Final report to South Carolina Department of Natural Resources for:

A resurvey of historical green salamander locations in South Carolina

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ABSTRACT.— Green Salamanders, *Aneides aeneus*, are habitat specialists found in narrow crevices of rock outcrops and under flaky bark of trees. The species is of high conservation priority throughout its range and has been negatively affected by habitat loss, climate change, disease, and over-collection. Many historical locations for this species have not been visited since the 1980's or earlier in portions of the Blue Ridge Escarpment population. Across three counties in South Carolina, we conducted visual encounter surveys of rock outcrops and used binoculars to conduct arboreal surveys. We detected Green Salamanders at 30 of the 61 sites surveyed (49.2%). We collected a variety of habitat variables and compared a suite of N-mixture models using an AIC framework. Detection probability was positively influenced by time of day. A model of abundance that included aspect, habitat size, and elevation had the most support. Specifically, Green Salamanders were more abundant at larger sites with lower elevations and south-facing slopes. We conducted a follow up survey on a subset of sites in the fall of 2018 to better understand the influence of season and season-related variables on detection probability. Detections for green salamanders were marginally higher during the fall surveys. Knowledge of factors that influence population abundance and survey success will help guide future efforts to protect the species in the southern portion of its range.

Key words: Amphibian; *Aneides aeneus*; Blue Ridge Mountains; Elevation; Habitat selection; Habitat specialist; N-mixture model;

Amphibian habitat suitability can be influenced by a wide array of factors attributable to natural habitat heterogeneity (Tockner et al., 1996; Vallan, 2002) and anthropogenic changes such as forest fragmentation and climate change (Petranka et al., 1993; Gibbs, 1998; Araújo et al., 2006; Barrett et al., 2014). Habitat specialists are particularly susceptible to factors that alter distributions at both local and landscape scales. Specialists suffer greater population declines when faced with habitat loss and tend to be less resilient to the effects of climate change when compared to generalists (Travis, 2003; Munday, 2004). Small-bodied specialists that live at higher elevations and also have limited ability to evade diseases (e.g., chytrid fungus) are at particularly high risk of extinction (Owens and Bennett, 2000; Pounds et al., 2006).

The Green Salamander, *Aneides aeneus* (Cope and Packard, 1881), is considered a habitat specialist and is the only member of the "climbing salamander" genus found on the east coast of the United States. This species is typically associated with narrow granitic or sandstone rock crevices (Bruce, 1968; Mount, 1975). Green Salamanders have specialized toe-tips which allow them to climb up vertical surfaces and a unique lichen-like pattern on their dorsum that allows them to blend in with their surroundings (Mount, 1975; Petranka, 1998). Green Salamanders occur from southwestern Pennsylvania to northern Alabama and into eastern Mississippi. There is a disjunct population in the Blue Ridge Escarpment (Petranka, 1998). Green Salamanders are considered "near threatened" by the International Union for Conservation of Nature (IUCN). Within the disjunct Blue Ridge Escarpment (BRE) population, Green Salamanders are state listed as "imperiled" in Georgia and North Carolina, and "critically imperiled" in South Carolina (Natureserve, 2017).

Snyder (1983) noted that Green Salamanders in the Carolinas are close to extirpation. Corser (2001) acknowledges four major threats facing Green Salamanders: habitat loss, climate change, over-collection of the species, and disease. Researchers have documented that this species is capable of dispersing between 42 – 54 m from the nearest rock outcrop (Waldron and Humphries, 2005; Riedel et al., 2006); thus, researchers believe it is important to have forested buffers around outcrops during clear-cutting (Petranka, 1998; Wilson, 2001; Waldron and Humphries, 2005). The BRE has experienced warmer summer temperatures and colder winter temperatures since the 1960’s, and like many other amphibians of high conservation priority, the Green Salamander is expected to lose a significant amount of its climatically suitable habitat in the next half-century (Snyder, 1991; Corser, 2001; Barrett et al., 2014). Nevertheless, the Carolinas have been identified as an area of resilience to climatic change relative to many other parts of the range (Barrett et al., 2014). Over-collection of Green Salamanders (which are collected for their attractiveness) could potentially lead to population declines (Corser, 2001; Wilson, 2001). For example, continual collection of egg-brooding Green Salamanders from the same site over consecutive years can result in population decline (Wilson, 2001). Green Salamanders are likely vulnerable to disease such as chytrid fungus because they occur in moist conditions at high elevations (Daszak et al., 1999; Young et al., 2001). Recently, cases of chytrid fungus in Green Salamanders have been detected in both Virginia and North Carolina and Ranavirus was reported in this species in Virginia (Blackburn et al., 2015; Moffitt et al., 2015).

The collective threats facing Green Salamanders prompted us to determine the current status of the species within South Carolina. The last extensive inventories for Green Salamanders in the area were done in 1968 and 1990 (Bruce, 1968; Hafer and Sweeney, 1993). These surveys identified different habitat affiliations; specifically, salamanders appeared more frequently on south-facing slopes in the 1960s survey and a wider range of elevations (Bruce 1968), but more commonly on north-facing slopes and higher elevations in the Hafer and Sweeney (1993) survey. It is an open question whether this is a real shift driven by temperature or some other factor, or if it resulted from sampling error. To identify the current distribution and status of Green Salamanders in the southern portion of the range, we sampled prospective Green Salamander habitat in the Blue Ridge Mountains of South Carolina. We did so by reassessing known historical Green Salamander localities and some newly-located prospective sites in South Carolina (sensu Corser, 2001). We assessed a wide range of habitat features within and around known Green Salamander rock outcrop sites to evaluate potential predictors of site-level abundance.

METHODS

Data Collection

We collected a comprehensive list of historical Green Salamander records in South Carolina from the South Carolina Department of Natural Resources and three publically-accessible online databases (Price and Dorcas, 2007; Cicero et al., 2010; USGS, 2013). We also identified potential localities through conversations with South Carolina state park officials and through searching rock outcrops while traveling to historical locations. A total of 96 distinct sites were identified within three counties containing the Blue Ridge Region of South Carolina (Fig. 1, inset map). Thirty-five of these sites were not surveyed because sites had no rocky outcrops or large trees with flaky bark that could be identified at the locale (n = 24), sites were inaccessible from roads or trails (n=10), or sites were on private land that we did not have permission to access (n = 1).

For the remaining 61 accessible sites with appropriate habitat (an emergent rock outcrop), we surveyed them three times each (with the exception of two sites which were only surveyed once due to time constraints) between May and August 2016 (Hafer and Sweeney, 1993; Corser, 2001; Waldron and Humphries, 2005). We surveyed a subset of these sites (n = 19) in the fall of 2017 specifically to assess the influence of time-of-year and temperature on detection probability. A site was considered distinct if the rock outcrop was at least 25 m away from the nearest adjacent outcrop. This distance was chosen because it has been shown that Green Salamanders can home back to the same rock outcrop after being displaced ~9m (Gordon, 1961). It is important to note that our analysis is specific to this definition of site, and differs from some previous analyses that have evaluated the influence of specific crevice conditions on the presence or absence of green salamanders (i.e., Rossell et al., 2009; Smith et al., 2017). A site as defined here contained several crevices and we did not record occupancy or abundance data at the level of these individual microhabitats. Surveys were spread across the entire survey period with two rounds of surveys conducted mid-morning to mid-day, and one round of surveys conducted at dawn (no surveys were conducted at night due to logistical and safety concerns). Surveys were done in a standardized fashion using a similar method outlined by Miloski (2010) by one to two observers depending on the rock outcrop size. We established circular plots around a rock outcrop within historical Green Salamander sites and we created four 25–m transects representing the four cardinal directions (N, E, S, and W). Each visit consisted of a two-part visual encounter survey by the observer(s): (1) a thorough search of the entire rock outcrop using a headlamp, and (2) a line-transect survey in which the observer(s) walked all four transects searching trees (2 m on each side of the transect line) using binoculars and flipping cover objects checking for salamanders. We also collected habitat variables (Table 1) during every survey (except for habitat size, which was measured once due to time constraints) in order to obtain an average measurement of these variables. Multiple measures were made to correct any bias resulting from measurement error (Table 1). We measured habitat size (outcrop size) by assuming the sites were roughly rectangular in shape (Lato et al., 2010). To obtain measurements, we took a north-south distance (beginning at their respective transect) and an east-west distance (beginning at their respective transect) using a reel measuring tape (Keson 300-ft Tape, Keson Industries, Inc.) and these measurements were multiplied. We collected elevation above sea level using a Garmin GPS (GPSmap 62s, Garmin, Ltd.), midpoint slope using a clinometer (PM5/1520, Suunto), and midpoint aspect using a compass (MCB CM/IN/NH, Suunto). We assessed drainage presence/absence within 400 m (Hafer and Sweeney, 1993) of the site based on a visual assessment and Google Earth (v7.1.8.3036, Google, Inc.), and land cover within a 25-m radius of the outcrop was categorized as mixed forest, hardwood, softwood, or shrub based on our observations during site visits. We measured basal area using a 10-factor prism (Jim-Gem Square-shaped, Forestry Suppliers) and canopy cover (to the nearest 1%) using a concave densitometer (Spherical Crown, Forestry Suppliers) at the beginning of each of the four line transects. We categorized landscape disturbances into three different categories: heavy (paved roads and houses within 50m of the rock outcrop), light (dirt roads, hiking trails, and powerline cuts within 50m of the rock outcrop), and none. We downloaded four bioclimatic variables (BIO1, BIO5, BIO12, BIO17) from World Clim (Hijmans et al., 2005) and extracted the raster values to the Green Salamander presence points in ArcMap (ArcGIS 10.3.1, ESRI). These data correspond to mean annual temperature, maximum temperature of the warmest month, annual precipitation, and precipitation of the driest quarter for the period 1960 – 1990.

Abundance Analysis

Using data from visual encounter surveys, we developed an N-mixture model for Green Salamanders in South Carolina to investigate the relationships between species counts and environmental site covariates (Royle, 2004). These models allow for estimates of abundance either as a single parameter average across all sites, or as a function of site-specific covariates. Unlike analyses based only upon count data alone, N-mixture models explicitly account for imperfect detections, and abundance estimates can be adjusted across all sites or based upon estimated relationships with one or more measured variables deemed to influence detection probability.

We used the “p-count” function within the unmarked package (Fiske and Chandler, 2011) in Program R 3.3.1 (R Core Team, 2017) to fit N-mixture models to the count data. N-mixture models assume that the population is closed and counts between sites (rock outcrops) are independent of other sites. We assessed the weight of evidence for a model using the Akaike Information Criterion (AIC; Burnham and Anderson, 2002). We standardized all continuous covariates before putting them into the models and removed highly correlated variables *a priori*. Elevation was used as both a linear covariate and as a quadratic term (to test the hypothesis that intermediate elevations had greater abundances than high or low elevation sites). We transformed the aspect variable on a north/south gradient by taking the absolute value of the difference of the aspect value and 180. The land cover variable was removed from the analysis because there was only a small proportion of sites with softwood and shrub-dominated habitats. The drainage variables were removed because all sites had a drainage present within 400-m of the site. Bioclimatic variables were removed because each of the measures had high pairwise correlation values with elevation ($\geq \pm 0.96$). We began by exploring three possible model structures on the null model: negative binomial, zero-inflated Poisson, and Poisson. A comparison of these structures via AIC revealed the most support for the negative binomial, so all subsequent models were created with this structure. All final parameter estimates were deemed to be ecologically plausible, so we believe the use of the negative binomial structure is defensible in this application (Joseph et al., 2009).

We first identified survey-specific covariates (observer experience, total search time, time of day, cloud cover, temperature, and day of the year) that may have influenced detection probability within known Green Salamander locales. Observers were given a ranking between 0 – 2 (0 = low experience; 2 = high experience). Observers new to the field or naïve to field equipment were designated as having less experience than those observers who have had 3+ years in the field and have worked with a variety of field equipment. After completing the first round of surveys, less experienced observers became more experienced and earned a ranking of 2 as the field season progressed. If multiple observers were conducting the survey, we averaged their experience score. We measured total search time measured as the amount of time it took the observer(s) to complete a survey effort, and we divided this measure by total habitat size to generate the search effort variable (hereafter, "duration"). We included time of day because searches ranged from dawn to mid-day. We divided cloud cover into three categories: overcast, rain events, and clear/sunny days. We took air temperature using a thermometer (6-1/4" Pocket Case Enviro-Safe, Forestry Suppliers) and measured to the nearest 1°C. We recorded the day of the year using the 2016 leap year calendar.

We began identifying possible covariates of detection by comparing a null model to all possible univariate models of detection covariates, while keeping abundance covariates constant across sites. Detection covariates with strong support (ΔAIC < 2) were evaluated in all possible combinations to explore support for additive models. Once we determined which detection model had the most support (ΔAIC = 0), we incorporated this detection covariate model in all subsequent models exploring covariates of abundance. Similar to our process for identifying detection covariates, we first generated all possible univariate models with abundance covariates, identified those variables with the most support (ΔAIC < 4; which also represented weights > 0.1), and then examined all possible combinations of those covariates. Our final set of candidate models for comparison using AIC contained the null model, all strongly supported univariate models, and all possible multivariate models involving the top abundance covariates.

To determine the influence of sampling in warm versus cool weather, we used a subset of the sites in the analysis above (n = 19). We examined the influence of season by assigning samples to one of two categories: "warm-weather" samples occurring from May 16 – August 21, 2016 and "cool-weather" samples from November 1 – December 18, 2016. We examined four models using data from these sites, each of which explored how detection probability may change throughout the year. We used AICc to compare a null model, and models where detection probability varied by one of the following: temperature, day of the year, and our seasonal category described above.

RESULTS

Distribution and Arboreal Use

Out of the 61 sites that we surveyed, ten had no previous record of survey effort for Green Salamanders. These previously unsurvyed sites were located in Pickens County, SC (n=7) and Oconee County, SC (n=3), and the majority of were south-facing (n=8), ranged in elevation from 399–641 m, and in size from 136–6649 m^2. A total of 30 sites had green salamander detections (49.1%), and there were 7 detections among the 10 previously unsurveyed sites. We found six Green Salamanders that were using arboreal habitats during surveys. In addition, we found six salamanders (three on one occasion) on a Red Oak, *Quercus falcata*, at Table Rock

State Park that was not in a survey plot. The farthest distance we documented a Green Salamander from a rock outcrop was 35.2 m. The highest observation of a Green Salamander on a tree was approximately 9 m from the ground on a mossy patch of a Red Oak. Green Salamanders were documented on hardwoods including Red Oaks, Red Maples (*Acer rubrum*), Black Cherries (*Prunus serotina*) as well as other arboreal/woody habitats such as rotten logs and tree snags.

Detection and Abundance Analyses

Time of day was the detection probability covariate with the most support among those we evaluated for Green Salamanders (others without support included observer experience, total search time, cloud cover, temperature, and day of the year). Detection probability of Green Salamanders ranged from ~0.03 – 0.13 for models that included time of day as a covariate. Salamanders had a higher probability of being detected later in the day. Aspect, size, and elevation were the only three variables that were supported among our candidate set of abundance covariates, and the top candidate model contained all three of these covariates (Table 2). Two other models had a ΔAIC < 2, which indicates they also offered plausible explanations given the data (Table 2). The model with the second-most support contained covariates for aspect and size). The parameter estimates for both variables were similar to those estimates from the top model (Table 2). The third-best model contained the same covariates as the top model; however, elevation was present as a quadratic term. The standard error estimates for this quadratic term crossed zero, which suggests the covariate was not particularly informative. Green salamanders were most abundant at large, lower-elevation sites with south-facing slopes (Table 2; Fig. 2). For a survey of average habitat size (988.69m^2) and elevation (495.57m), abundance increased by ~4.7-fold (from 1.72 to 8.08) as aspect shifted from more northerly- to southerly-facing sites. For a survey of average aspect (189.08°) and elevation, abundance increased by ~5-fold (from 5.93 to 29.24) as habitat size ranged from approximately 1–6650 m^2. For a survey of average aspect and habitat size, abundance increased by ~15-fold (from 1.21 to 18.06) as elevation ranged from approximately 280-1040 m.

Out of the 51 historical locations that we surveyed, 23 of these sites had detections. We adjusted for detection probability and used our model-based relationships between abundance and aspect, habitat size, and elevation to predict abundance at each historical site. Based on these relationships, abundance estimates ranged from 0.7 (95% CI = 0.1 – 4.7) to 36 (95% CI = 13.0 – 101.6). One of the sites with a detection had the lowest estimated abundance, thus it is quite possible that all of the historical sites still have salamanders present.

Our analysis of detection probability in warm- versus cool-weather sampling revealed that a model with a categorical seasonal variable had the most support (ΔAIC = 0). Detection probability in cool-weather samples (November – December) was 0.08, whereas detection probability in our warmer weather samples (May – August) was 0.04 on average. The next-best model included temperature and had a ΔAIC = 6.29, which suggests it had relatively low support. Nevertheless, the results from this model reinforce the seasonal model. That is, temperature was had a significant negative relationship to detection probability.

DISCUSSION

Green Salamander abundance was influenced by aspect, habitat size, and elevation (Table 2; Fig 2). Interestingly, sites with south-facing slopes (which tend to be xeric) had higher estimated abundances of Green Salamanders than those with north-facing slopes. This is consistent with

Bruce (1968) who suggests that rock outcrops sites on south-facing slopes may be buffered from sunlight penetration because of the narrowness and irregularity of the crevices in which Green Salamanders are found in. Our findings, however, are inconsistent with more recent literature suggesting a preference for northerly-facing slopes (Hafer and Sweeney, 1993). Hafer and Sweeney (1993) based their criteria for "high probability of containing suitable Green Salamander habitat" off of 14 known Green Salamander locales (with 10 of those sites having a northerly-facing aspect), thus it is likely this small sample size may have biased their conclusions. As expected, larger sites had higher estimated abundances of salamanders than smaller sites, and thus are important for preserving genetic diversity (Petranka et al., 1993; Noël et al., 2007). The model with the most support indicated a negative relationship between estimated abundance and elevation. A study in Ohio suggested that Green Salamanders preferred low elevations between 183 – 244 m (Lipps, 2005). Bruce (1968) found rock outcrops with Green Salamanders in the BRE across a wide range of elevations, including elevations as low as 305 m. He suggests that although higher elevations may be available to salamanders in the BRE, they may not be able to disperse to them because of the topography. Further, salamanders may prefer the stable microclimates provided by lower elevation gorges of the BRE (Bruce, 1968). Hafer and Sweeney (1993) characterized habitat suitability of Green Salamanders in South Carolina to increase with elevation, which is contrary to our findings. Knowledge of site-specific population growth rates and genetic diversity would be valuable contributions toward further contextualizing the environmental associations we describe here.

Detection of Green Salamanders was influenced by time of day in an unexpected manner. Surprisingly, time of day had a positive influence on detection of salamanders. This relationship suggests salamanders were more surface active (and therefore easier to detect) later in the day, which is also when temperatures were highest. Rock outcrop microclimate is likely buffered from the surrounding warm and dry air associated with the hottest times of the day (Locosselli et al., 2016). Several findings within this study and others suggest Green Salamanders in the BRE may be somewhat resilient to warm and dry conditions (Gordon, 1952; Bruce, 1968; Barrett et al., 2014). For example, one preliminary laboratory study documented Green Salamanders to have a higher tolerance to drying compared to another plethodontid salamander, *Plethodon metcalfi* (=*Plethodon jordani melavantris*) (Gordon, 1952). This suggests that Green Salamanders may be able to take advantage of sites that are less suitable for other species using rock outcrops (e.g., *Plethodon metcalfi*).

Many of the historical localities in South Carolina that we surveyed fell short of the suggested 100-m forested buffer (Petranka, 1998; Wilson, 2001; Waldron and Humphries, 2005). For example, 14 rock outcrop sites had < 20 m of forest between the site and a paved road or powerline cut (8 of which were occupied). Throughout surveys, we only saw six salamanders within arboreal habitats. Occupied trees were predominately hardwoods, similar to those found in the Waldron and Humphries (2005); however, two detections were found on rotten logs/tree snags. The majority of detections outside of rocky outcrops occurred on moss, lichen, or flaky bark which likely provide moist refugia. Our farthest documented occurence during the survey season was 35 m from the nearest rock outcrop meaning that it is likely that some salamanders at these sites are leaving moist rock outcrops and being exposed to a lack of shade due to open canopy. The lack of detections away from rock outcrops may have been influenced by the extreme drought (in part from the 2015-2016 El Niño event; NOAA, 2016), which could have decreased movements away from moist rock crevices. Furthermore, many sites had a thick *Rhododenron* understory so it is possible that we missed detections in this thick shrub.

Rhodoendron detections were high in North Carolina Green Salamander surveys (pers. communication, M. Hall). Open canopies have been found to limit migration opportunities and lead to patchy distributions (Gordon, 1952; Snyder, 1991; Corser, 2001), but we do not have data on movement among the habitats studied here.

Green Salamanders were detected in less than half of the sites that we surveyed and when they were detected, they were not typically abundant (Fig 1, main map). When we adjusted for detection probability, four sites were predicted to have less than ten individual Green Salamanders. Because the species has low detection probability it is probable that some sites were occupied even though we never detected individuals. Nevertheless, our survey methods represent a more intensive survey effort than either of the two previous surveys in South Carolina (Bruce, 1968; Hafer and Sweeney, 1993). However, it is also important to note that our abundance estimates are from one season, so there may be some limitations (i.e., extreme drought) when directly comparing with previous surveys. Future status assessments should explore ways to increase detection of individuals by incorporating fall (September and October) and nighttime salamander surveys. Knowledge of distributional shifts relative to historical trends will allow for a better understanding of how Green Salamanders will respond to threats such as land use and climate change, as well as disease and collection.

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TABLE 1— Abundance covariates (and associated supporting literature) used to develop single-species abundance models for Green Salamanders in the South Carolina Blue Ridge Mountains. We measured these variables at each site, and their relative importance was assessed in a multi-model Akaike Information Criterion (AIC) framework.

Abundance covariate	**Type**	**Description**	**Source**
Size	Continuous	Size of rock outcrop (m^2)	Brodman, 2004
Elev	Continuous	Average midpoint elevation (m)	Bruce, 1968; Corser, 1991; Hafer and Sweeney, 1993; Lipps, 2005
Slope	Continuous	Average midpoint slope (°)	Bruce, 1968; Corser, 1991; Hafer and Sweeney, 1993
Aspect	Continuous	Average midpoint aspect (°)	Bruce, 1968; Hafer and Sweeney, 1993
BA	Continuous	Average basal area taken from start of four transects (m^2/ha)	Spickler et al., 2006
CC	Continuous	Average percentage canopy cover taken from start of four transects (0-100)	Gordon, 1952; Spickler et al.,2006
Drain_Presc	Categorical	Presence or absence or drainage at a site	Hafer and Sweeney, 1993

Table 1, continued,

Dist_Water	Categorical	Drainage < or > 400m from site	Hafer and Sweeney, 1993
LC	Categorical	Type of forest (mixed forest, mixed hardwood, softwood, shrubs)	Gordon, 1952; Bruce, 1968; Waldron and Humphries, 2005
Dist	Categorical	Presence or absence of a landscape disturbance at a site (heavy, light, none)	Gordon, 1952; Snyder, 1991; Corser, 2001
BIO 1	Continuous	Annual mean temperature (World Clim)	Corser, 2001; Barrett et al., 2014
BIO 5	Continuous	Maximum temperature of the warmest month (World Clim)	Corser, 2001; Barrett et al., 2014
BIO 12	Continuous	Annual precipitation (World Clim)	Corser, 2001; Barrett et al., 2014
BIO 17	Continuous	Precipitation of the driest quarter (World Clim)	Corser, 2001; Barrett et al., 2014

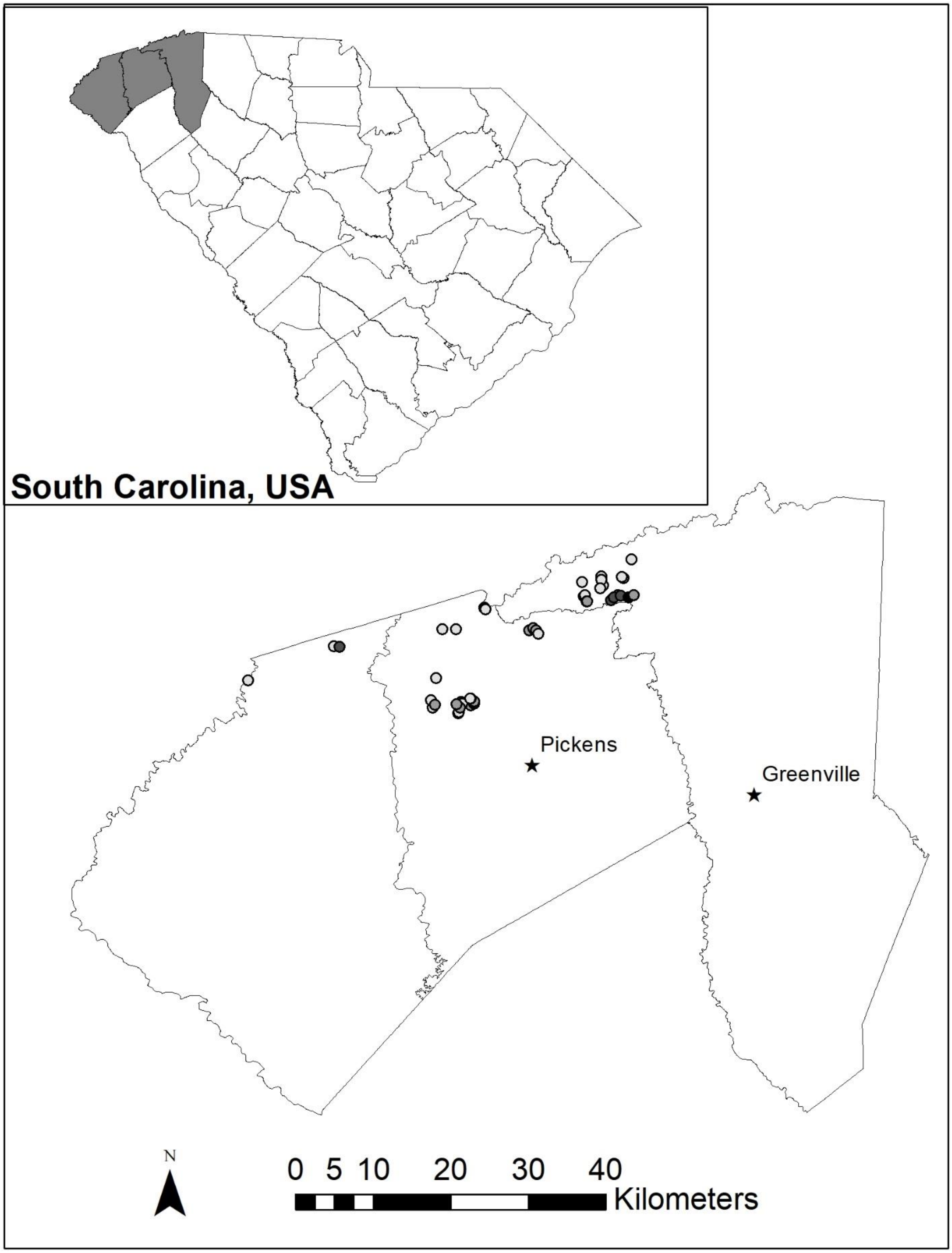
TABLE 2— Results of AIC analysis for 12 candidate models describing environmental covariates of Green Salamander abundance among rock outcrops in the Blue Ridge Escarpment of South Carolina. All models include time of day as the covariate of detection probability. The models below represent our final AIC comparison, which included the null model, all competitive univariate models, and all possible combinations of covariates from those univariate models. See Table 1 for definitions of model abbreviations; k = number of modeled parameters.

Model	**k**	**λ (SE)**	**AIC**	**ΔAIC**	**AIC weight**	**Cum. weight**
Aspect+Size+Elev	7	-0.60(±0.28), 0.36(±0.18), -0.54(±0.29)	338.65	0.00	0.32	0.32
Aspect+Size	6	-0.67(±0.29), 0.30(±0.19)	340.24	1.59	0.15	0.46
Aspect+Size+Elev^2	8	-0.59(±0.29), 0.33(±0.18), -0.45(±0.37), -0.09(±0.23)	340.47	1.82	0.13	0.59
Aspect	5	-0.72(±0.29)	341.27	2.62	0.09	0.68
Size+Elev	6	0.40(±0.19), -0.61(±0.30)	341.46	2.81	0.08	0.76
Aspect+Elev	6	-0.68(±0.29), -0.39(±0.29)	341.47	2.82	0.08	0.84
Aspect+Elev^2	7	-0.61(±0.30), -0.17(±0.35), -0.23(±0.24)	342.31	3.66	0.05	0.89
Size+ Elev^2	7	0.35(±0.20), -0.40(±0.38), -0.22(±0.27)	342.72	4.07	0.04	0.93
Size	5	0.34(±0.21)	343.79	5.13	0.03	0.95

$Elev^2$	6	-0.12(±0.36), -0.39(±0.28)	344.37	5.72	0.02	0.97
Elev	5	-0.47(±0.30)	344.80	6.15	0.02	0.99
(.)	4	2.38(±0.38)	345.15	6.50	0.01	1.00

FIG 1 —The inset map at the top represents the counties within South Carolina known to contain Green Salamander localities. From left to right the shaded polygons are Oconee, Pickens, and Greenville Counties. The main map shows the known distributional range of Green Salamanders, *Aneides aeneus*, in upstate South Carolina. Expected abundance for Green Salamander at historical localities in the state is represented by circles colored in with a gray-scale gradient (with lighter shades being less abundant sites and darker colors being more abundant sites).

FIG 2—Aspect, habitat size, and elevation emerged as the best predictors of abundance for Green Salamanders (*Aneides aeneus*) in South Carolina (Table 2). The top panel is illustrating the effect of aspect on the estimated abundance of Green Salamanders when both habitat size and elevation are held at their mean values. The middle panel is illustrating the effect of size on the estimated abundance of Green Salamanders when both aspect and elevation are held at their mean values. The bottom panel is illustrating the effect of elevation on the estimated abundance of Green Salamanders when both aspect and habitat size are held at their mean values. All panels have 95% CI.



South Carolina, USA
Pickens
Greenville
N
0 5 10 20 30 40
Kilometers

Estimated Green Salamander Abundance