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Effectiveness of Using Burlap Bands to Sample Arboreal Green Salamander Populations in the Blue Ridge Mountains of Georgia and North Carolina

TYLER F. THIGPEN*
Warnell School of Forestry and Natural Resources, University of Georgia Athens, Georgia 30602, USA

W. JEFFREY HUMPHRIES
North Carolina Wildlife Resources Commission
404 Barclay Road, Chapel Hill, North Carolina 27516, USA

and
JOHN C. MAERZ
Warnell School of Forestry and Natural Resources, University of Georgia Athens, Georgia 30602, USA

**Corresponding author; current address (TFT):*
U.S. Geological Survey, National Wetlands Research Center
700 Cajundome Boulevard, Lafayette, Louisiana 70506, USA
e-mail: thigpent@usgs.com

Green Salamanders, *Aneides aeneus*, occur as two distinct populations in the eastern United States. The more extensive population is located throughout the Cumberland and Allegheny Mountain regions from Pennsylvania to Alabama and northeastern Mississippi. The smaller disjunct population is located in the Blue Ridge Mountains of Georgia, South Carolina, and North Carolina (Petranka 1998). A study conducted in the Blue Ridge Escarpment of western North Carolina, northwestern South Carolina, and northeastern Georgia documented a 98% decline in some populations of Green Salamanders since 1970 (Corser 2001). The U.S. Fish and Wildlife Service currently recognizes *A. aeneus* as a species of concern. The Blue Ridge Escarpment population is listed as rare in Georgia, endangered in North Carolina, and a species of special concern in South Carolina. Corser (2001) attributed declines to climate change, loss and alteration of habitat, a chytrid fungal pathogen, and exploitation through collection by researchers. The issue of forest ecosystem alteration and its importance in understanding Green Salamander arboreality and species declines have recently garnered attention (Pauley and Watson 2005; Waldron and Humphries 2005).

Green Salamanders are generally considered crevice-dwelling species associated with rock outcrops, and only "weakly" arboreal (Pauley and Watson 2005). Green Salamander morphology is consistent with rock-crevice habits, particularly their dorso-ventrally compressed bodies with elongate limbs and toes with expanded square toe tips (Petranka 1998). Most associations with Green Salamanders and non-rock outcrop habitats were reports of large numbers of individuals under the bark of dead and fallen trees, particularly large American Chestnut (Barbour 1949). Contradicting the perception of Green Salamanders as weakly arboreal, Waldron and Humphries (2005) recently documented large numbers of Green Salamanders using arboreal habitats in some Blue Ridge Escarpment populations. Using day and night searches with flashlights, they recorded 345 Green Salamander observations between April and October, of which 43% occurred in trees, 41% in rock outcrops, and only 15% on or in logs. They also reported arboreal nesting. Additionally, Wilson (2003) documented Green Salamanders in woody and arboreal habitats at sites throughout the Blue Ridge Mountains. These studies raise questions about the importance of arboreal habits to Green Salamander populations and highlight the potential need to include methods for searching arboreal habitats as part of Green Salamander monitoring.

Although the technique used by Waldron and Humphries (2005) was successful at discovering many salamanders using arboreal habitats, it was very time consuming (more than 210 h over a 3.5 yr period) and difficult to standardize. Survey success varied widely based on weather conditions and other variables. Further, the effectiveness of the technique is likely to vary greatly among observers who differ in ability to spot salamanders high in trees. A standardized and less labor-intensive technique for studying arboreal habits of Green Salamanders would be useful.

Artificial cover is widely utilized as a technique for standardized monitoring of terrestrial salamanders (Houze and Chandler 2002; Monti et al. 2000). Artificial cover can provide the necessary microclimates to attract salamanders during diurnal retreat, making detection of species less dependent upon the immediate climate. Artificial cover generally involves the application of boards or other materials to the forest floor, or litter bags or baskets along stream banks (Monti et al. 2000). We are not aware of any standardized artificial cover technique for capturing salamanders in arboreal habitats. However, burlap fabric attached to trees (known as burlap bands) has been used to sample arboreal invertebrates and reptiles (Campbell and Sloan 1977; Duguay et al. 2000; Horn and Hanula 2006; Reardon 1976). In addition to attracting invertebrates, these artificial shelters are sometimes occupied by salamanders, including Red-backed Salamanders (*Plethodon cinereus*) and Northern Two-lined Salamanders (*Eurycea bislineata*) (J. Waldron, pers. comm.). Attaching artificial cover to trees at distance and heights determined within the predicted range of Green Salamanders may provide a reliable technique for capturing Green Salamanders occupying arboreal habitats. In 2005, we deployed burlap bands on trees at four study sites in Georgia and North Carolina in order to determine whether Green Salamanders will occupy burlap bands as an artificial cover type.

Methods.—The populations of Green Salamanders surveyed were located in the Nantahala National Forest in Jackson County, North Carolina, and Chattahoochee National Forest in Rabun

County, Georgia. Both populations are located in the Blue Ridge physiographic province. We identified three study sites in the Chattahoochee National Forest and one site in the Nantahala National Forest where Green Salamanders were known to occur (M. Elliott, Georgia Natural Heritage Program, pers. comm.). The vegetation at all sites consists of mixed, uneven-aged conifer/hardwood forest with dense Rhododendron (*Rhododendron maximum*) midstory. The dominant tree species at the sites are Eastern Hemlock (*Tsuga canadensis*), Red Maple (*Acer rubrum*), Tulip Poplar (*Liriodendron tulipifera*), Frasier Magnolia (*Magnolia fraseri*), White Oak (*Quercus alba*), Eastern White Pine (*Pinus strobus*), Pignut Hickory (*Carya glabra*), Northern Red Oak (*Quercus rubra*), Chestnut Oak (*Quercus montana*), and Witchhazel (*Hamamelis virginiana*) (Gordon 1952). Annual precipitation in the area ranges from 215–254 cm (Bruce 1968). The rock outcrops at sites known to be occupied by Green Salamanders are composed of granite. The deep, narrow crevices and asymmetrical walls provided by the granite outcrops offer individuals protection from sunlight (Bruce 1968) and predators. Green Salamanders overwinter, mate, and lay eggs within the outcrops (Pauley and Watson 2005; Petranka 1998). The site in the Nantahala National Forest is located at 950 m elevation (Gordon and Smith 1949) with 15% slope and 75% canopy cover. The three sites in the Chattahoochee National Forest range in elevation from 600–750 m with 10–55% slope and 25–65% canopy cover. Herbaceous understory is dominated by Galax (*Galax aphylla*), Hayscented Fern (*Dennstaedtia punctilobula*), Pansy (*Viola* sp.), Striped Wintergreen (*Chimaphila maculata*), Speckled Wood Lily (*Clintonia umbellata*), and Mountain Laurel (*Kalmia latifolia*) (Gordon 1952).

Burlap fabric was washed with a concentrated liquid detergent formulated for use in laboratories to remove chemicals that aid water resistance and may potentially harm salamanders (Liqui-Nox®). Prior to use, the burlap fabric was tested for anions at U.S. Forest Service, Coweeta Hydrologic Laboratory and results show the fabric contained less than 0.5 ppm of chloride, sulfate, nitrate, phosphate, and bromide. At each site, burlap strips measuring 76.2 cm by 45.7 cm were attached to hardwood trees with hemp rope two meters from the ground on 15 trees with a diameter at breast height (DBH) ≥ 20.3 cm (Fig. 1). Trees ranged from 1-50 m from the rock outcrops. Large hardwood trees were selected because previous research suggested that Green Salamanders are observed on large hardwoods compared to conifers (Waldron and Humphries 2005).

We visited each site three times per month (~1-2 weeks between visits) from June–December 2005. During each visit, we lifted the fabric and searched the entire area under the burlap with a flashlight. For comparative purposes, we also searched crevices for salamanders on each occupied rock outcrop during each visit. We recorded the number and species of salamanders observed, measured individuals (we did not capture and measure salamanders observed in rock crevices), and recorded distance from the nearest occupied rock outcrop. Green Salamanders under burlap were classified as adults (> 44.5 mm total length, TL), sub-adults (29.5–44.4 mm TL), or juveniles (< 29.5 mm TL) (Waldron and Humphries 2005). Salamanders were released at their capture location. Sites were surveyed during the day, at dusk, and after dark.

Results.—Over 16 sample days, we observed 31 salamanders under burlap, only 11 of which were Green Salamanders (Table 1). We also observed Southern Appalachian Slimy Salamanders (*Plethodon chattahoochee*), Southern Gray-cheeked Salamanders (*Plethodon metcalfi*), and a single Ocoee Salamander (*Desmognathus ocoee*). We observed a greater number (16) of juvenile Southern Appalachian Slimy Salamanders under burlap than Green Salamanders. By comparison, we observed 80 salamanders in rock outcrops including 57 Green Salamanders during the same sample period (Fig. 2). Though we did not systematically search for salamanders on non-burlap trees, we did not observe any salamanders on trees outside of burlap covers. Further, while we observed few Southern Gray-cheeked Salamanders under burlap, we did observe them routinely off the forest floor on Rhododendron during wet nights. All Green Salamanders and Southern Appalachian Slimy Salamanders found under the burlap were sub-adults, while the Ocoee Salamander and the Southern gray-Cheeked Salamanders were adults. We determined Ocoee Salamander and Southern gray-salamander adult and juvenile size classes by comparing measurements of each individual to published size classes for the two species (Petranka 1998). Southern Gray-cheeked Salamanders were observed singly, while up to five Southern Appalachian Slimy Salamanders were observed under one piece of burlap at the same time. One Green Salamander was observed under a piece of burlap with three Southern Appalachian Slimy Salamanders. All individu-

Fig. 1. Burlap bands were attached to hardwood trees with hemp rope two meters from the ground on trees with a diameter at breast height (DBH) ≥ 20.3 cm to assess arboreality of Green Salamanders in the Nantahala National Forest, North Carolina and Chattahoochee National Forest, Georgia, 2005.

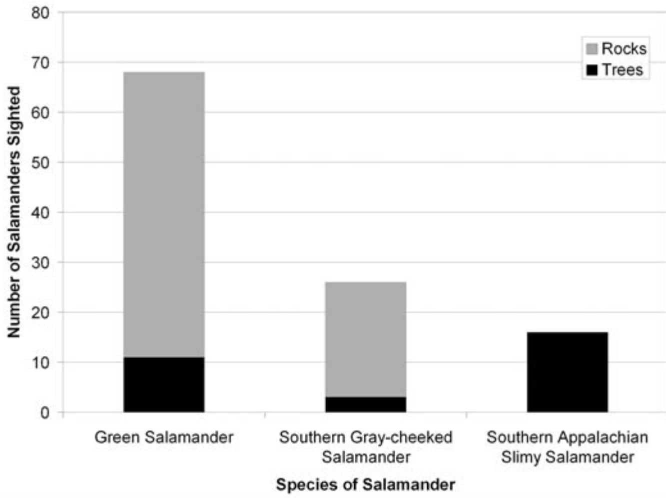

FIG. 2. Number of Green Salamanders, Southern Gray-cheeked Salamanders, and Southern Appalachian Slimy Salamanders in and on rocks versus the number observed under the burlap cover on trees in Chattahoochee National Forest, Georgia, and Nantahala National Forest, North Carolina, 2005.

als were observed between the burlap and tree bark, not between the two layers of the burlap at the top of the band where the burlap was attached to the tree with hemp rope (Fig. 1).

Salamanders were only observed beneath burlap from August–November. However, Green Salamanders and Southern Gray-cheeked Salamanders were observed in the rock outcrops as early as May, when we began establishing transects, until late November. Green Salamanders were found a maximum distance of 10 m from rock outcrops. Southern Gray-cheeked Salamanders were found up to 7 m from rock outcrops. Southern Appalachian Slimy Salamanders were never observed on the rock outcrop; they were only observed under burlap on trees located within 1 m of the rock outcrop.

No salamanders were observed under burlap in surveys conducted before 1600 h and individuals were most abundant under burlap in months with high precipitation (correlation between cumulative monthly rainfall and number of salamanders observed under burlap: $R^2 = 0.87$, $p = 0.067$). Southern Appalachian Slimy and Gray-cheeked Salamanders were common on the forest floor. However, we never observed Green Salamanders on the forest floor, similar to Waldron and Humphries (2005). More Green Salamanders and Southern Gray-cheeked Salamanders were observed in rock crevices than on trees during our surveys.

Discussion.—Our results indicate that Green Salamanders and other terrestrial plethodontid salamanders will occupy burlap as artificial cover during periods of sufficient precipitation. That we did not opportunistically observe any Green or slimy salamanders on trees outside of burlap suggests that despite low captures of salamanders the burlap did improve observation of arboreal habitat use by salamanders. In contrast to Waldron and Humphries (2005) observations, we did not observe any Green Salamanders on trees during day searches. All arboreal observations of salamanders occurred after dusk following recent rains. This is consistent with other observations of plant climbing behavior in terrestrial *Plethodon* (e.g., Jaeger 1978) and strongly suggests that all salamanders including Green Salamanders were moving from forest floor or rock habitats up the trunks of trees to forage on rainy nights. We did observe large numbers of invertebrates under the burlap. We did not capture any Green Salamanders on trees farther than 10 m from the associated rock outcrops, which contrasts sharply with prior observation of Green Salamanders up to 40 m from rock outcrops at one of the same study sites (Waldron and Humphries 2005). This may simply be an artifact of the greater sampling effort of Waldron and Humphries increasing the opportunity to detect Green Salamanders farther from rock outcrops.

One interpretation of our results is they are more consistent with the characterization of Green Salamanders as "weakly arboreal," and their use of trees may be comparable to that of other forest plethodontids. Alternatively, the difference between our results and those of Waldron and Humphries (2005) may be an artifact of the suitability of burlap as refugia. The burlap did not retain much water and the surface under the burlap usually dried within days of a rain. Dry conditions are unfavorable to salamanders, and may explain why we did not observe any individuals under the burlap during the day. Waldron and Humphries (2005) report Green Salamanders in trees, often tucked beneath small flaps of bark, even during dry periods. Burlap apparently did not adequately simulate loose bark that could be used by Green Salamanders; therefore, burlap may be suitable for use if surveying arboreal foraging habits of plethodontids, but unsuitable for measuring other arboreal habits. The effectiveness of burlap might be improved if a strip of foam is attached at the top of the burlap flap to absorb and retain water. Alternately, another substrate such as slabs of real or artificial bark could be attached to trees to provide better microclimates for salamanders.

Further, Waldron and Humphries (2005) found that Green Salamanders prefer American Beech trees and hardwood trees over other tree species. Therefore, conducting a study to determine

TABLE 1. Number of individuals of each species of salamander observed at sites surveyed using burlap bands attached to trees in Chattahoochee National Forest, Georgia, and Nantahala National Forest, North Carolina, 2005. T = Trees, RO = Rock Outcrops.

	Chattahoochee I		Chattahoochee II		Chattahoochee III		Nantahala	
Salamander Species	T	RO	T	RO	T	RO	T	RO
Aneides aeneus	0	2	5	3	4	23	2	31
Plethodon metcalfi	0	0	0	5	0	8	3	9
Plethodon chattahoochee	0	0	16	0	0	0	0	0
Desmognathus ocoee	0	0	1	0	0	0	0	0
Total	0	2	22	8	4	31	5	40

Green Salamander tree species preference is important in assessing arboreality of the species. Trees in this study were chosen because of their size since American Beech trees were scarce at our sites or did not meet size requirements. Tree preference may be because of species of invertebrates found on different species of trees. Future studies include determining if a correlation exists between number of arthropods on trees and number of salamanders present.

Number of salamanders observed under burlap on trees and in the rock outcrops in November 2005 supports earlier findings (Waldron and Humphries 2005) that Green Salamanders as well as Southern Gray-cheeked Salamanders and Southern Appalachian Slimy Salamanders (Petranka 1998) show strong seasonal use of the forest floor and trees. We did not observe any species of salamanders under burlap in trees after November. Most likely Green Salamanders move to rock outcrops where they overwinter, then emerge and disperse in late-March or early-April (Waldron and Humphries 2005). Southern Appalachian Slimy Salamanders are suggested to overwinter in caves in Georgia. Southern Gray-cheeked Salamanders are suggested to overwinter in the ground in extensive burrows. Southern Gray-cheeked Salamanders move to their overwintering habitats and emerge and disperse in the spring at approximately the same time as Green Salamanders (Petranka 1998); therefore, surveys assessing arboreal habitat use should be conducted from August–November or late March–May.

The issue of arboreal habitat use by Green Salamanders and its importance to their population ecology remains unclear. While our results do not disagree with the characterization of Green Salamanders as "weakly arboreal", the results of Waldron and Humphries (2005) suggest that studies of Green Salamander arboreal habits needs greater attention. A 100-m buffer zone around each outcrop containing Green Salamanders has been suggested (Petranka 1998) to maintain cool microclimates on rock outcrops. If arboreal habitats are as important as Waldron and Humphries (2005) observations suggest, then the importance of forest buffers goes beyond maintenance of mild climates on rock outcrops. Though we did not capture large numbers of Green Salamanders under burlap, numerous individuals of other Southern Appalachian Salamanders were found. It should be noted that our study was only conducted during a few months during one season. Just as coverboards used in other reptile and amphibian studies oftentimes need time to "age" before they are successful, burlap or other artificial cover objects may increase in efficiency as they remain in the forest. We suggest the use of numerous sampling techniques for Green Salamanders and other salamander species in the Appalachians, as all methods have their benefits and biases.

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