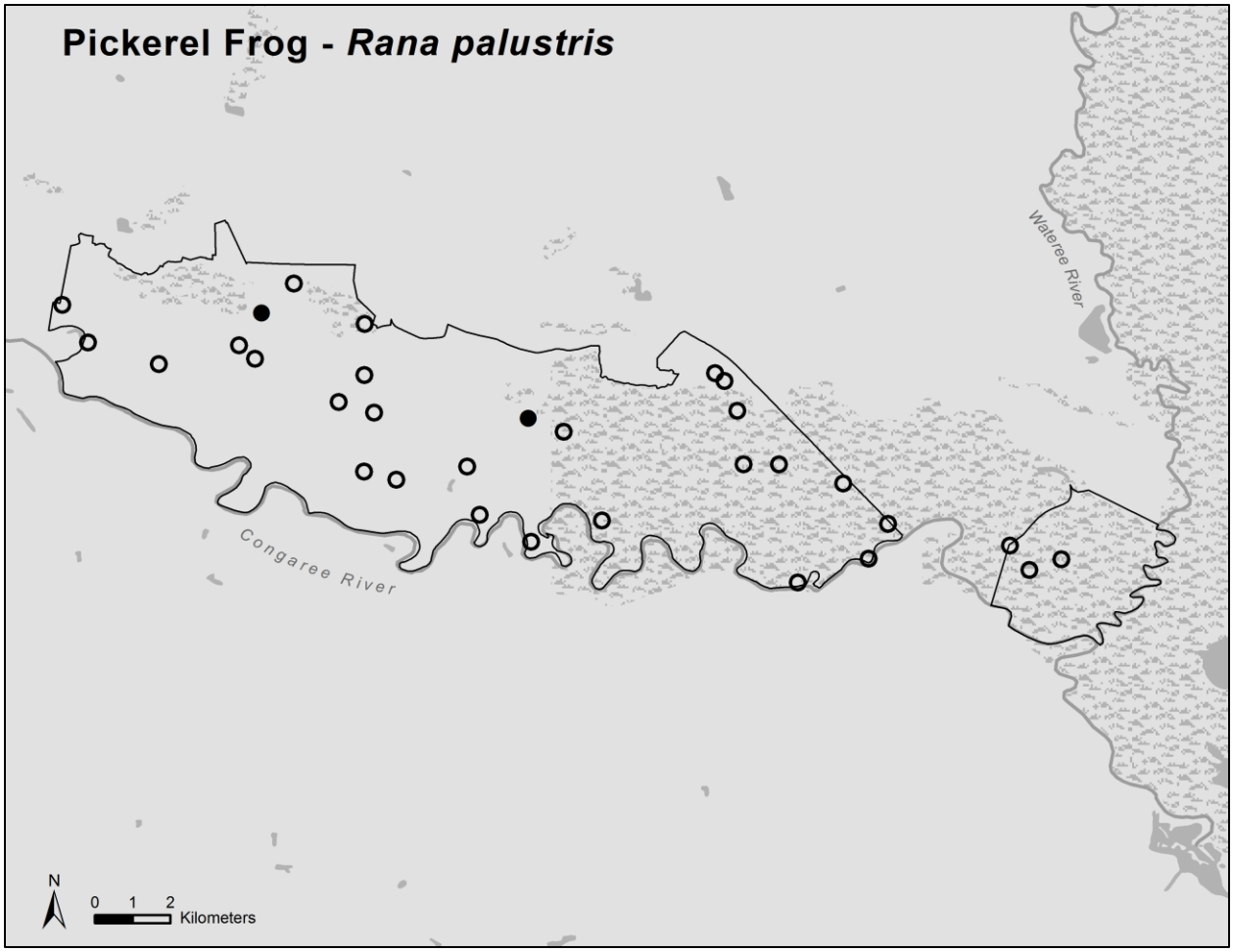

Figure 18. Sampling locations where pickerel frog (*Rana palustris*) was detected at CONG, 2010.
● = detected, ○ = not detected.

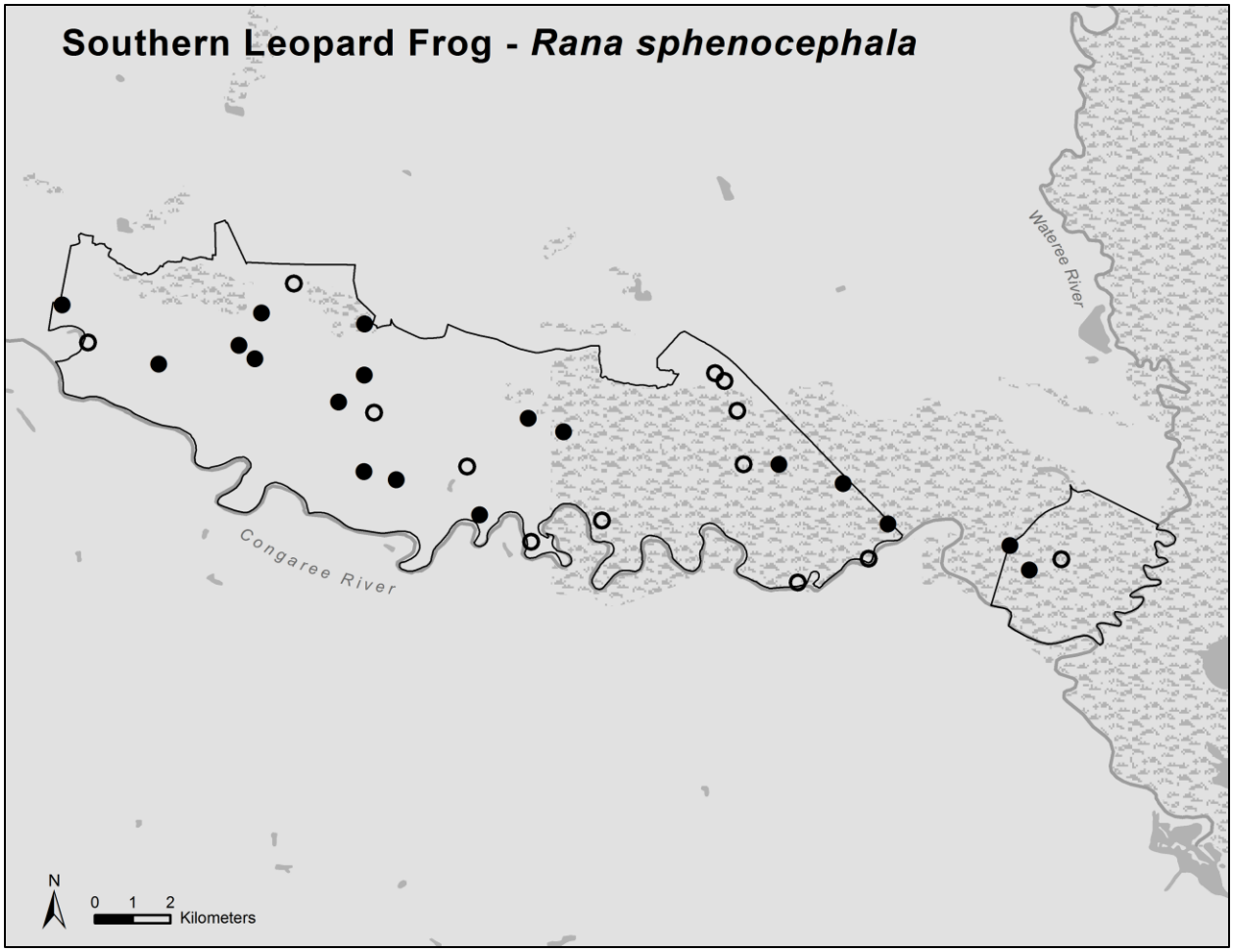

Figure 19. Sampling locations where Southern leopard frog (*Rana sphenocephala*) was detected at CONG, 2010. ● = detected, ○ = not detected.

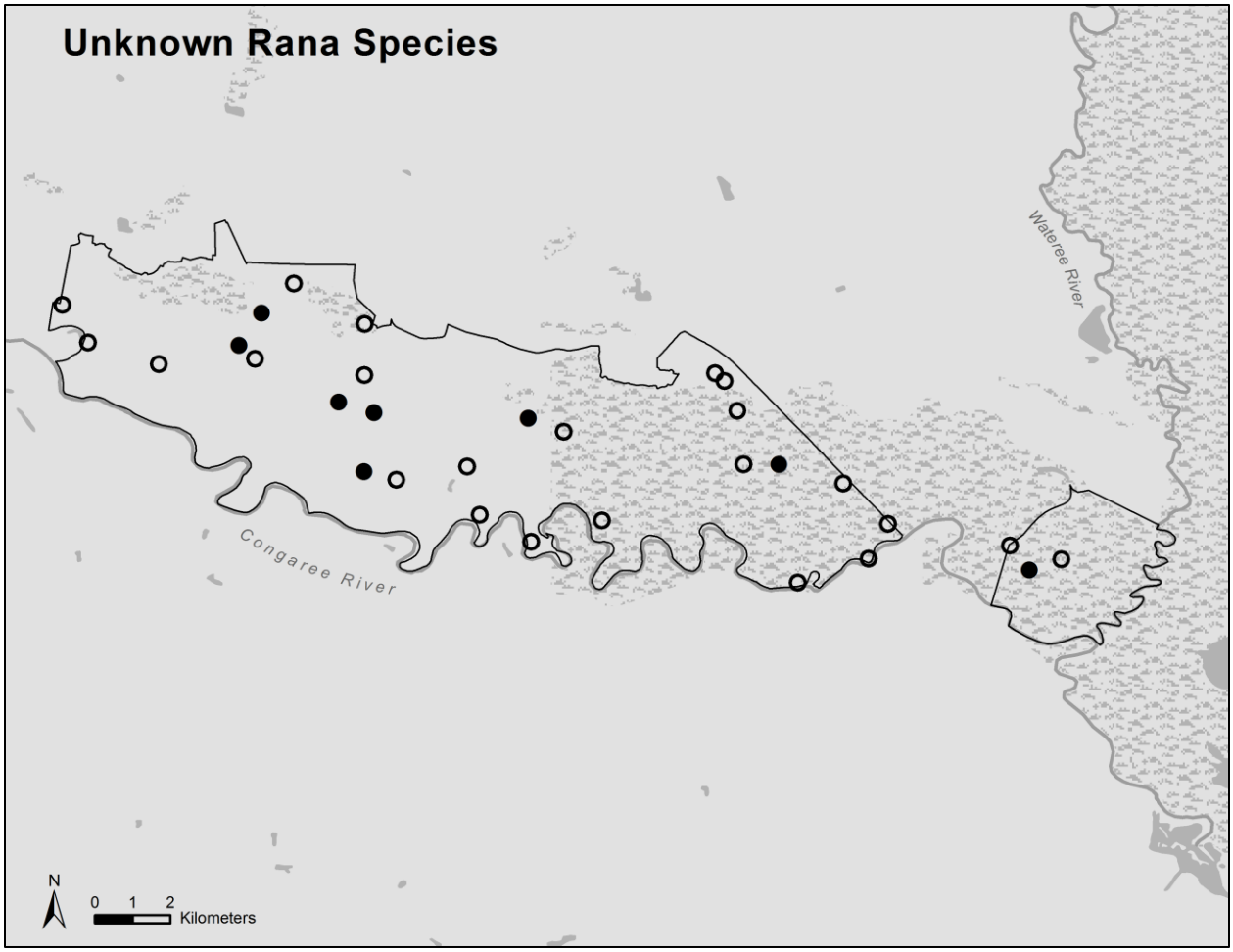

Figure 20. Sampling locations where unknown *Rana* sp. was detected at CONG, 2010.
● = detected, ○ = not detected.

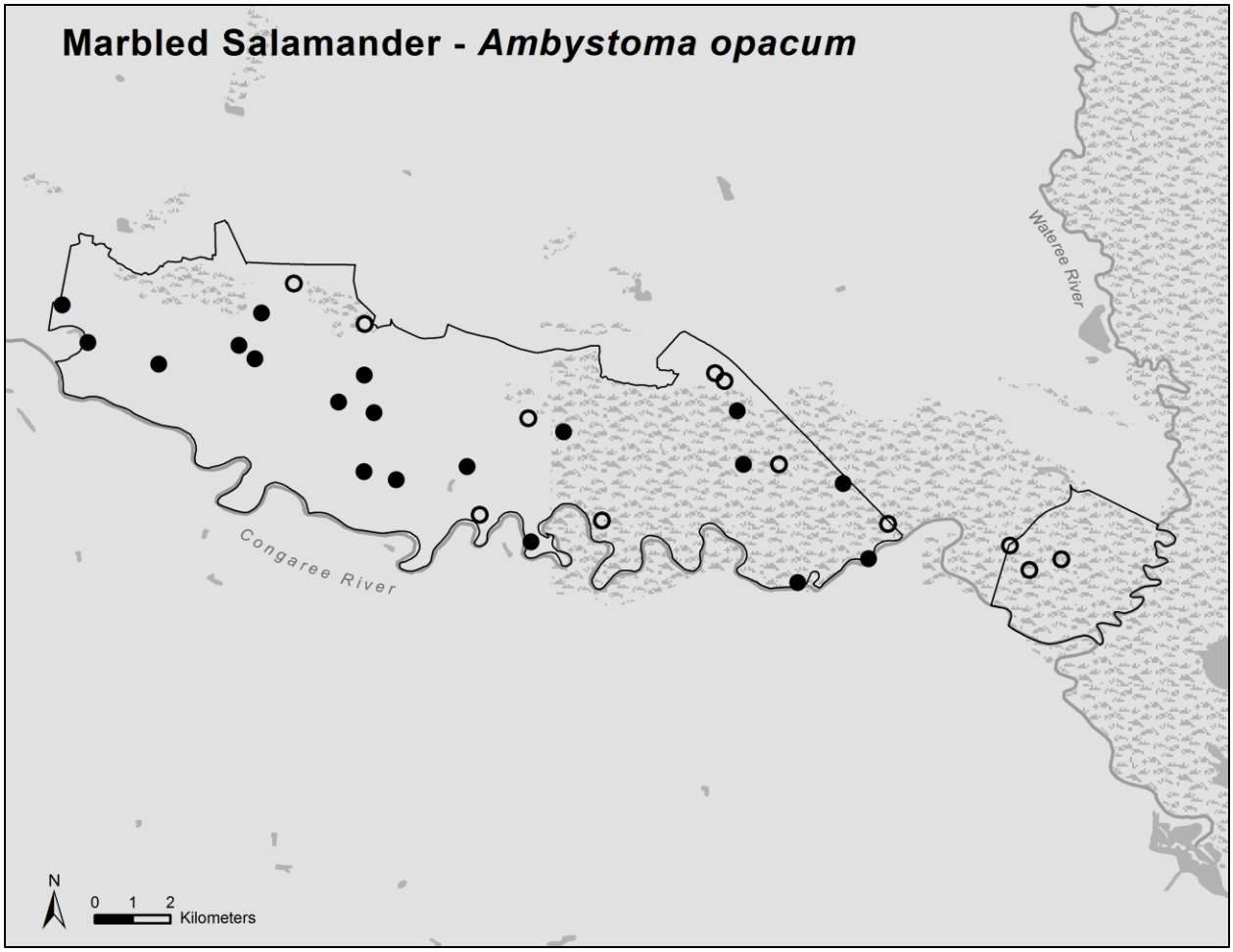

Figure 21. Sampling locations where marbled salamander (*Ambystoma opacum*) was detected at CONG, 2010. ● = detected, ○ = not detected.

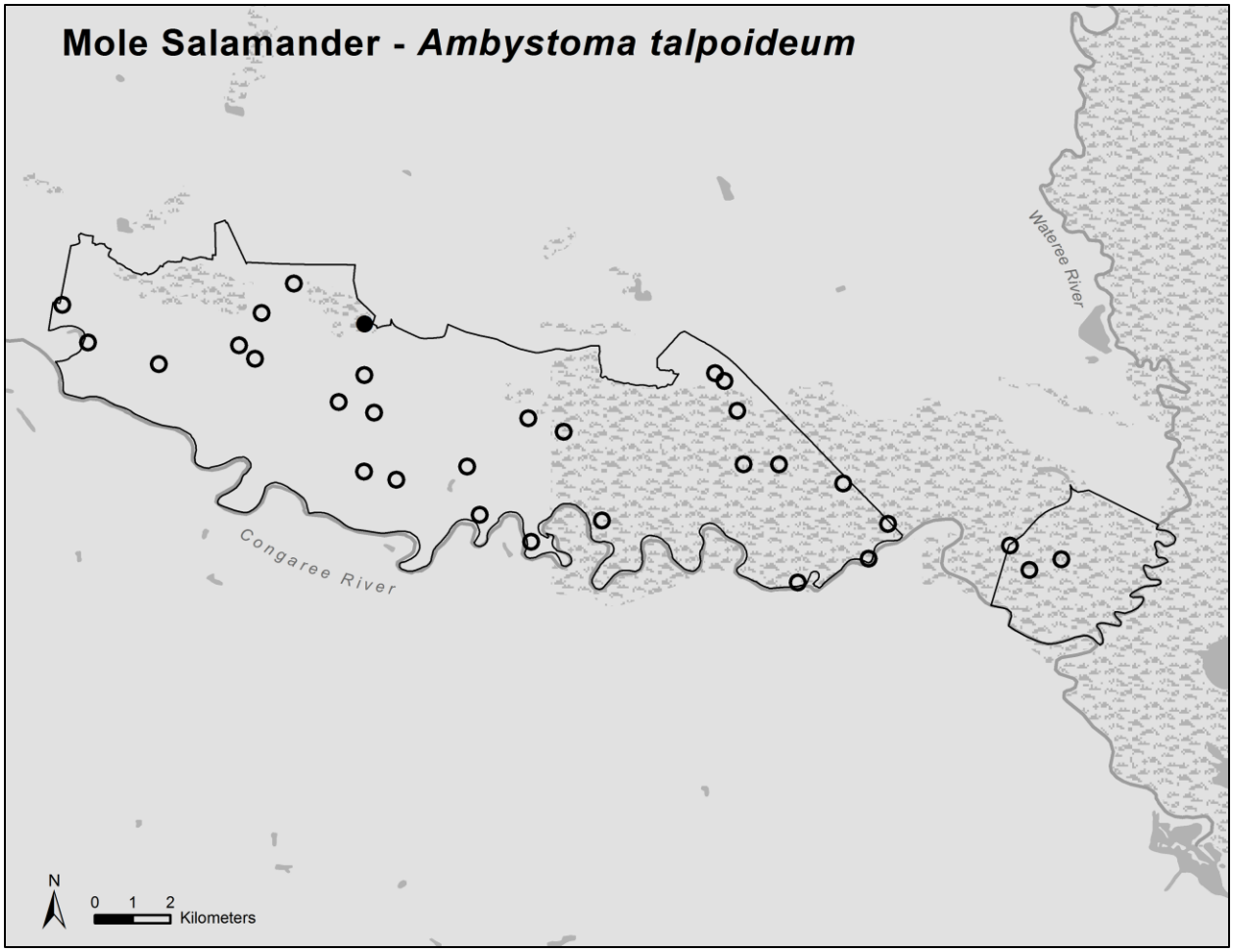

Figure 22. Sampling locations where mole salamander (*Ambystoma talpoideum*) was detected at CONG, 2010. ● = detected, ○ = not detected.

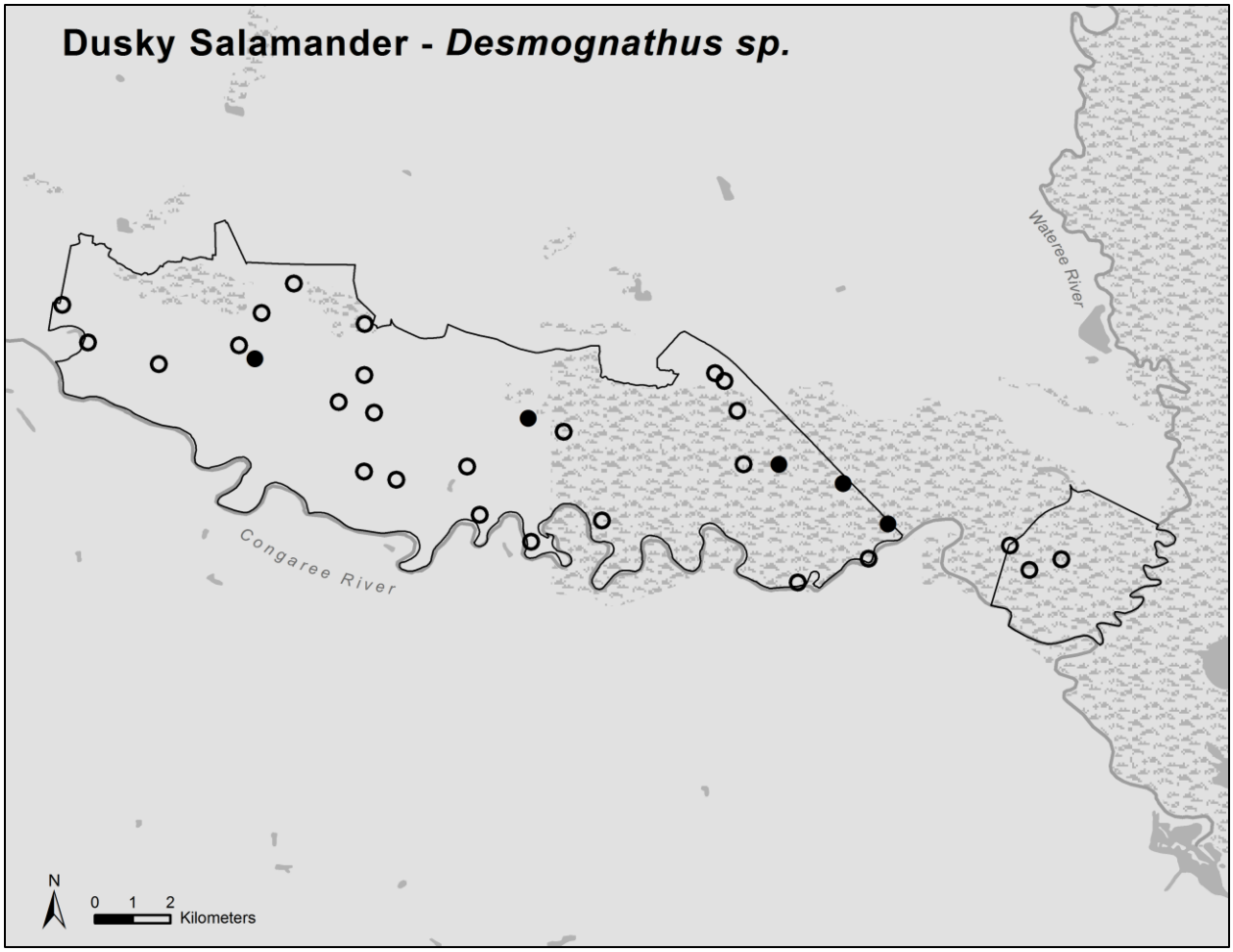

Figure 23. Sampling locations where dusky salamander (*Desmognathus* sp.) was detected at CONG, 2010. ● = detected, ○ = not detected.

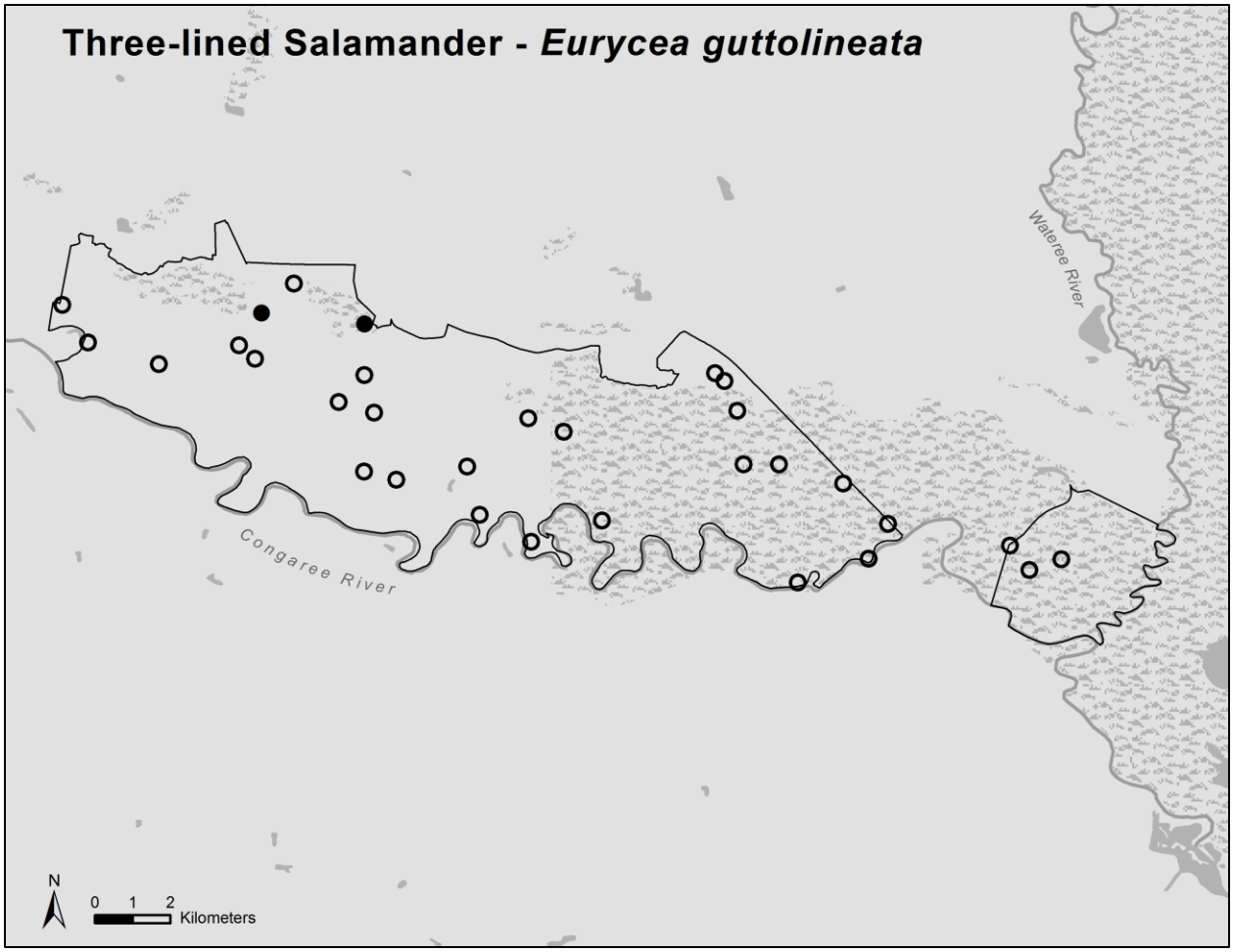

Figure 24. Sampling locations where three-lined salamander (*Eurycea guttolineata*) was detected at CONG, 2010. ● = detected, ○ = not detected.

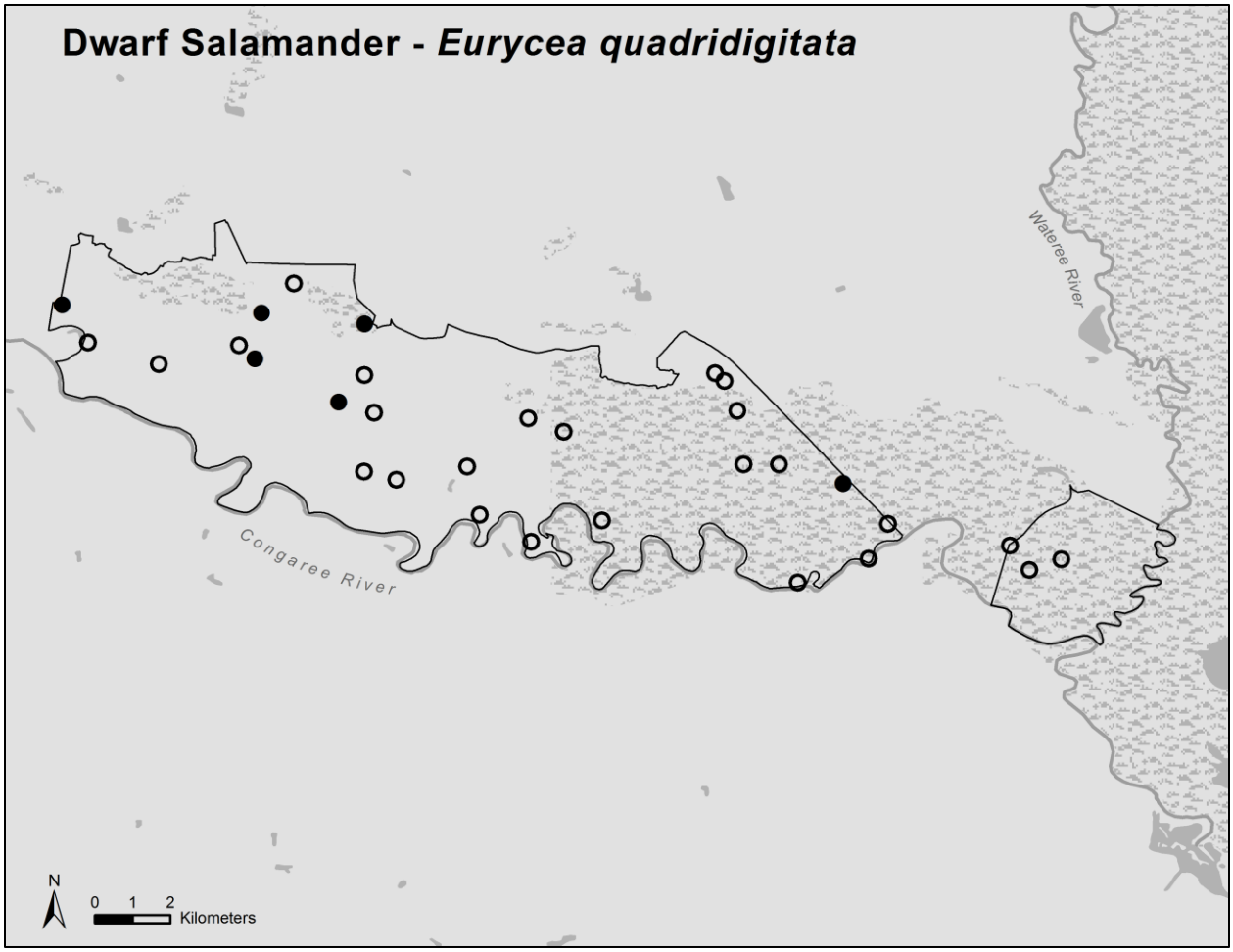

Figure 25. Sampling locations where dwarf salamander (*Eurycea quadridigitata*) was detected at CONG, 2010. ● = detected, ○ = not detected.

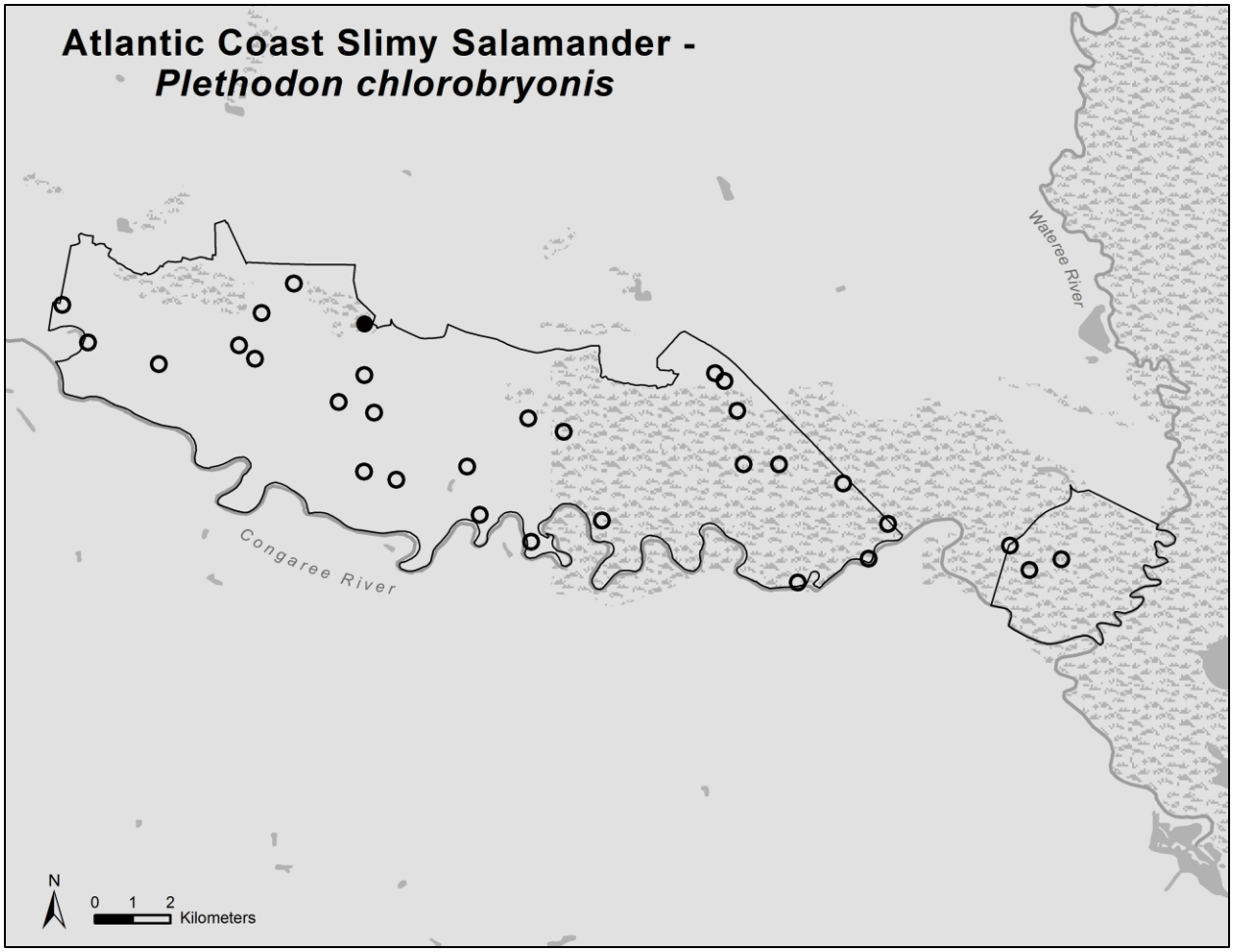

Figure 26. Sampling locations where Atlantic coast slimy salamander (*Plethodon chlorobryonis*) was detected at CONG, 2010. ● = detected, ○ = not detected.

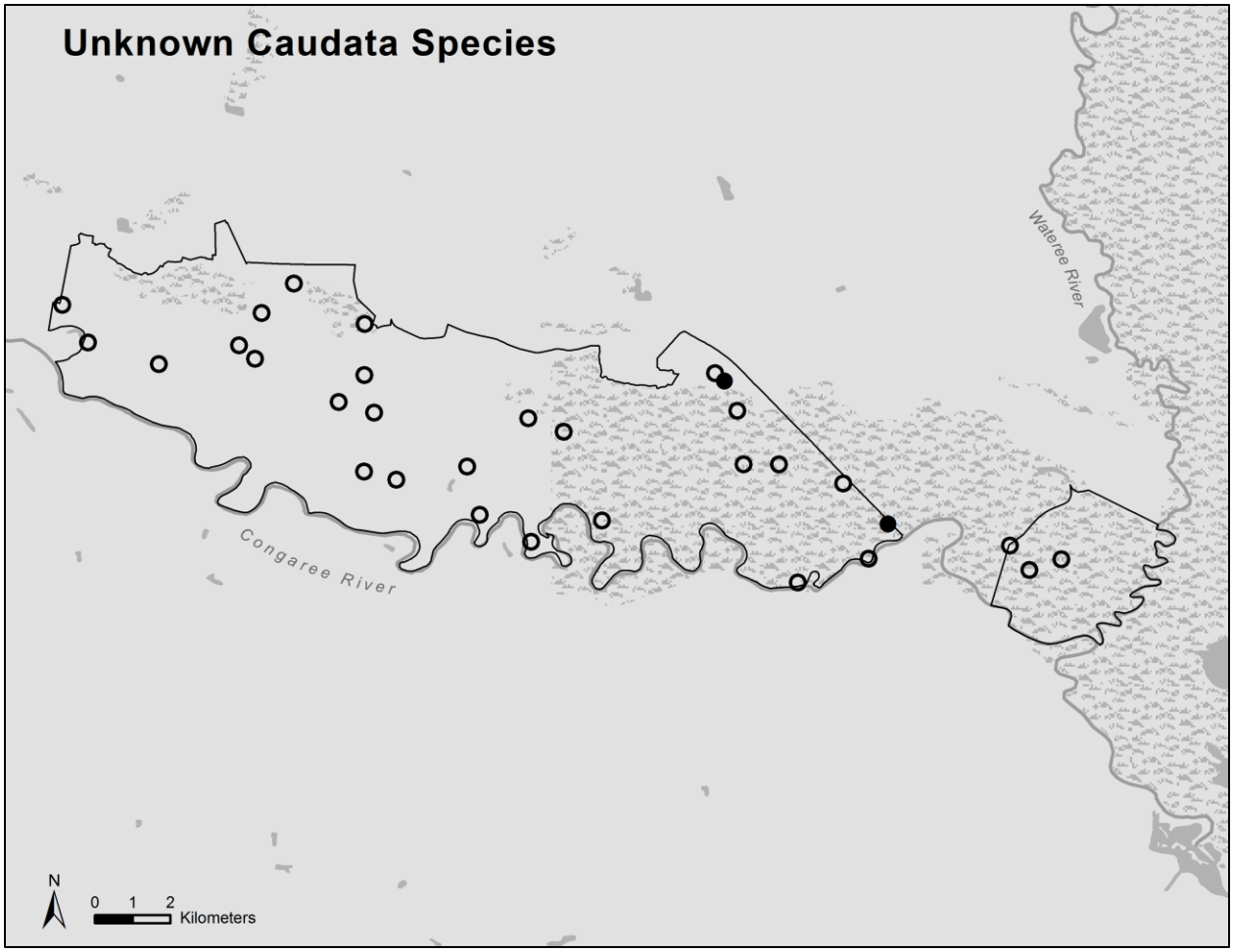

Figure 27. Sampling locations where unknown Caudata sp. was detected at CONG, 2010.
● = detected, ○ = not detected.

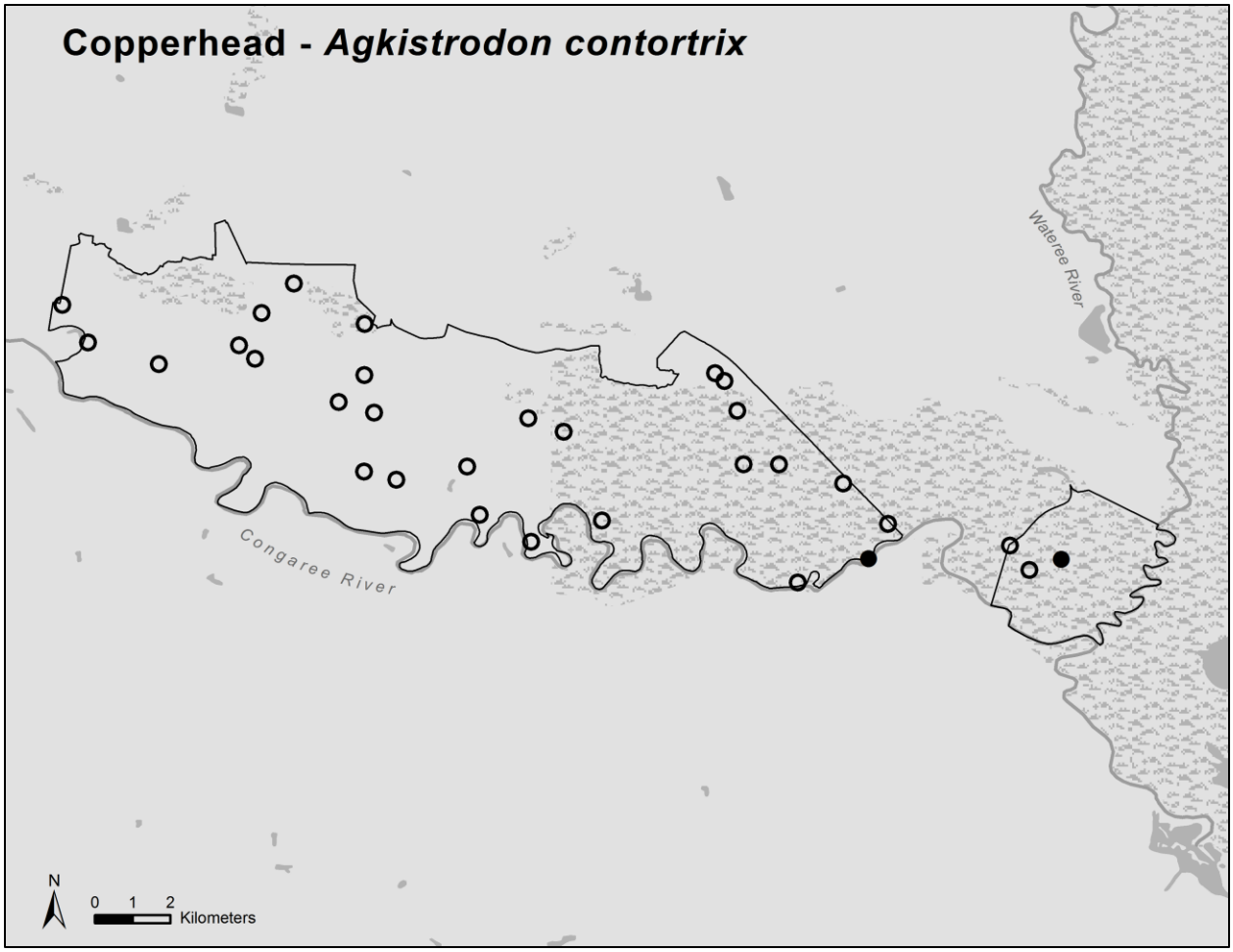

Figure 28. Sampling locations where copperhead (*Agkistrodon contortrix*) was detected at CONG, 2010. ● = detected, ○ = not detected.

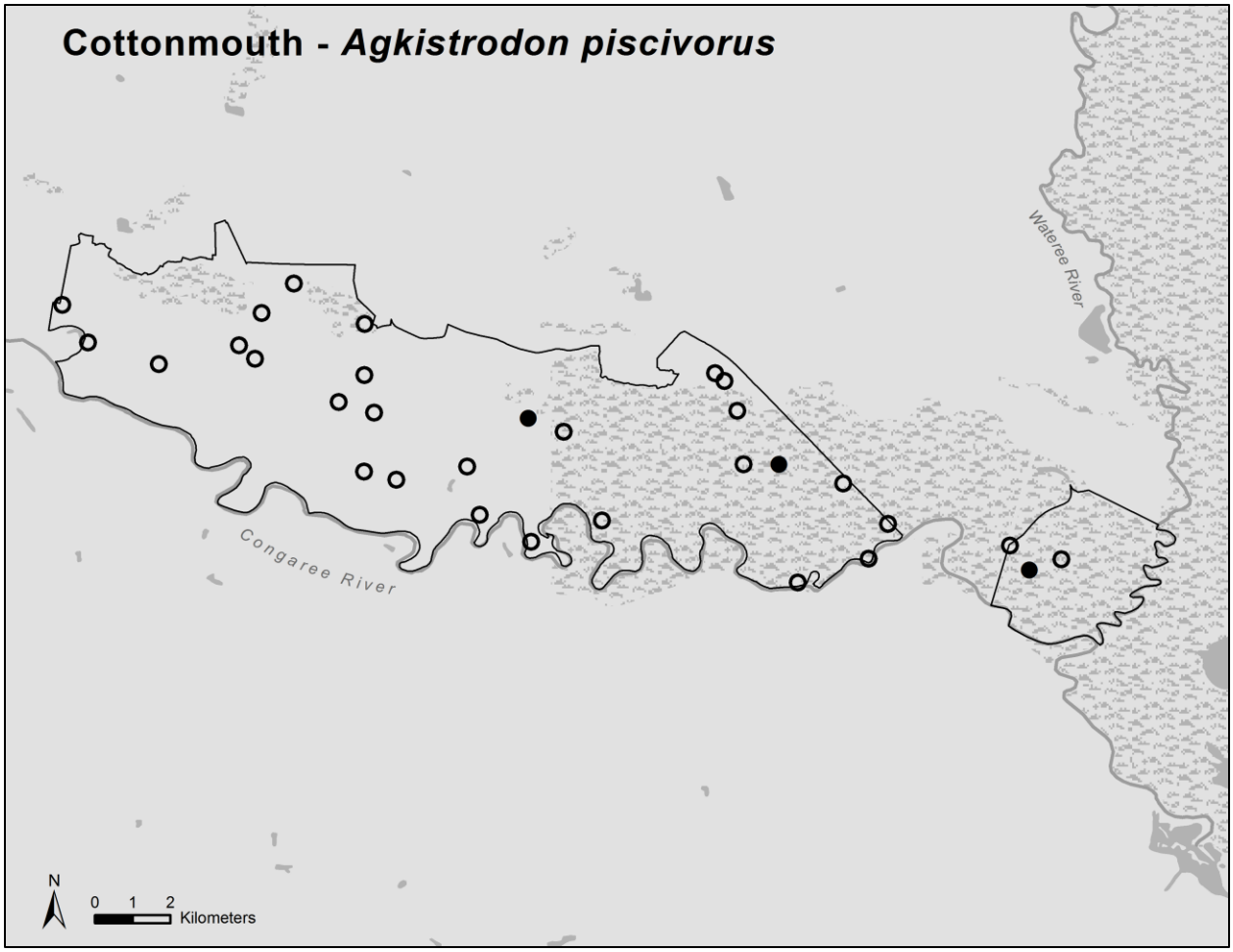

Figure 29. Sampling locations where cottonmouth (*Agkistrodon piscivorus*) was detected at CONG, 2010. ● = detected, ○ = not detected.

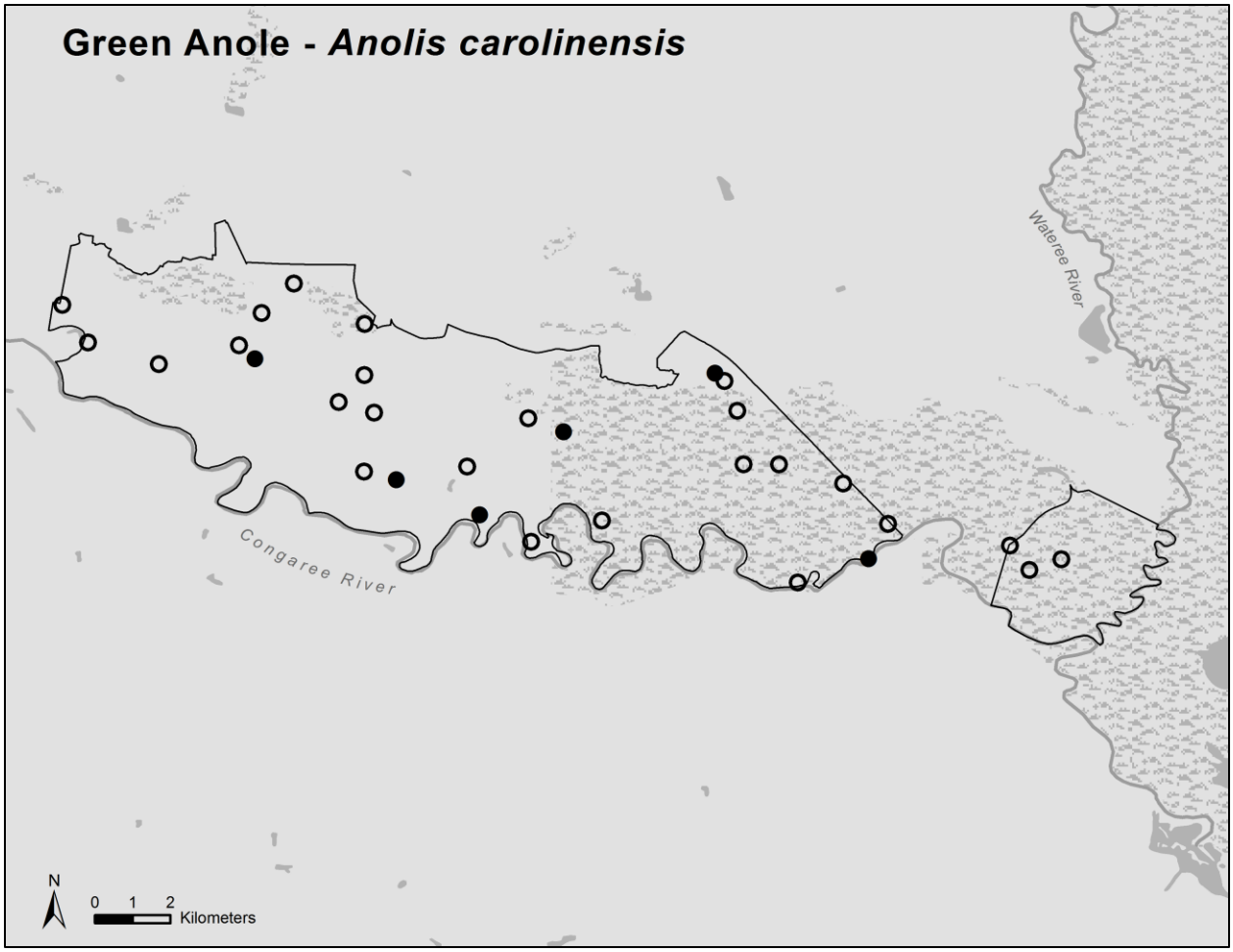

Figure 30. Sampling locations where green anole (*Anolis carolinensis*) was detected at CONG, 2010. ● = detected, ○ = not detected.

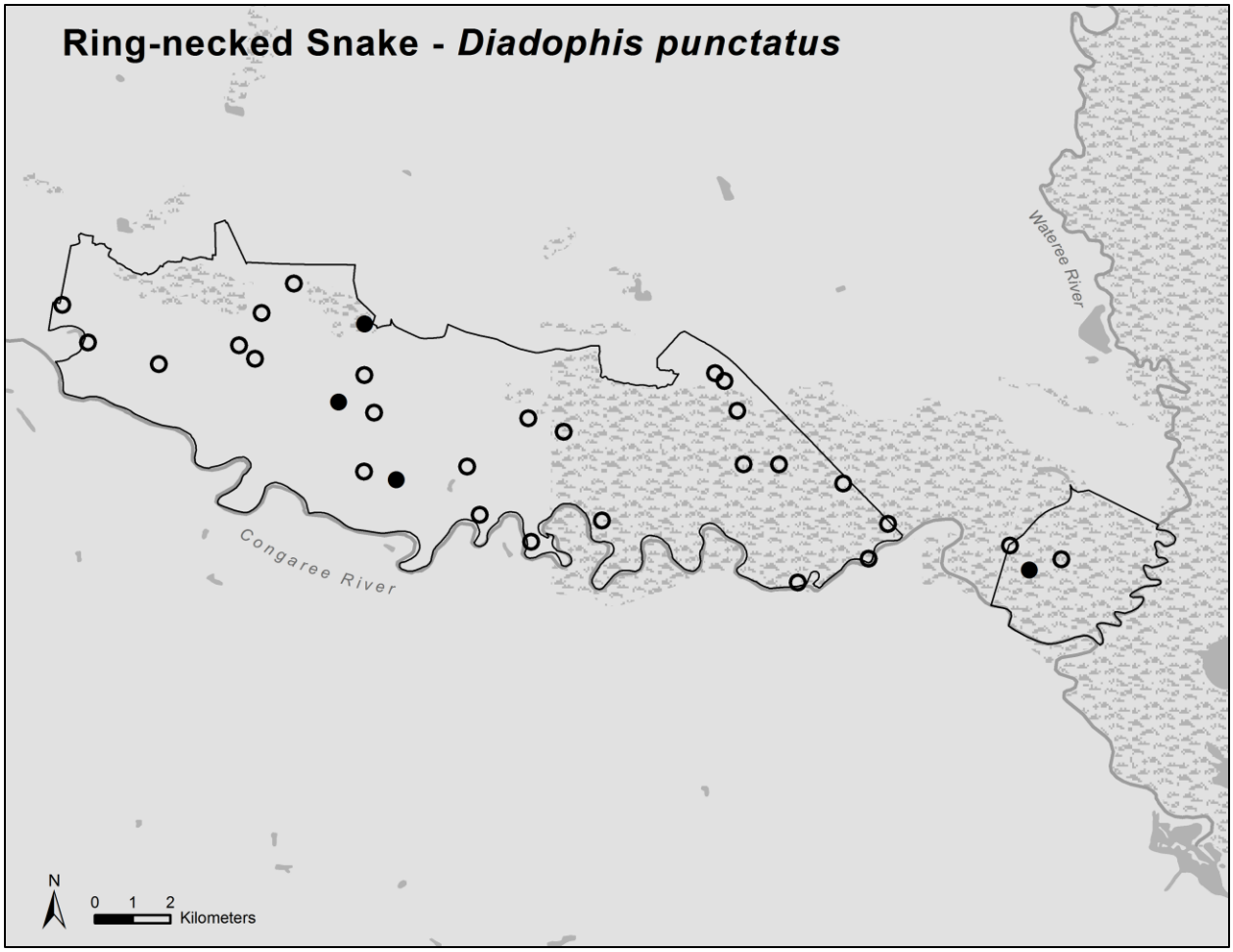

Figure 31. Sampling locations where ring-necked snake (*Diadophis punctatus*) was detected at CONG, 2010. ● = detected, ○ = not detected.

Figure 32. Sampling locations where black rat snake (*Elaphe obsoleta obsoleta*) was detected at CONG, 2010. ● = detected, ○ = not detected.

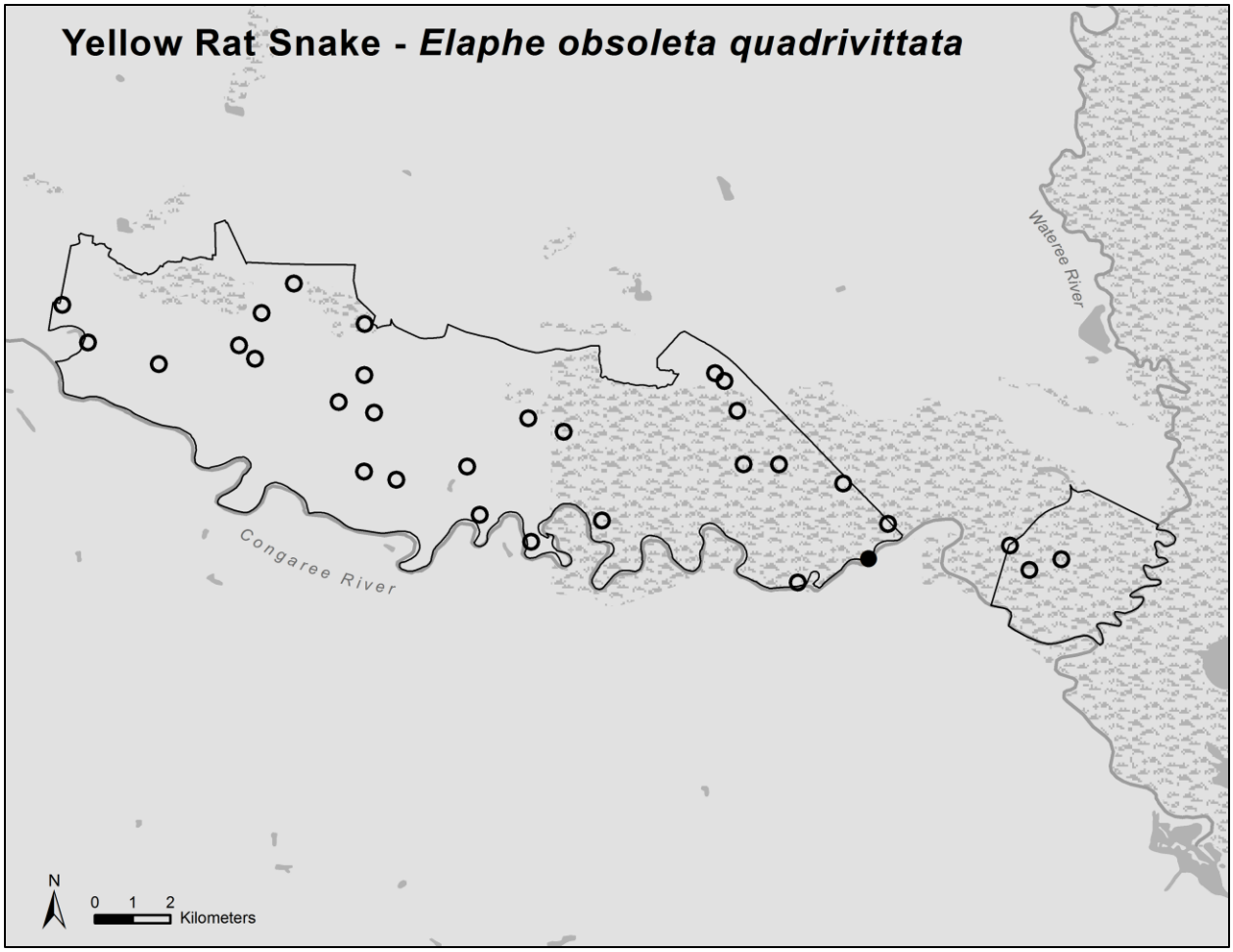

Figure 33. Sampling locations where yellow rat snake (*Elaphe obsoleta quadrivittata*) was detected at CONG, 2010. ● = detected, ○ = not detected.

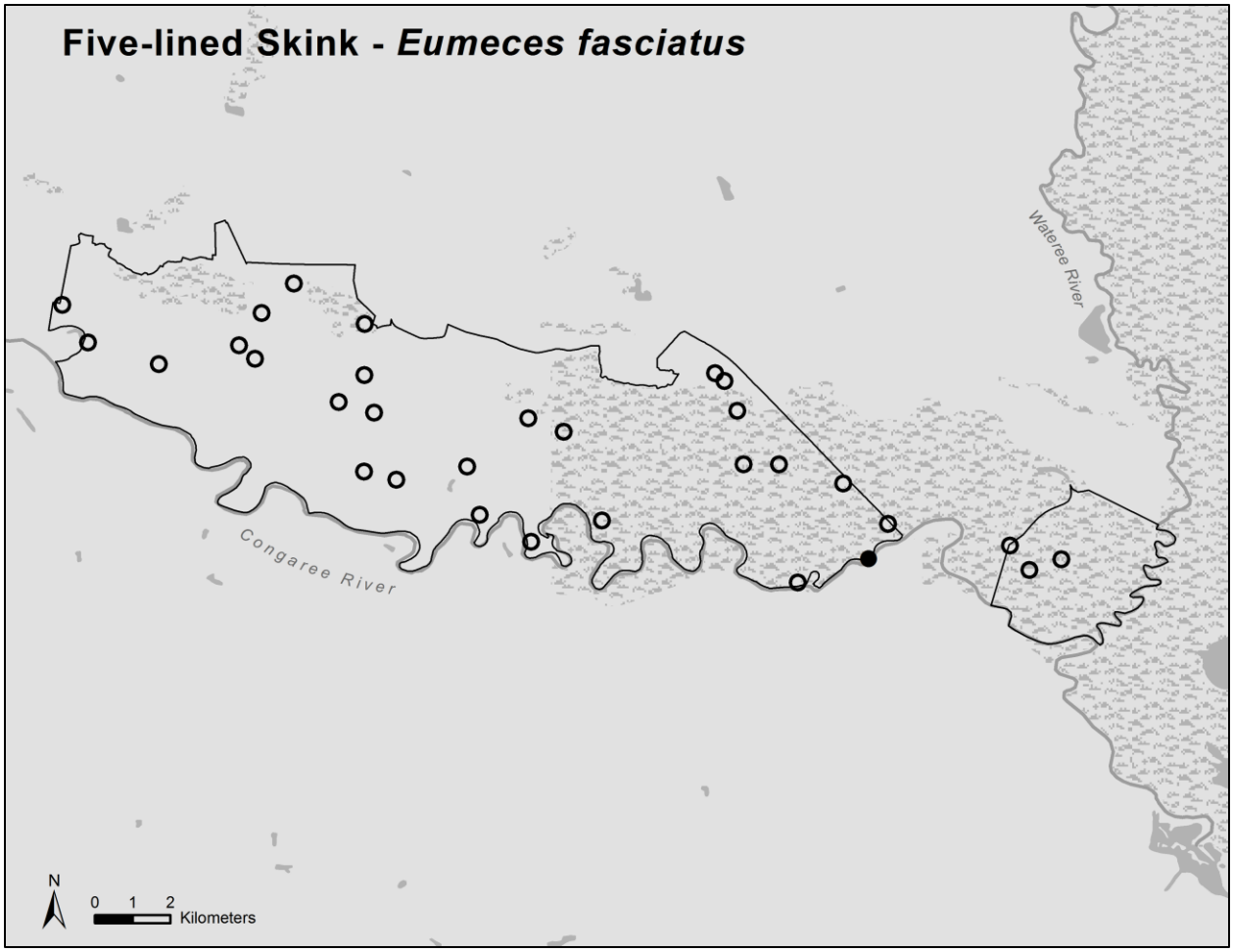

Figure 34. Sampling locations where five-lined skink (*Eumeces fasciatus*) was detected at CONG, 2010. ● = detected, ○ = not detected.

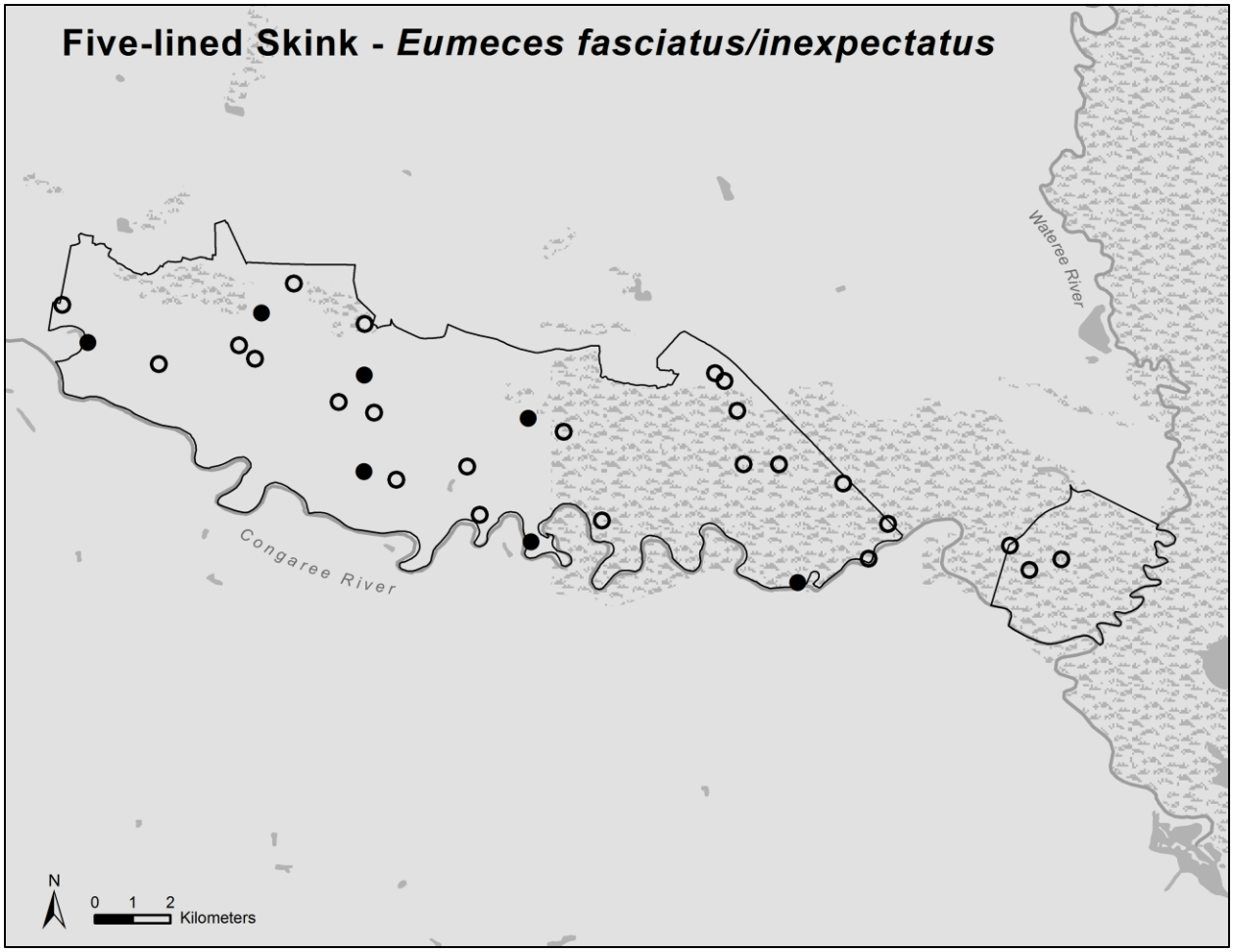

Figure 35. Sampling locations where five-lined/ Southeastern skink (*Eumeces fasciatus / inexpectatus*) was detected at CONG, 2010. ● = detected, ○ = not detected.

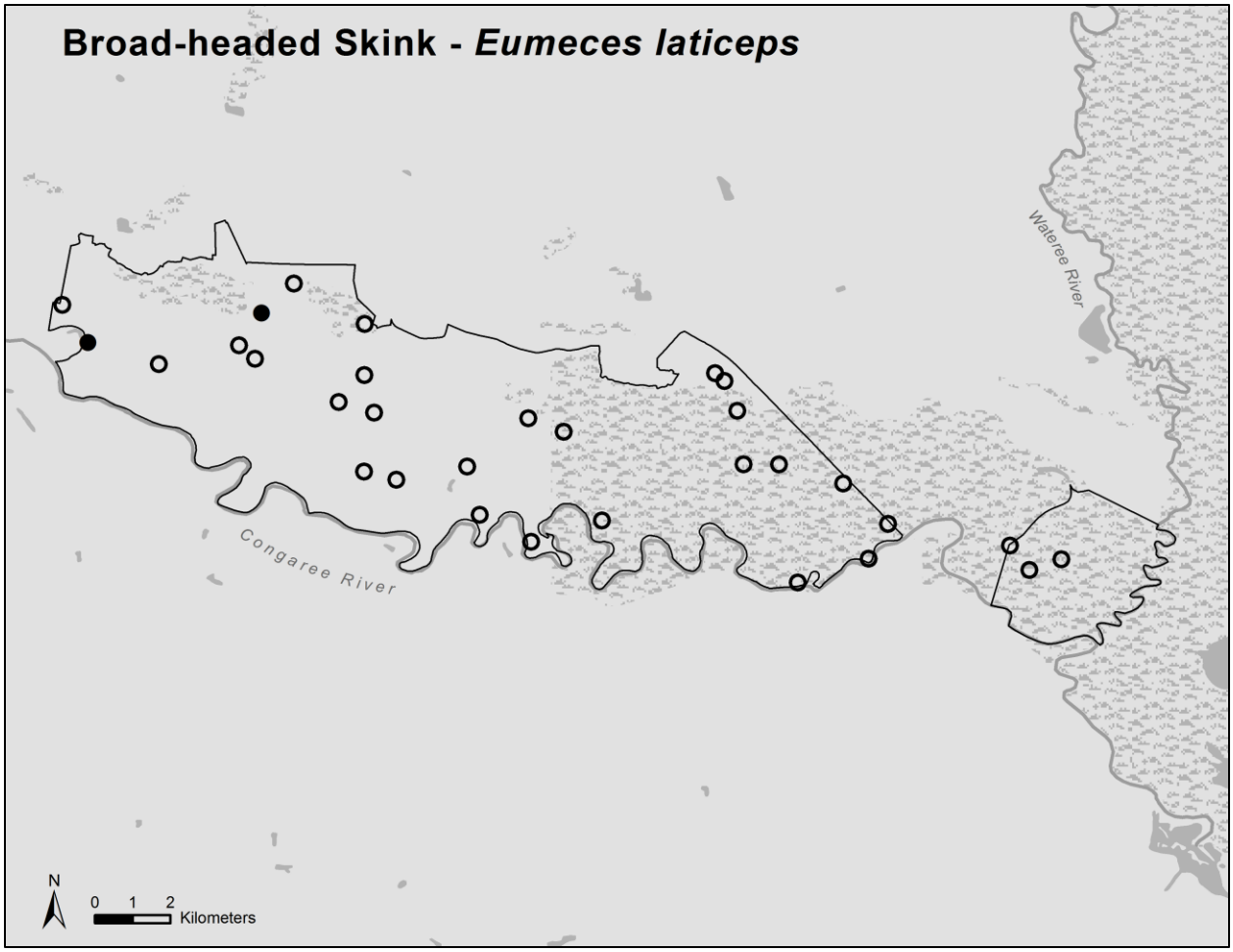

Figure 36. Sampling locations where broad-headed skink (*Eumeces laticeps*) was detected at CONG, 2010. ● = detected, ○ = not detected.

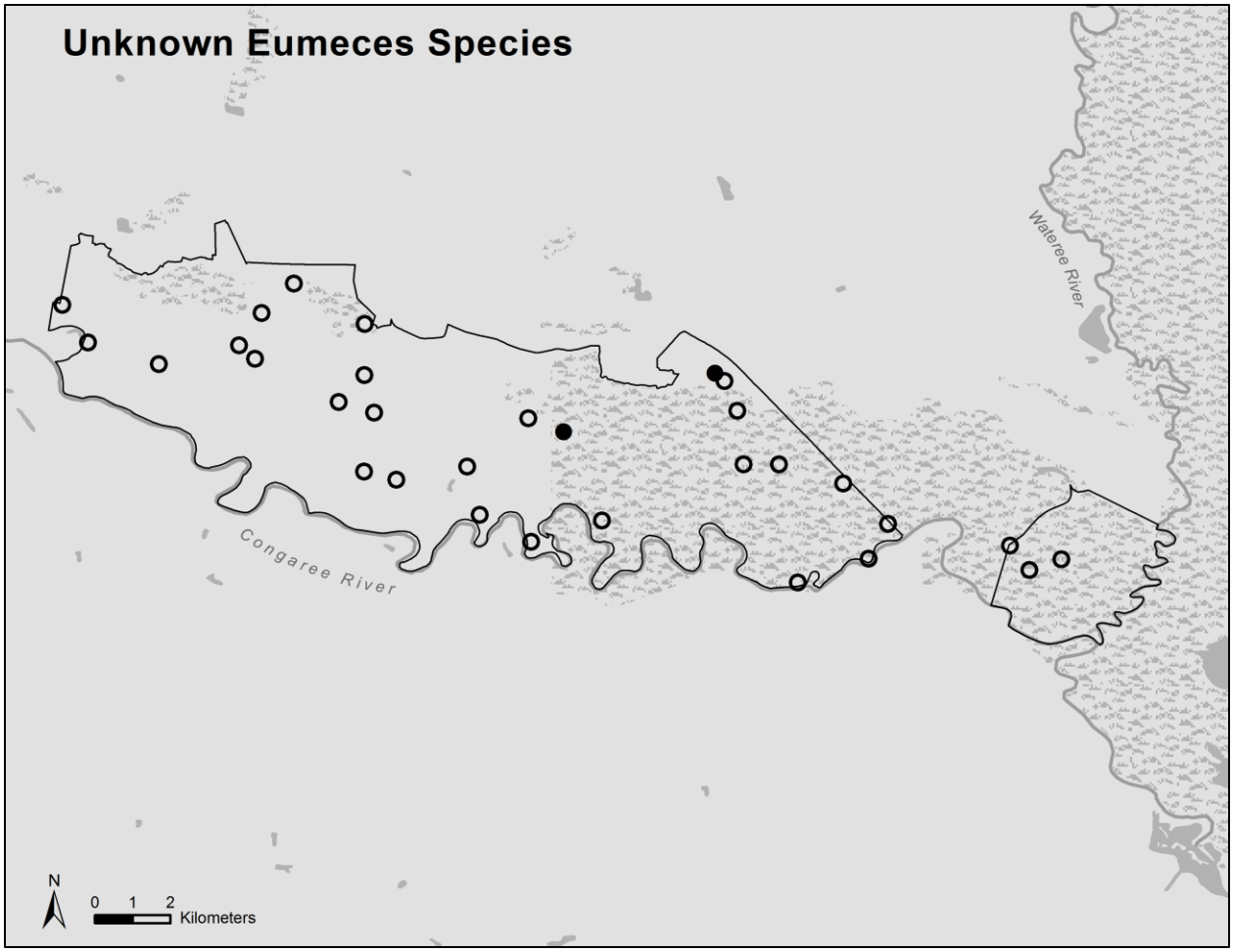

Figure 37. Sampling locations where unknown *Eumeces* sp .was detected at CONG, 2010.
● = detected, ○ = not detected.

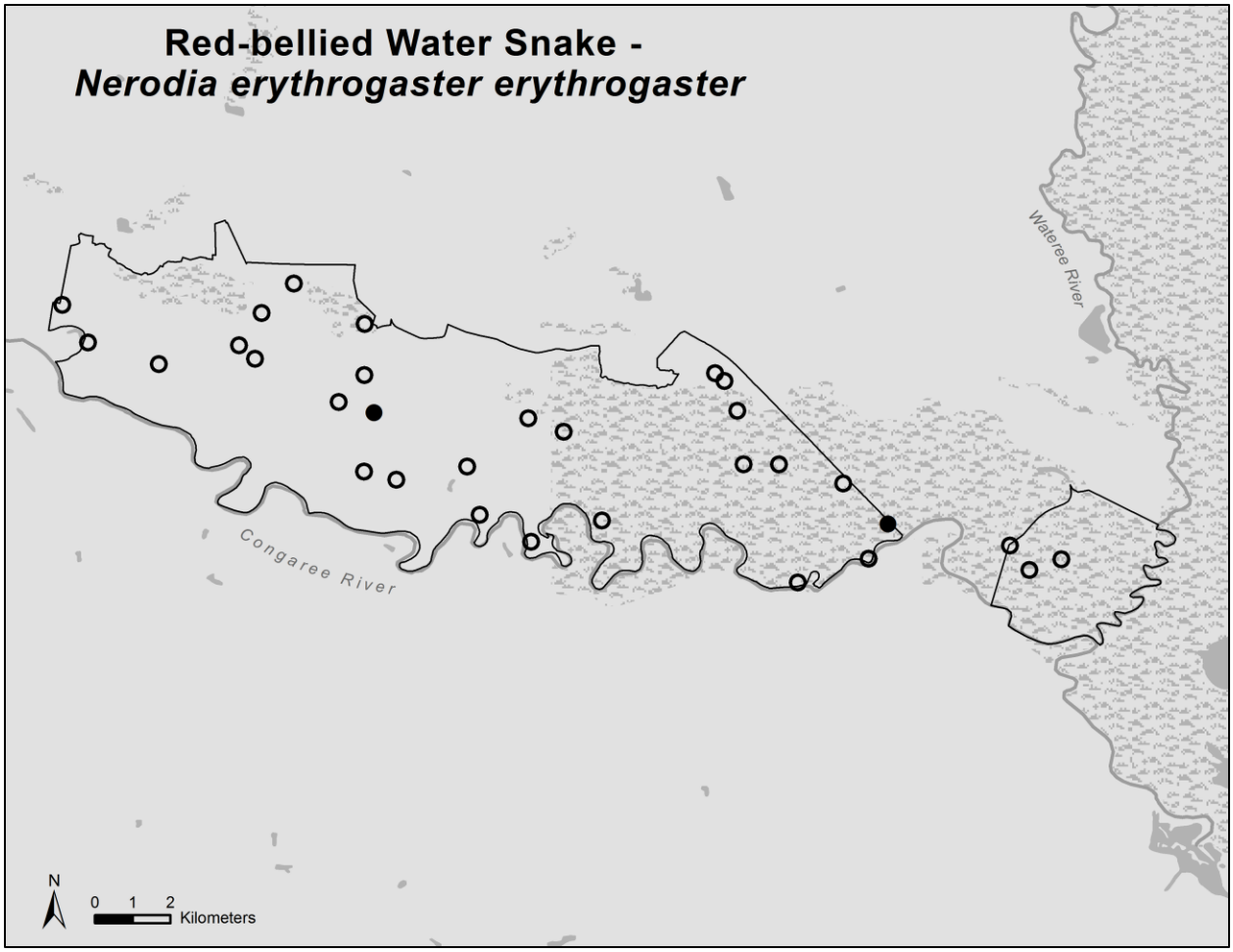

Figure 38. Sampling locations where red-bellied watersnake (*Nerodia erythrogaster erythrogaster*) was detected at CONG, 2010. ● = detected, ○ = not detected.

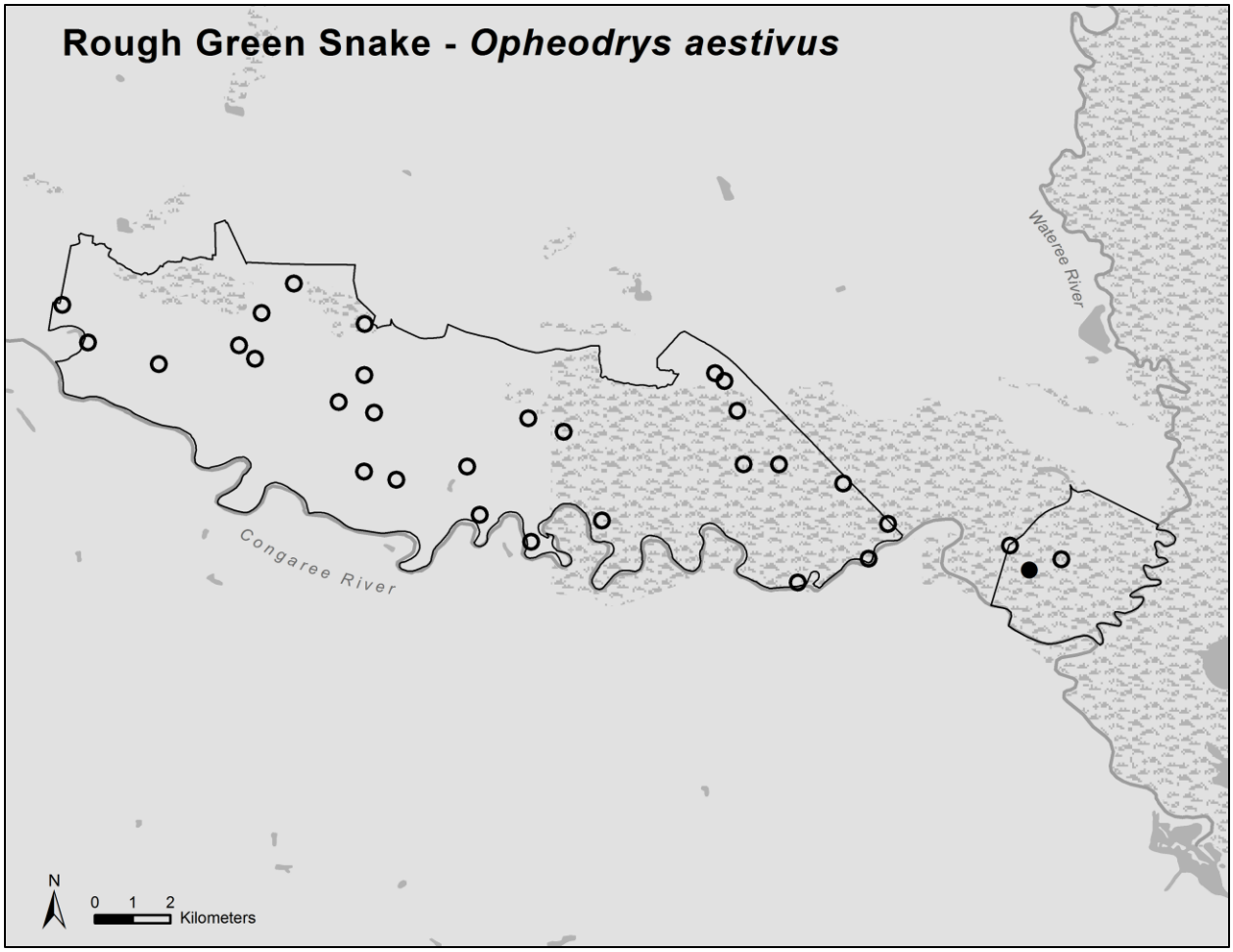

Figure 39. Sampling locations where rough green snake (*Opheodrys aestivus*) was detected at CONG, 2010. ● = detected, ○ = not detected.

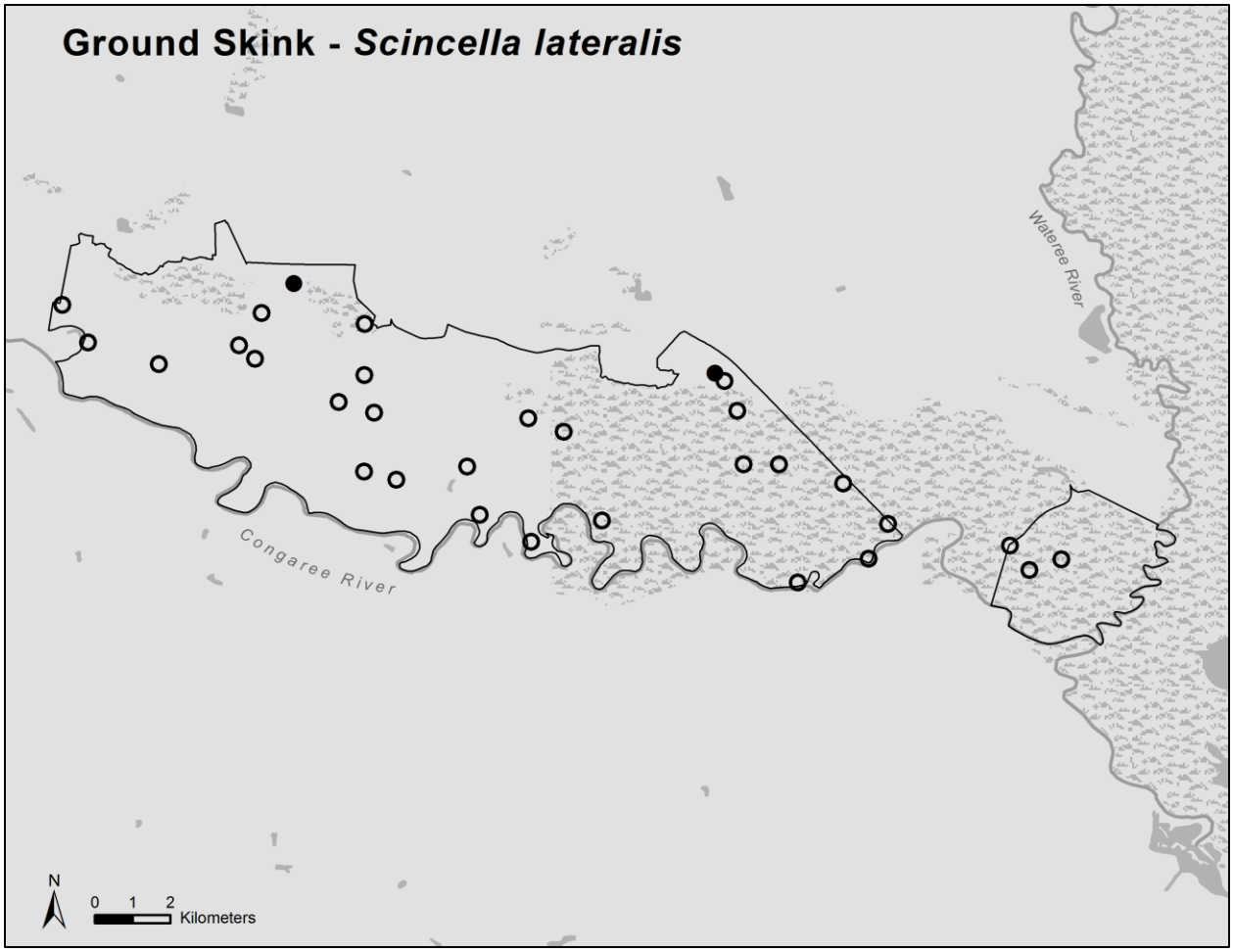

Figure 40. Sampling locations where ground skink (*Scincella lateralis*) was detected at CONG, 2010. ● = detected, ○ = not detected.

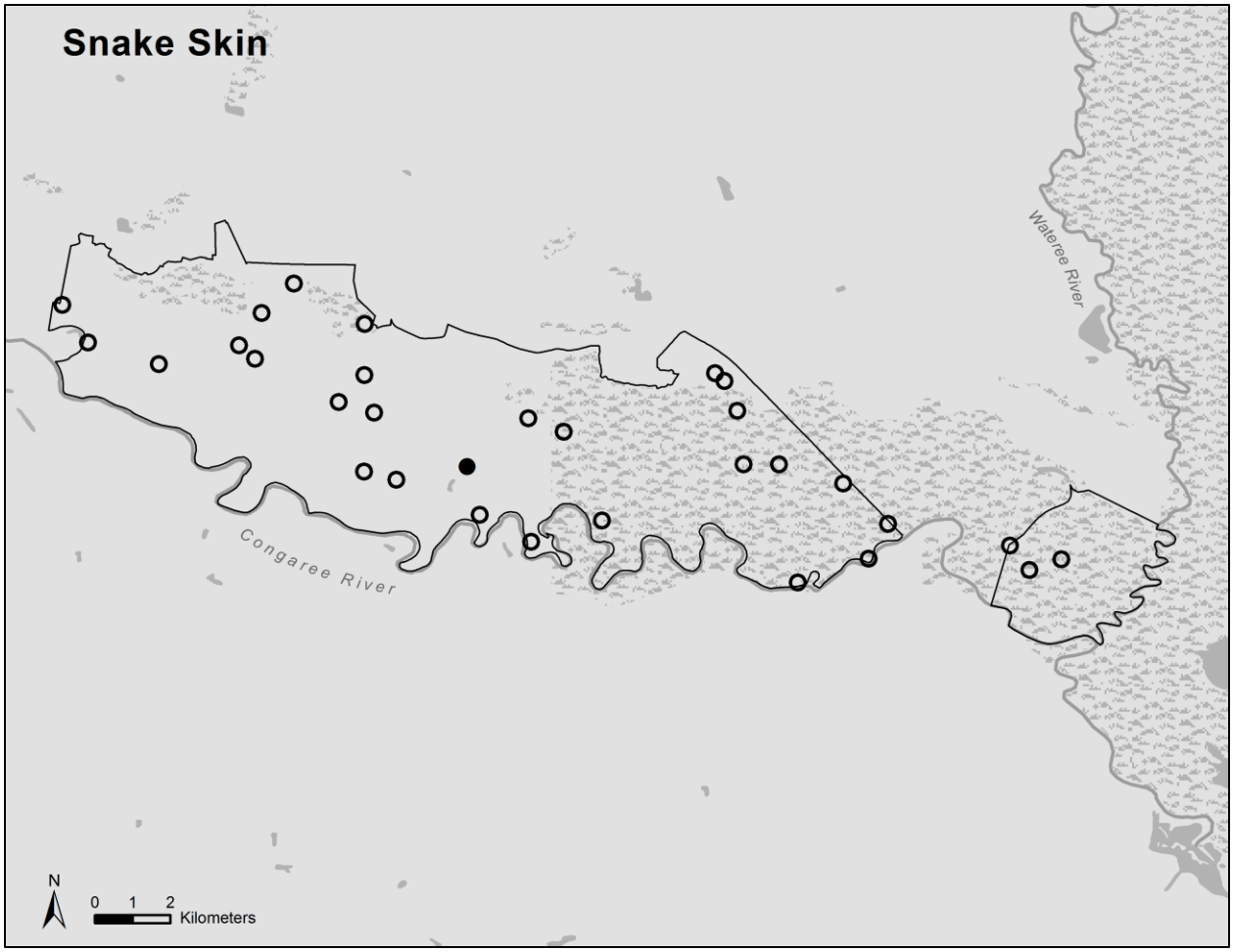

Figure 41. Sampling locations where snake skin was detected at CONG, 2010.
● = detected, ○ = not detected.

Figure 42. Sampling locations where Dekay's brown snake (*Storeria dekayi*) was detected at CONG, 2010. ● = detected, ○ = not detected.

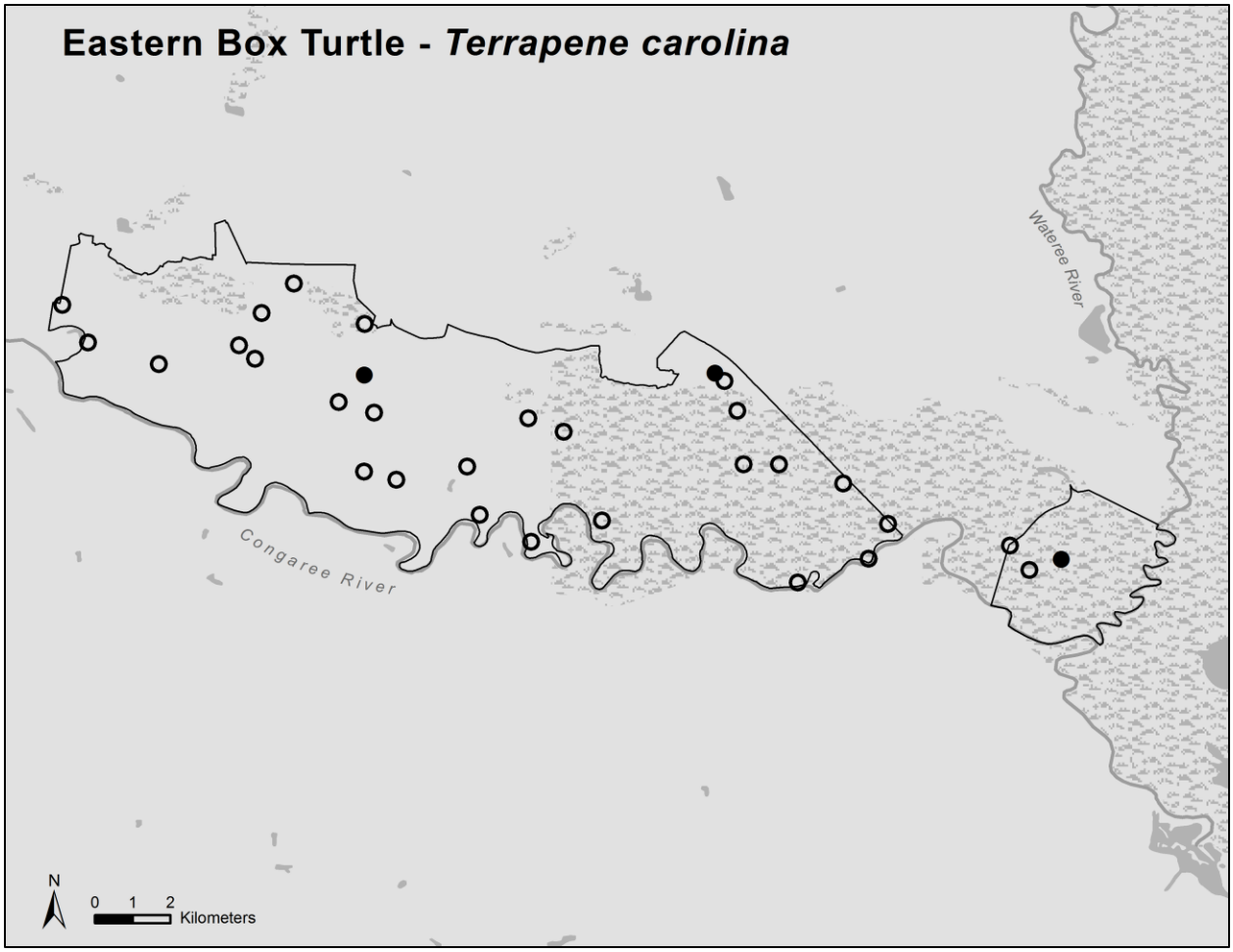

Figure 43. Sampling locations where eastern box turtle (*Terrapene carolina*) was detected at CONG, 2010. ● = detected, ○ = not detected.

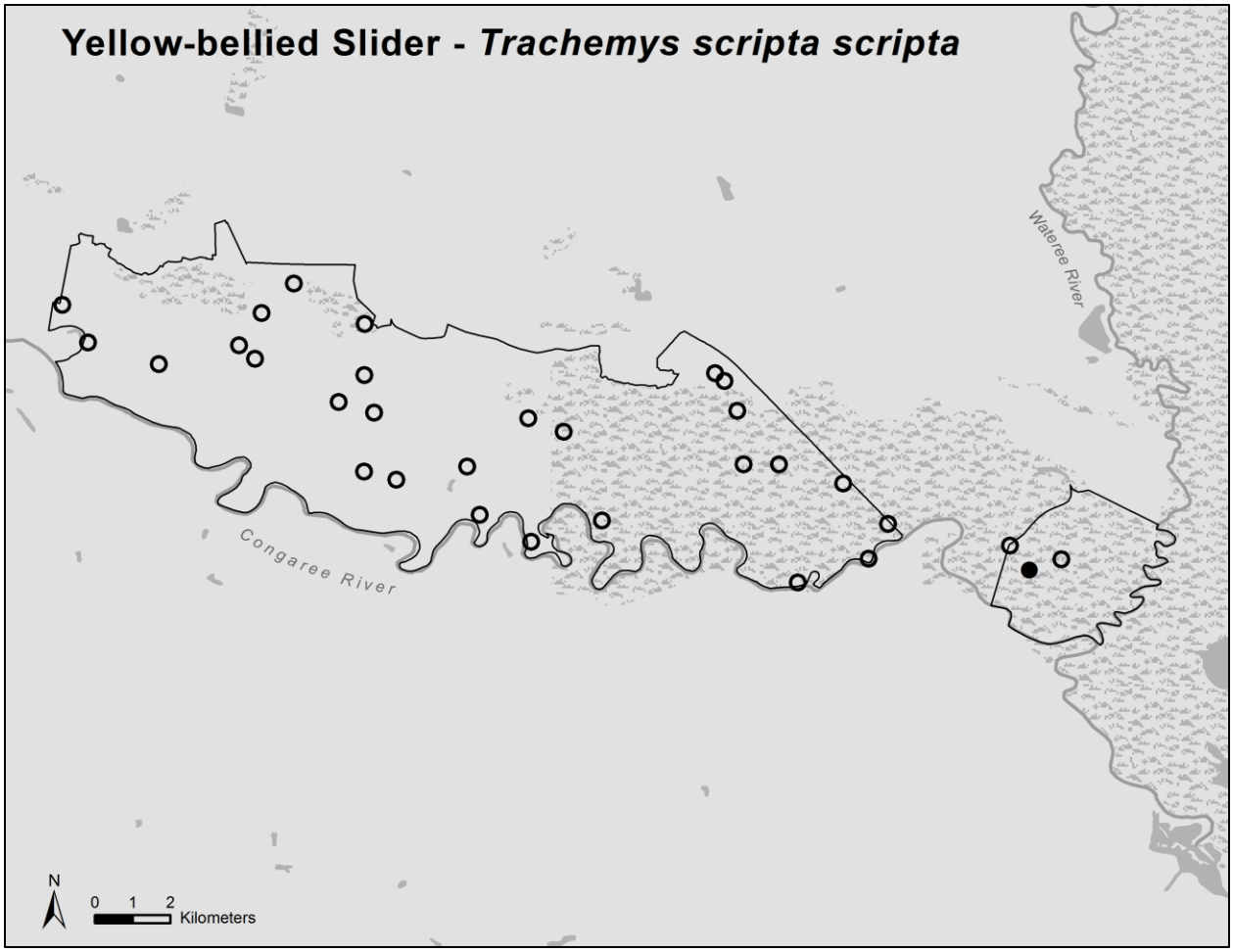

Figure 44. Sampling locations where yellow-bellied slider (*Trachemys scripta scripta*) was detected at CONG, 2010. ● = detected, ○ = not detected.

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Appendix A. Amphibians and reptiles known to occur at CONG.

Table A-1. Amphibians and reptiles known to occur at CONG based upon records in NPSpecies (2011) or from monitoring efforts presented herein.

Order	Family	Scientific Name	Common Name	NPSpecies	ARD	VES
Anura	Bufonidae	*Bufo terrestris*	Southern Toad	X	X	X
Anura	Hylidae	*Acris crepitans*	Northern Cricket Frog	X		
Anura	Hylidae	*Acris gryllus*	Southern Cricket Frog	X		X
Anura	Hylidae	*Hyla chrysoscelis*	Cope's Gray Treefrog	X	X	X
Anura	Hylidae	*Hyla cinerea*	Green Treefrog	X	X	X
Anura	Hylidae	*Hyla femoralis*	Pine Woods Treefrog	X		
Anura	Hylidae	*Hyla gratiosa*	Barking Treefrog	X		
Anura	Hylidae	*Hyla squirella*	Squirrel Treefrog	X		X
Anura	Hylidae	*Hyla versicolor*	Gray Treefrog	X		
Anura	Hylidae	*Pseudacris brimleyi*	Brimley's chorus frog	X		X
Anura	Hylidae	*Pseudacris crucifer*	Spring Peeper	X		X
Anura	Hylidae	*Pseudacris feriarum*	Southeastern Chorus Frog	X		
Anura	Hylidae	*Pseudacris nigrita*	Southern Chorus Frog	X		
Anura	Hylidae	*Pseudacris ornata*	Ornate Chorus Frog	X		
Anura	Microhylidae	*Gastrophryne carolinensis*	Eastern Narrow-mouthed Toad	X		X
Anura	Ranidae	*Rana catesbeiana*	Bullfrog	X	X	X
Anura	Ranidae	*Rana clamitans*	Green Frog	X		X
Anura	Ranidae	*Rana clamitans clamitans*	Bronze Frog			X
Anura	Ranidae	*Rana heckscheri*	River Frog	X		
Anura	Ranidae	*Rana palustris*	Pickerel Frog	X		X
Anura	Ranidae	*Rana sphenocephala*	Southern Leopard Frog	X	X	X
Anura	Ranidae	*Rana virgatipes*	Carpenter Frog	X		
Anura	Scaphiopodidae	*Scaphiopus holbrookii*	Eastern Spadefoot	X		
Caudata	Ambystomatidae	*Ambystoma opacum*	Marbled Salamander	X		X
Caudata	Ambystomatidae	*Ambystoma talpoideum*	Mole Salamander	X		X
Caudata	Plethodontidae	*Desmognathus auriculatus*	Southern Dusky Salamander	X		X
Caudata	Plethodontidae	*Eurycea guttolineata*	Three-lined Salamander	X		X
Caudata	Plethodontidae	*Eurycea quadridigitata*	Dwarf Salamander			X
Caudata	Plethodontidae	*Plethodon chlorobryonis*	Atlantic Coast Slimy Salamander	X		X

Table A-1. (Continued).

Order	Family	Scientific Name	Common Name	NPSpecies	ARD	VES
Caudata	Plethodontidae	*Pseudotriton montanus*	Mud Salamander	X		
Caudata	Proteidae	*Necturus punctatus*	Dwarf Waterdog	X		
Caudata	Sirenidae	*Siren lacertina*	Greater Siren	X		
Crocodilia	Alligatoridae	*Alligator mississippiensis*	Alligator	X		
Squamata	Colubridae	*Carphophis amoenus*	Worm Snake	X		
Squamata	Colubridae	*Coluber constrictor*	Racer	X		
Squamata	Colubridae	*Diadophis punctatus*	Ring-necked Snake	X		X
Squamata	Colubridae	*Elaphe obsoleta*	Common Rat Snake	X		
Squamata	Colubridae	*Elaphe obsoleta obsoleta*	Black Rat Snake			X
Squamata	Colubridae	*Elaphe obsoleta quadrivittata*	Yellow Rat Snake			X
Squamata	Colubridae	*Farancia abacura*	Mud Snake	X		
Squamata	Colubridae	*Heterodon platirhinos*	Eastern Hog-nosed Snake	X		
Squamata	Colubridae	*Lampropeltis getula*	Common Kingsnake	X		
Squamata	Colubridae	*Masticophis flagellum*	Coachwhip	X		
Squamata	Colubridae	*Nerodia erythrogaster*	Plain-bellied Water Snake	X		
Squamata	Colubridae	*Nerodia erythrogaster erythrogaster*	Red-bellied Water Snake			X
Squamata	Colubridae	*Nerodia fasciata*	Southern Water Snake	X		
Squamata	Colubridae	*Nerodia taxispilota*	Brown Water Snake	X		
Squamata	Colubridae	*Opheodrys aestivus*	Rough Green Snake	X		X
Squamata	Colubridae	*Storeria dekayi*	Dekay's Brown Snake	X		X
Squamata	Colubridae	*Storeria occipitomaculata*	Red-bellied Snake	X		
Squamata	Colubridae	*Thamnophis sauritus*	Eastern Ribbon Snake	X		
Squamata	Colubridae	*Thamnophis sirtalis*	Garter Snake	X		
Squamata	Polychrotidae	*Anolis carolinensis*	Green Anole	X		X
Squamata	Scincidae	*Eumeces fasciatus*	Five-lined Skink	X		X
Squamata	Scincidae	*Eumeces inexpectatus*	Southeastern Five-lined Skink	X		
Squamata	Scincidae	*Eumeces laticeps*	Broad-headed Skink	X		X
Squamata	Scincidae	*Scincella lateralis*	Ground Skink	X		X

Table A-1. (Continued).

Order	Family	Scientific Name	Common Name	NPSpecies	ARD	VES
Squamata	Viperidae	*Agkistrodon contortrix*	Copperhead	X		X
Squamata	Viperidae	*Agkistordon contortrix mokasen*	Northern Copperhead	X		X
Squamata	Viperidae	*Agkistrodon piscivorus*	Cottonmouth	X		
Squamata	Viperidae	*Crotalus horridus*	Timber Rattlesnake	X		
Testudines	Chelydridae	*Chelydra serpentina*	Common Snapping Turtle	X		
Testudines	Emydidae	*Clemmys guttata*	Spotted Turtle	X		
Testudines	Emydidae	*Pseudemys concinna*	River Cooter	X		
Testudines	Emydidae	*Terrapene carolina*	Eastern Box Turtle	X		X
Testudines	Kinosternidae	*Kinosternon subrubrum*	Common Mud Turtle	X		
Testudines	Kinosternidae	*Sternotherus odoratus*	Common Musk Turtle	X		
Testudines	Emydidae	*Trachemys scripta*	Common Slider	X		X
Testudines	Emydidae	*Trachemys scripta scripta*	Yellow-bellied Slider			X

Appendix B. Map of sampling locations with point labels.

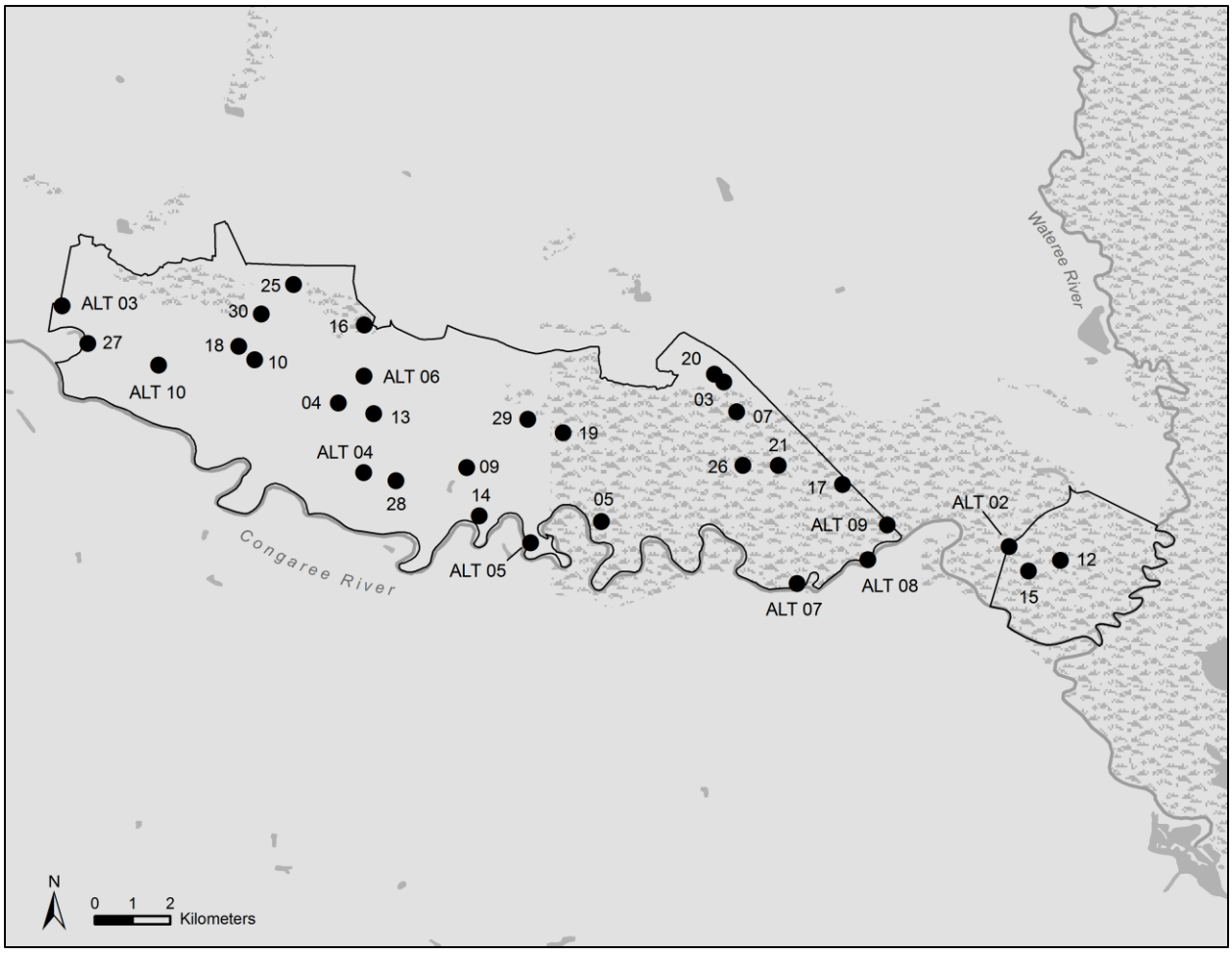

Figure B-1. Spatially-balanced random sampling locations at CONG with labels, 2010.

Appendix C. Species detections by sampling location.

Table C-1. Species, group, or species sign detected at each sampling location at CONG, 2010. Refer to Appendix B for labeled sampling-locations. Gray-shaded cells indicate that ARD data are incomplete.

	Sampling Location																														
Scientific Name	**3**	**4**	**5**	**7**	**9**	**10**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**25**	**26**	**27**	**28**	**29**	**30**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**
Acris gryllus									X																						
Bufo terrestris						X			X		X						X	X	X	X		X	X	X		X		X	X		X
Gastrophryne carolinensis																									X						
Hyla chrysoscelis		X			X	X		X	X	X		X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hyla chrysoscelis tadpoles						X														X	X										
Hyla cinerea																							X						X		
Hyla squirella							X												X			X	X								X
Pseudacris brimleyi																									X						
Pseudacris crucifer													X				X							X							
Unk. *Pseudacris* sp.																						X									
Rana catesbeiana																						X	X								
Rana clamitans		X						X	X			X									X			X							
Rana clamitans clamitans											X																				
Rana palustris																					X	X									
Rana sphenocephala		X				X			X	X	X	X	X	X		X				X	X	X	X	X	X		X			X	X
Unk. *Rana* sp.		X						X		X			X			X					X	X			X						
Unk. Anura larvae																							X	X							
Ambystoma opacum		X		X	X	X		X				X	X	X				X	X	X		X		X	X	X	X	X	X		X
Ambystoma talpoideum											X																				
Desmognathus sp.						X						X				X					X									X	
Eurycea guttolineata											X											X									
Eurycea quadridigitata		X				X					X	X										X		X							
Plethodon chlorobryonis											X																				
Unk. Caudata sp.	X																													X	
Agkistrodon contortrix							X																						X		
Agkistrodon piscivorus										X						X					X										
Anolis carolinensis						X			X					X	X					X									X		
Diadophis punctatus		X								X	X									X											
Elaphe obsoleta obsoleta																										X					
Elaphe obsoleta quadrivittata																													X		

Table C-1. (Continued).

	Sampling Location																													
Scientific Name	**3**	**4**	**5**	**7**	**9**	**10**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**25**	**26**	**27**	**28**	**29**	**30**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**
Eumeces fasciatus																													X		
Eumeces fasciatus/inexpectatus																			X		X	X			X	X	X	X			
Eumeces laticeps																			X			X									
Unk. *Eumeces* sp.														X	X																
Nerodia erythrogaster erythrogaster								X																						X	
Opheodrys aestivus										X																					
Scincella lateralis															X		X														
Snake skin					X																										
Storeria dekayi						X		X												X							X	X			
Unk. Squamata sp.	X																														
Terrapene carolina							X								X												X				
Trachemys scripta scripta										X																					

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