Quantifiable Long-term Monitoring on Parks and Nature Preserves

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Abstract - Herpetofauna have declined globally, and monitoring is a useful approach to document local and long-term changes. However, monitoring efforts often fail to account for detectability or follow standardized protocols. We performed a case study at Hemlock Bluffs Nature Preserve in Cary, NC to model occupancy of focal species and demonstrate a replicable long-term protocol useful to parks and nature preserves. From March 2010 to 2011, we documented occupancy of *Ambystoma opacum* (Marbled Salamander), *Plethodon cinereus* (Red-backed Salamander), *Carphophis amoenus* (Eastern Worm Snake), and *Diadophis punctatus* (Ringneck Snake) at coverboard sites and estimated breeding female *Ambystoma maculatum* (Spotted Salamander) abundance via dependent double-observer egg-mass counts in ephemeral pools. Temperature influenced detection of both Marbled and Red-backed Salamanders. Based on egg-mass data, we estimated Spotted Salamander abundance to be between 21 and 44 breeding females. We detected 43 of 53 previously documented herpetofauna species. Our approach demonstrates a monitoring protocol that accounts for factors that influence species detection and is replicable by parks or nature preserves with limited resources.

Introduction

Reptile and amphibian species have declined globally, with more species declining than either birds or mammals (Gibbons et. al 2000, Gardner et al. 2007, Heyer et al. 1994, Pechman et al. 1991, Wake 1991). Climate change, disease, invasive species, and habitat loss and degradation contribute to declines (Alford and Richards 1999, Gamble et al. 2009, Stuart et al. 2004). Additionally, reptiles and amphibians are important bio-indicators of ecosystem health, so understanding the drivers of population change is critical (Bury and Corn 1988, Dunson et al. 1992, Gibbons et al. 2000, Hanlin et al. 2000, Wake 1991).

Documenting species distribution and abundance is essential to comprehending changes in global biodiversity. Some reptiles and amphibians are wide ranging and could serve as global indicators of biodiversity change; other species are endemic to smaller areas and could indicate local conservation threats (Heyer et al. 1994). However, knowledge of the distribution and status of most herpetofauna species is lacking, even on public lands (Smith et al. 2006). Therefore, long-term monitoring of local sites is particularly critical to describing larger-scale changes in biodiversity (Gooch et al. 2006).

Park and nature preserves need repeatable and affordable methods for monitoring herpetofaunal populations to document long-term population trends and

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make well-informed management decisions. Standardized monitoring is necessary to assess changes in local species diversity and species-specific responses to management (Yoccoz et. al 2001). Data from monitoring programs are critical for making inferences about species occurrence, conservation status, and metapopulation dynamics (Heyer et al. 1994, Nichols et al. 2007, Williams and Berkson 2004). Standardized sampling protocols that account for variations in detection probability reduce biases associated with nondetection, and allow managers to compare estimates of species distribution, abundance, and occurrence across space and time (Heyer et al. 1994, Feest 2006). Nevertheless, inferences about system dynamics often are derived from monitoring data that represent spatial and temporal snapshots of species distribution. Additionally, perfect detection of species on surveys is rare, so practitioners often are faced with the challenge of determining whether the absence of a species represents a true absence or simply a case where an observer failed to detect a species that actually occurred on a site. Occupancy modeling accounts for the probability of imperfectly detecting a species during a survey (MacKenzie 2005, MacKenzie et al. 2002). Multi-season occupancy modeling is a modern technique that provides direct estimates of detection probability through replicated presence-absence surveys at a series of sites, is often less labor intensive than methods used to estimate abundance, and can provide useful information on species distribution and abundance to parks and natural preserves with limited resources (MacKenzie et al. 2006).

We used a 1-year monitoring study at Hemlock Bluffs Nature Preserve (HBNP), Cary, NC to demonstrate this approach for other nature preserves, parks, and land trusts that are interested in developing long-term monitoring programs. We monitored the presence of herpetofauna within the preserve to develop a preliminary inventory and standardized and replicable survey methods. Our study determined baseline occupancy and detection probability estimates of *Ambystoma opacum* Gravenhorst (Marbled Salamander), *Plethodon cinereus* Green (Red-backed Salamander), *Carphophis amoenus* Say (Eastern Worm Snake), and *Diadophis punctatus* L. (Ringneck Snake), which will provide the opportunity to model long-term changes in species distribution on the property. Also, we estimated the abundance of breeding female *Ambystoma maculatum* Shaw (Spotted Salamander) using egg-mass counts, which can be used with other pool-breeding amphibians to provide a useful index for modeling long-term changes in reproductive effort.

Field-Site Description

Hemlock Bluffs is a 64-ha nature preserve located in southwestern Cary, NC. The property is co-owned by the State of North Carolina and the Town of Cary and has high patron visitation (annual visitation estimate for 2010 was 100,000 patrons [J. Logan, Hemlock Bluffs Nature Preserve Customer Service Representative, Cary, NC, pers. comm.]). Several boardwalks, overlooks, and approximately 4.8 km of trails occur within the preserve. A natural area owned by the State of North Carolina includes a system of north-facing bluffs featuring a disjunct population of *Tsuga canadensis* Carr (Eastern Hemlock). This bluff system is adjacent to Swift Creek, which runs through the preserve and along a portion of the property boundary. Also, several small tributaries of Swift Creek intersect the property. The bluffs create a division between upland ridges and flats and the floodplain forest habitat, which is primarily at the east end of the preserve. Upland areas are mainly a pine-hardwood mix. The floodplain forest lies in the northeastern part of the property and contains several ephemeral pools, which provide essential breeding areas for many amphibian species such as Marbled Salamander, Spotted Salamander, *Pseudacris feriarum* Baird (Upland Chorus Frog), and *Pseudacris crucifer* Wied-Neuwied (Spring Peeper).

Areas of urban development encompass 3 sides of the preserve, with a 4-lane road on the southeastern boundary. The loss of forest cover adjacent to the preserve has increased water discharge of Swift Creek (Fig. 1; USGS 2011), which is a primary variable affecting transport of sediment and channel morphology in alluvial streams (Doyle et al. 2005). The increase of water discharge could lead to increased flooding, bank erosion, stream sedimentation, and overall changes in hydrology of the floodplain forest, affecting key amphibian breeding sites.

Historically, HBNP has not conducted standardized and quantifiable herpetofauna monitoring, which has limited the ability of park staff to directly compare results from species inventories conducted in the preserve. Preserve managers recognized the need for a standardized monitoring program to track the response of the herpetofaunal community to urban development and other long-term conservation threats.

Methods

During fall 2009, we established coverboards (0.6-m x 0.6-m x 0.0127-m untreated plywood boards) at 35 sites throughout HBNP, each site containing one coverboard. Coverboard locations effectively sampled each major habitat type, surrounded ephemeral pools, and avoided visibility from walking trails. We were unable to establish coverboards randomly at HBNP because we were concerned that patrons would venture off trails and disturb boards at visible

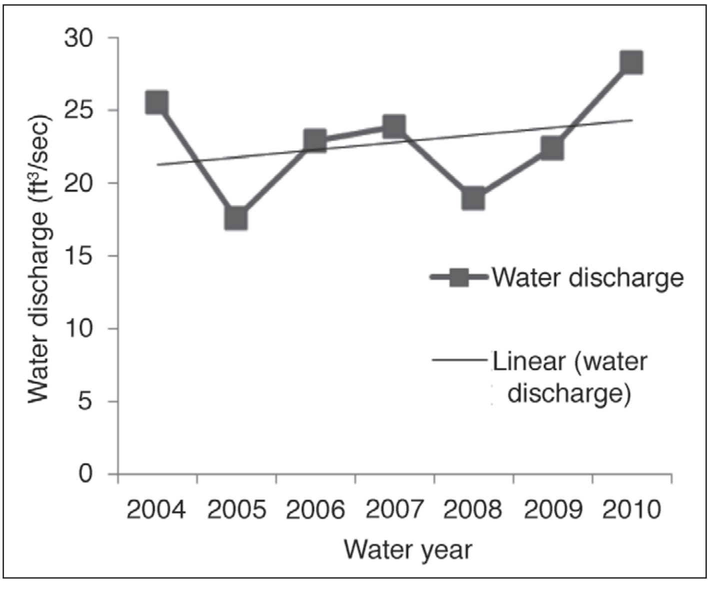

Figure 1. Annual water discharge for Swift Creek near Apex, NC from 2004–2010. Water volume in Swift Creek has increased from 2004–2010.

locations (Fig. 2). We located coverboards at least 30 m apart, numbered each, and recorded locations with a GPS. We checked all 35 coverboards during each survey from March 2010 through March 2011. We checked coverboards every 2 weeks and recorded each species detected. We conducted 28 coverboard surveys from 2010 through 2011 with 7 surveys in each of 4 sampling seasons. We designated samplings seasons as spring (March–May 2010), summer (June–August 2010), fall (September–December 2010), and winter (January–March 2011).

We recorded the covariates ambient temperature, precipitation, and sampling season that could influence herpetofauna detection and habitat type (upland or bottomland habitat) which could influence occupancy. We recorded precipitation as a categorical variable, denoting if a rain event occurred during each survey. We measured ambient temperature at the beginning of each survey.

We conducted Spotted Salamander egg-mass surveys in 3 ephemeral pools within HBNP. We used a dependent double-observer approach, where observer 1 pointed out and counted egg masses to observer 2, who then recorded the observations and noted any egg masses missed by observer 1 (Grant et al. 2005). Halfway through each survey at individual pools, observer 1 and 2 switched responsibilities (Grant et al. 2005). We counted egg masses by viewing from the shore, and the same observers conducted surveys on 2 occasions in each pool to ensure the maximum number of egg masses was counted. We conducted surveys during March, which is prime oviposition time for Spotted Salamanders (Egan and Paton 2004). Spotted Salamander breeding females lay between 2 and 4 egg

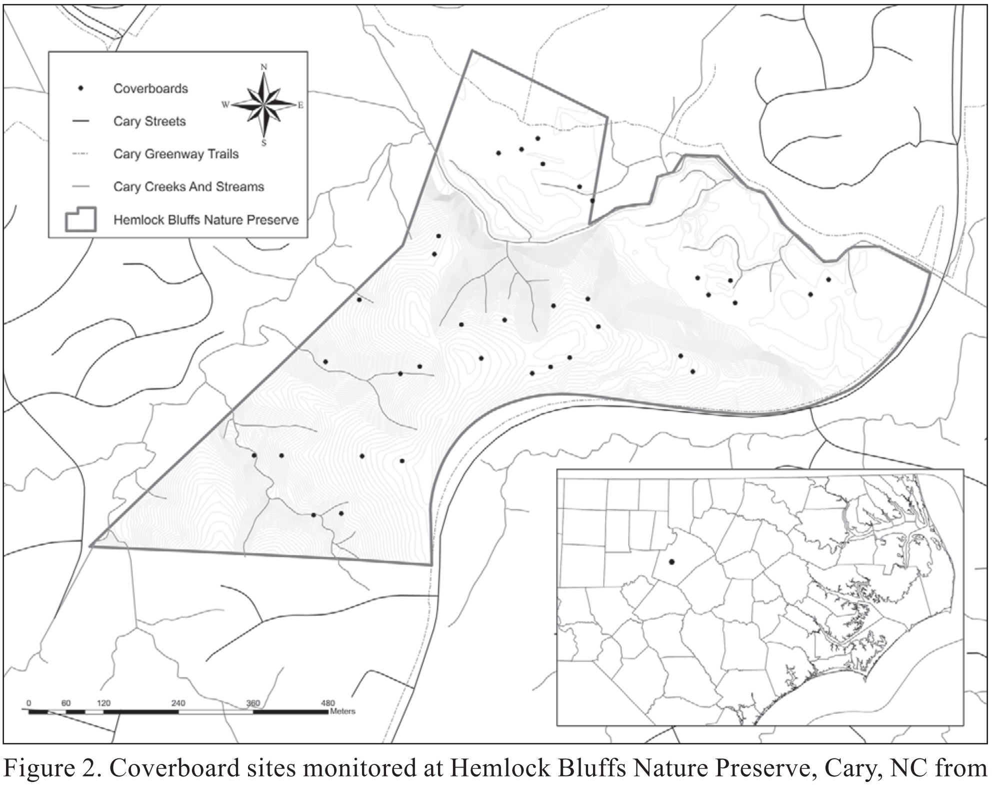

Figure 2. Coverboard sites monitored at Hemlock Bluffs Nature Preserve, Cary, NC from March 2010–March 2011.

masses each year (Petranka 1998); we used this range in egg masses per female to estimate the number of breeding female salamanders in the 3 pools.

We used the program PRESENCE to estimate detection probabilities and site occupancy for Marbled Salamanders, Red-backed Salamanders, Eastern Worm Snakes, and Ringneck Snakes through multiple sampling seasons (Hines and MacKenzie 2002). These 4 species were selected as focal species because they were the only species detected >5 times over the entire year. By conducting multiple surveys within each sampling season, we were able to model changes in occupancy and detection probabilities across the seasons (MacKenzie et al. 2002, 2003, 2006). We developed multi-season models with every combination of covariates (precipitation, temperature, and habitat type) for each focal species. We reported only models with ΔAIC_c scores of less than 2. We used program DOBSERVE to estimate detection probabilities and abundance of egg masses (Hines 1996). We used egg-mass abundance estimates to calculate the abundance of breeding Spotted Salamander females (Nichols et al. 2000). We used 2 models, the first held variation of detection due to observer effect constant and the second allowed for variation of detection based on observer.

We recorded opportunistic encounters by HBNP staff to supplement the species inventory. This species list was compared with historical records of species within HBNP from personal field notes of A. Braswell (North Carolina Museum of Natural Sciences [NCMNS], Raleigh, NC, 2010 unpubl. data) and a species list developed by M. Johns (Hemlock Bluffs Nature Preserve [HBNP], Cary, NC, 2010 unpubl. data).

Results

Occupancy estimation

Sampling season influenced detection for all focal species (Table 1). Detection of Ringneck Snake was highest in summer, and we did not detect individuals during spring or winter (Table 2). Ringneck Snake had the lowest number of detections of the 4 focal species. We detected Eastern Worm Snake the most during spring and did not detect this species during summer or fall (Table 2). We most commonly detected Marbled Salamander during fall and Red-backed Salamander during winter but did not detect either species during the spring or summer

Table 1. Multi-season occupancy models for each focal species from program PRESENCE. ΔAICc scores of less than 2 designate appropriate top models for each species. Habitat type influenced site occupancy (Ψ), whereas ambient temperature and precipitation events influenced detection probability (P).

Species	Top occupancy models	AICc	Δ AICc
Worm Snake	Ψγεp(seasons)(precip)	91.77	0.00
Marbled Salamander	Ψγεp(seasons)(temp)	128.24	0.00
Red-backed Salamander	Ψγεp(seasons)(temp)	109.82	0.00
Ringneck Snake	Ψγεp(seasons)	61.23	0.00
	Ψγεp(seasons)(precip)	61.46	0.23
	Ψ(habitat)γεp(seasons)	63.03	1.80

(Table 2). Temperature was an important predictor of detection for the 2 salamander species, with higher detection probabilities during the cooler months of the year (Table 1, 3). Precipitation was present in top models for both snake species; however, 95% confidence intervals of parameter estimates overlapped zero.

Site-occupancy estimates for Eastern Worm Snake and Ringneck Snake were constant across seasons (Table 2). Occupancy estimates were highest in winter for Marbled Salamander and in fall for Red-backed Salamander. Increased site-occupancy parameter estimates during fall and winter corresponded with the timing of breeding-season migrations for both salamander species. Habitat type was not an influential predictor of occupancy for any of the four focal species (Table 1).

Egg-mass detection and salamander abundance

The first survey produced a higher count of egg masses, so we used it for analysis in the DOBSERV software. Detection of egg masses differed only by an AICc weight of 0.0002 between the 2 models, and the top model did not include the observer covariate (Table 4). The estimated range of egg-mass abundance was 84.7 to 88.6. Therefore, estimates of breeding female Spotted Salamander abundance, considering egg masses could range from 2 to 4 per female, were between 21.2 and 44.3 across the 3 pools surveyed.

Table 2. Occupancy (Ψ), standard error (SE), and detection probability (P) estimates from the top model for each focal species across the seasons. Seasons were designated as spring = March–May, summer = June–August, fall = September–December, winter = January–March. * = species not detected.

Species	Season	Ψ	95%CI	SE	*P*
Worm Snake	Spring	0.34	0.08–0.75	0.20	0.13
	Summer*				
	Fall*				
	Winter	0.34	0.08–0.75	0.20	0.02
Marbled Salamander	Spring*				
	Summer*				
	Fall	0.47	0.03–0.91	0.23	0.09
	Winter	0.62	0.13–1.10	0.25	0.02
Red-backed Salamander	Spring*				
	Summer*				
	Fall	0.23	0.05–0.41	0.09	0.09
	Winter	0.11	-0.02–0.24	0.07	0.14
Ringneck Snake	Spring*				
	Summer	0.18	-0.13–0.49	0.16	0.07
	Fall	0.18	-0.13–0.49	0.16	0.02
	Winter*				

Table 3. Parameter estimates, standard error (SE), and 95% confidence intervals for temperature from multi-season occupancy models.

Species	Estimate	SE	95%CI
Marbled Salamander	1.105887	0.448135	0.2324–1.9842
Red-backed Salamander	-1.308516	0.674132	-2.6298–0.0128

Species richness inventory

We documented 22 of the 25 amphibian species previously known to occur within HBNP (Table 5). Two caudate and 2 anuran species were recorded in historical surveys but not detected in recent surveys. Three anuran species detected in recent surveys (Historic 2 and Present surveys) went undetected in Historic 1 (Table 5). In addition, we documented 21 of the 28 reptilian species reported in historical accounts (Table 6). Six squamate species and 1 testudinate species not detected in present surveys had been previously detected (Table 6). Thirteen reptilian species detected in recent surveys (Historic 2 and Present surveys) had not been detected in Historic survey 1. Overall, we documented 43 of the 53 reptile and amphibian species previously known to occur within HBNP.

Table 4. Models for Spotted Salamander egg-mass abundance estimates from program DOBSERV.

Model	AICc	ΔAICc	*P*	*n* (egg masses)	95% CI	*n* (adult females)
p (.,.)	8.178	0.000	0.9921	86.68	84.7–88.6	21.2–44.3
p (.,observer)	10.230	2.052	0.9923	86.67	84.7–88.6	21.2–44.3

Table 5. Comprehensive list of amphibian species detected within Hemlock Bluffs Nature Preserve, Cary, NC. Species from current survey (March 2010 through March 2011) were compared against historical inventory data collected from March 1973 through February 1984 (Historic 1) and inventory data collected from 1990 through 2009 (Historic 2).

Species	Historic 1	Historic 2	Present
Anurans			
Acris crepitans (Northern Cricket Frog)	X	X	X
Anaxyrus americanus (American Toad)	X	X	X
Anaxyrus fowleri (Fowler's Toad)		X	X
Gastrophryne carolinensis (Eastern Narrowmouth Toad)	X	X	X
Hyla chrysoscelis (Cope's Gray Treefrog)	X	X	X
Hyla cinerea (Green Treefrog)		X	X
Hyla squirella (Squirrel Treefrog)		X	
Lithobates catesbeianus (American Bullfrog)	X	X	X
Lithobates clamitans (Green Frog)	X	X	X
Lithobates sphenocephalus (Southern Leopard Frog)		X	X
Pseudacris crucifer (Spring Peeper)	X	X	X
Pseudacris feriarum (Upland Chorus Frog)	X	X	X
Scaphiopus holbrookii (Eastern Spadefoot)		X	
Caudates			
Ambystoma maculatum (Spotted Salamander)	X	X	X
Ambystoma opacum (Marbled Salamander)	X	X	X
Desmognathus fuscus (Northern Dusky Salamander)	X	X	X
Eurycea cirrigera (Southern Two-lined Salamander)	X	X	X
Eurycea guttolineata (Three-lined Salamander)	X	X	X
Eurycea quadridigitata (Dwarf Salamander)	X	X	X
Hemidactylium scutatum (Four-toed Salamander)	X	X	X
Notophthalmus viridescens viridescens (Red-spotted Newt)	X	X	X
Plethodon cinereus (Red-backed Salamander)	X	X	X
Plethodon cylindraceus (White-spotted slimy Salamander)	X	X	X
Pseudotriton montanus (Mud Salamander)	X	X	
Pseudotriton ruber (Red Salamander)		X	

Discussion

Occupancy modeling is an efficient method for parks and nature preserves to monitor the presence of species. Common approaches to monitoring herpetofauna based on ad-hoc inventories are subject to biases from a variety of factors affecting species detection probabilities. We detected several species not previously recorded at HBNP, possibly due to site colonization or our sampling design, which provided more spatially complete sampling. *Anaxyrus fowleri* Hinckley (Fowler's Toad), *Lithobates sphenocephalus* Cope (Southern Leopard Frog), and 13 historically undetected reptilian species have wide ranges across North Carolina and were likely present but not detected during surveys prior to 1990 (Historic 1) (Beane et al. 2010). Conversely, the *Hyla cinerea* Schneider (Green Treefrog) range in North Carolina has expanded westward from the

Table 6. Comprehensive list of reptilian species detected within Hemlock Bluffs Nature Preserve, Cary, NC. Species from current survey (March 2010 through March 2011) were compared against historical inventory data collected from March 1973 through February 1984 (Historic 1) and inventory data collected from 1990 through 2009 (Historic 2).

Species	Historic 1	Historic 2	Present
Squamates			
Agkistrodon contortrix (Copperhead)		X	X
Anolis carolinensis (Green Anole)		X	X
Carphophis amoenus (Eastern Worm Snake)		X	X
Coluber constrictor (Black Racer)		X	X
Diadophis punctatus (Ringneck Snake)	X	X	X
Elaphe guttata guttata (Corn Snake)		X	
Elaphe obsolete obsoleta (Black Rat Snake)	X	X	X
Eumeces fasciatus (Five-lined Skink)	X	X	X
Eumeces laticeps (Broadhead Skink)		X	X
Heterodon platirhinos (Eastern Hog-nosed Snake)		X	X
Lampropeltis calligaster rhombommaculata (Mole Kingsnake)		X	
Lampropeltis getula getula (Eastern Kingsnake)		X	
Nerodia erythrogaster erythrogaster (Redbelly Water Snake)		X	
Nerodia sipedon (Northern Water Snake)	X	X	X
Opheodrys aestivus (Rough Green Snake)		X	X
Sceloporus undulatus (Eastern Fence Lizard)		X	X
Scincella lateralis (Ground Skink)		X	X
Storeria dekayi (Brown Snake)	X	X	X
Tantilla coronata (Southeastern Crowned Snake)	X		
Thamnophis sauritus (Eastern Ribbon Snake)		X	X
Thamnophis sirtalis (Common Garter Snake)		X	X
Virginia striatula (Rough Earth Snake)		X	
Testudinates			
Chelydra serpentine (Common Snapping Turtle)		X	X
Clemmys guttata (Spotted Turtle)	X	X	X
Kinosternon subrubrum (Eastern Mud Turtle)	X	X	X
Sternotherus odoratus (Common Musk Turtle)	X	X	X
Terrapene carolina (Eastern Box Turtle)		X	X
Tracemys scripta scripta (Yellow-bellied Slider)		X	

Coastal Plain indicating it may have been absent from HBNP during Historic 1 (Beane et al. 2010).

Site extinction and the short time frame of our study may explain why we did not detect 7 reptilian and 2 anuran species historically recorded at HBNP. Generally, herpetofauna have low detection probabilities and detection can be highly variable depending on changes in environmental covariates (Dodd 2010). Most of the species we did not detect are nocturnal, secretive, or rare (Beane et al. 2010). These characteristics and our short sampling time frame reduced the probability of detection. In addition to our short sampling time frame, changing habitat conditions leading to site extinctions may explain why 2 caudate (*Pseudotriton montanus* Baird [Mud Salamander] and *Pseudotriton ruber* Sonni de Manoncourt and Latreille [Red Salamander]) and 2 squamate (*Thamnophis sauritus* L. [Eastern Ribbon Snake] and *Nerodia erythrogaster erythrogaster* Forster [Red-bellied Water Snake]) species were not detected. Forest succession and increased water discharge enabled vegetation to encroach into the spring-fed seeps within the lowlands of HBNP, which altered the Swift Creek stream morphology and made habitat conditions less suitable for these 4 species (Beane et al. 2010; M. Johns, pers. comm.).

Although our comparisons across inventories imply site extinction or colonization, there is no quantifiable data from historical methods to help explain non-detections. Conversely, estimating occupancy and detection probabilities allowed park staff to account for external influences and design a replicable protocol for future long-term monitoring. Although Hemlock Bluffs Nature Preserve had historical records of several species of special concern to North Carolina, including *Tantilla coronata* Baird and Girard (Southeastern Crowned Snake) and *Hemidactylium scutatum* Temminck and Schlegel (Four-toed Salamander) (Alvin Braswell, North Carolina Museum of Natural Sciences, Raleigh, NC, and M. Johns, pers. comm.), we are not able to use these historical records to assess changes in species occurrence because prior surveys lacked any measure of detection probability.

In the future, occupancy modeling will allow preserve staff to work more efficiently by accounting for environmental covariates that influence detection. Because sampling season influenced detection probability for all 4 focal species, sampling could occur only during seasons with the highest detection probabilities. Ambient temperature influenced detection of both salamander species, indicating monitoring programs could account for the influence of annual climatic variation on salamander detection. Detection of both salamander species was low from April to October, when temperatures were above monthly averages (SRCC 2011).

Although modeling occupancy and detection probability provides a preferable alternative to compiling simple species inventories, there are limitations to this approach. Rare species that are often the focus of monitoring programs occur with very low and highly variable detection probabilities (Royle and Nichols 2003). However, including covariates influential to detection (e.g., weather conditions, seasonal behavior patterns, and differences between observers) improves occupancy estimates for rare species (MacKenzie et al. 2006). Additionally, occupancy modeling estimates only species occurrence and not population abundance. Therefore, tracking changes in population size is not possible with this approach alone.

We used two sampling methods to monitor herpetofauna on HBNP, but there are other methods not implemented in this survey that may increase detection probabilities of focal species (Heyer et al. 1994, Hutchens and DePerno 2009). Repeated visual encounter surveys in selected plots would provide more sampling events and improve estimate accuracy (MacKenzie et al. 2006). Drift-fence arrays provide a passive capture method that is especially effective at detecting nocturnal and secretive species; however, effort required to install, maintain, and monitor drift-fence arrays is often more expensive and time consuming than small preserves can afford (Heyer et al. 1994). Calling amphibian surveys can account for anuran species that otherwise have low detection probabilities, require no equipment, and can cover large sampling areas (Dodd 2010).

Available statistical software such as PRESENCE and DOBSERV may present an additional challenge for park staff not trained in statistical analysis. We recommend parks and nature preserves work with local universities or hire system-wide personnel that are trained to use statistical software. Some training of HBNP staff is needed to collect and compile data using occupancy-based methods, but the cost of this training is minimal.

Randomization of site locations helps reduce estimate bias (Heyer et al. 1994), but randomization may be difficult to accomplish at small parks and nature preserves. We were unable to establish site locations randomly at HBNP because we were concerned that patrons would disturb our plots and reduce our detection probabilities. Parks with high visitation such as HBNP prioritize preservation of wildlife habitat and patron safety. Sampling locations often represent a balance between effectively sampling each habitat type and reducing the visibility of site locations.

We believe long-term multi-season occupancy modeling provides a useful approach for long-term species monitoring in parks and nature preserves with limited resources. Traditional approaches based on simple inventories are subject to multiple sources of bias due to variations in detection probability. Integrating occupancy modeling into a park or nature preserve monitoring protocol generates quantifiable results that can be compared across long time frames and provide reliable insight to guide management decisions.

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Appendix 1. Taxonomic classification of all reptilian and amphibian species referenced in the study with corresponding authority names (ITIS 2011).

Amphibia
- Anura
  - Anaxyridae
    - *Anaxyrus americanus* Holbrook (American Toad)
    - *Anaxyrus fowleri* Hinckley (Fowler's Toad)
  - Hylidae
    - *Acris crepitans* Baird (Northern Cricket Frog)
    - *Hyla chrysoscelis* Cope (Cope's Gray Treefrog)
    - *Hyla cinerea* Schneider (Green Treefrog)
    - *Hyla squirella* Bosc (Squirrel Treefrog)
    - *Pseudacris crucifer* Wied-Neuwied (Spring Peeper)
    - *Pseudacris feriarum* Baird (Upland Chorus Frog)
  - Lithobatidae
    - *Lithobates catesbeianus* Shaw (American Bullfrog)
    - *Lithobates clamitans* Latreille (Green Frog)
    - *Lithobates sphenocephalus* Cope (Southern Leopard Frog)
  - Microhylidae
    - *Gastrophryne carolinensis* Holbrook (Eastern Narrowmouth Toad)
  - Pelobatidae
    - *Scaphiopus holbrookii* Harlan (Eastern Spadefoot)
- Caudates
  - Ambystomatidae
    - *Ambystoma maculatum* Shaw (Spotted Salamander)
    - *Ambystoma opacum* Gravenhorst (Marbled Salamander)
  - Plethodontidae
    - *Desmognathus fuscus* Rafinesque (Northern Dusky Salamander)
    - *Eurycea cirrigera* Green (Southern Two-lined Salamander)
    - *Eurycea guttolineata* Holbrook (Three-lined Salamander)
    - *Eurycea quadridigitata* Holbrook (Dwarf Salamander)
    - *Hemidactylium scutatum* Temminck & Schlegel (Four-toed Salamander)
    - *Plethodon cinereus* Green (Red-backed Salamander)
    - *Plethodon cylindraceus* Harlan (White-spotted slimy Salamander)
    - *Pseudotriton montanus* Baird (Mud Salamander)
    - *Pseudotriton ruber* Sonnini de Manoncourt and Latreille (Red Salamander)
  - Salamandridae
    - *Notophthalmus viridescens viridescens* Rafinesque (Red-spotted Newt)

Reptilia
- Squamata
  - Sauria
    - Phrynosomatidae
      - *Sceloporus undulatus* Bosc & Daudin (Eastern Fence Lizard)
    - Polychrotidae
      - *Anolis carolinensis* Voigt (Green Anole)
    - Scincidae
      - *Eumeces fasciatus* L. (Five-lined Skink)
      - *Eumeces laticeps* Schneider (Broadhead Skink)
      - *Scincella lateralis* Say (Ground Skink)

Serpentes
Colubridae
Carphophis amoenus Say (Eastern Worm Snake)
Coluber constrictor L. (Black Racer)
Diadophis punctatus L. (Ringneck Snake)
Elaphe guttata guttata L. (Corn Snake)
Elaphe obsolete obsoleta Say (Black Rat Snake)
Heterodon platirhinos Latreille (Eastern Hog-nosed Snake)
Lampropeltis calligaster rhombommaculata Holbrook (Mole Kingsnake)
Lampropeltis getula getula L. (Eastern Kingsnake)
Nerodia erythrogaster erythrogaster Forster (Redbelly Water Snake)
Nerodia sipedon L. (Northern Water Snake)
Opheodrys aestivus L. (Rough Green Snake)
Storeria dekayi Holbrook (Brown Snake)
Tantilla coronata Baird & Girard (Southeastern Crowned Snake)
Thamnophis sauritus L. (Eastern Ribbon Snake)
Thamnophis sirtalis L. (Common Garter Snake)
Virginia striatula L. (Rough Earth Snake)
Viperidae
Agkistrodon contortrix L. (Copperhead)
Chelonia
Testudines
Chelydridae
Chelydra serpentina L. (Common Snapping Turtle)
Emydidae
Clemmys guttata Schneider (Spotted Turtle)
Terrapene carolina L. (Eastern Box Turtle)
Tracemys scripta scripta Schoepff (Yellow-bellied Slider)
Kinosternidae
Kinosternon subrubrum Lacepede (Eastern Mud Turtle)
Sternotherus odoratus Latreille (Common Musk Turtle)