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STATUS AND POSSIBLE DECLINE OF THE SOUTHERN DUSKY SALAMANDER (*DESMOGNATHUS AURICULATUS*) IN GEORGIA AND ALABAMA, USA

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***Abstract*.—The southeastern United States has not been spared from the phenomenon of worldwide amphibian declines. However, in nearly every case, declining species have been obviously impacted by habitat modification. The region's only example of a species that has apparently undergone massive declines for reasons that remain unexplained is the Southern Dusky Salamander (*Desmognathus auriculatus*). To estimate this species' current status, and provide baseline information for future efforts, we resurveyed 39 historic *D. auriculatus* collection localities in Georgia and Alabama, and 25 additional sites that appeared suitable for this species. We conducted timed surveys of at least one hour and we noted all salamanders encountered such that we could compare the relative abundance of *D. auriculatus* to other species in its habitat. With 94 person hours of searching, we collected only seven individual *D. auriculatus* from two Georgia sites, and this species was not among the more common amphibians we encountered. We did not locate any *D. auriculatus* in Alabama despite repeated visits to historical localities. Although the historical abundance of this salamander is difficult to assess due to the lack of baseline data and the recognition that other *Desmognathus* species are more common and widely distributed in the Coastal Plain than once assumed, our results suggest a decline in this species in the study region.**

Key Words.—Alabama; amphibian declines; baseline survey; *Desmognathus auriculatus; Desmognathus conanti; Desmognathus apalachicolae;* Georgia; morphological analysis

INTRODUCTION

Documentation and mitigation of worldwide amphibian declines has been hampered by the inability to assess the past and present status of many species (Lannoo 2005). This handicap, combined with the difficulty of determining declines from census data sensitive to population fluctuations, temporal confounds, and variable collection effort, has lead to skepticism in some cases of reported declines (Pechman et al. 1991). However, thorough documentation and long-term monitoring in multiple sites throughout the world have lead to recognition that many amphibian populations are indeed declining (Lips 1998; Alford and Richards 1999; Pounds et al. 1999; Kiesecker et al. 2001; Blaustein et al. 2003). Additional studies are needed and baseline surveys are especially worthwhile in certain regions.

Many familiar examples of amphibian declines (e.g., the Golden Toad, *Incilius periglenes*) have taken place in seemingly pristine habitat, and therefore defy immediate explanation (Kiesecker et al. 2001). Some regions of the world have been affected by these declines (e.g., Central America, Australia; Berger et al. 1998), while in others, declines are obviously and directly attributable to anthropogenic habitat loss (e.g., eastern North America). In the southeastern United States, several well-documented population declines have occurred, and most of them have been attributed to habitat loss (e.g., Reticulated Flatwoods Salamander, *Ambystoma bishopi;* Frosted Flatwoods Salamander, *A. cingulatum*; Gopher Frogs, *Lithobates capito* and *L. sevosus*; and Striped Newts, *Notophthalmus perstriatus*; Lannoo 2005). However, at least one species (Southern Dusky Salamander, *Desmognathus auriculatus*) from the southeastern United States has apparently declined without an obvious cause and in seemingly pristine habitat (Boundy 2005; Means 2005).

Desmognathus auriculatus' historical range once included the southeastern Coastal Plain from Virginia to Texas (Petranka 1998), although a recent phylogeography provided evidence that *D. auriculatus* represents a paraphyletic group, with topotypic *D. auriculatus* occupying a smaller region (Beamer and Lamb 2008). Despite this finding, *D. auriculatus* (*sensu lato*) has reportedly experienced a range-wide decline during the past 40 years (Boundy 2005; Means 2005; Beamer and Lamb 2008). However, only two studies provide quantitative data to support this assertion (Dodd 1998; Means and Travis 2007), and both of these were restricted to relatively small geographic areas (both in Florida) where baseline population data were available.

The goals of this study were to estimate current abundance and distribution of *D. auriculatus* in a large portion of its range (southern Georgia and Alabama; likely within the range of *D. auriculatus*, *sensu stricto*; clade C of Beamer and Lamb 2008), and assess the

TABLE 1. Suite of characteristics used to identify *Desmognathus* salamander specimens, based on Means (1974), Means and Karlin (1989), Conant and Collins (1991), and Petranka (1998). TH = Tail Height; TW = Tail Width.

	Dorsal Coloration	Ventral Color	Tail	Costal Grooves between Adpressed Limbs	Sinuate Jaw Commissure
D. conanti	Light - dark, often with 6–8 pairs of spots	Grey to dark grey usually lightening after capture	Moderately keeled; TH > TW	3–4, with light flecks along sides	Absent
D. apalachicolae	Light - dark, sometimes with dark scalloped stripes or spots	White to dark grey usually lightening after capture	Lightly keeled to un-keeled, with tip attenuating to narrow tip; TW > TH	2–3, with light flecks along sides	Males with large jaw muscles and a sinuate jaw commissure
D. auriculatus	Dark with no evidence of pattern	Dark grey, doesn't lighten after capture	Heavily keeled and bladelike, especially on posterior 2/3 of tail; TH > TW	≥ 4, with large circular spots on sides	Absent

status of this species in this region by establishing quantitative data in the form of a thorough baseline search effort. Furthermore, we assess morphological ambiguities among *Desmognathus* species in the southeastern Coastal Plain, providing additional support for the phylogeographic analysis of Beamer and Lamb (2008). They suggest that species level diversity within populations currently recognized as *D. auriculatus* is underestimated. We suggest that this morphological and taxonomic confusion may be partially responsible for inflated estimates of the past abundance of *D. auriculatus*. We do not provide rigorous quantitative comparisons between the current and past abundance of *D. auriculatus* because quantitative data on its historical abundance in this area are unavailable. However, we estimate this species' current abundance by comparing our results to past anecdotal population estimates, and by comparing its current abundance to that of other Coastal Plain salamanders. This study therefore provides a valuable inventory and starting point for future efforts employing rigorous standardized methods that incorporate detection and abundance data.

MATERIALS AND METHODS

Survey techniques.—We surveyed for salamanders in December 2005, March-May 2006, and October-November 2006 in Georgia, and December and March 2007, 2008, and 2009 in Alabama. We (SPG and EKT) used museum records to locate and re-survey historical localities, focusing on those records with sufficient locality data to find the original site. Within Georgia, we relied on locality information for *D. auriculatus* available in Williamson and Moulis (1994). For Alabama, one of us (SPG) re-surveyed collection sites previously identified by D.B. Means (Auburn University Natural History Museum—AUM). In addition, we selected 25 new sites based on suitable habitat and our own expertise. At each site (most of which were bridge crossings of blackwater creeks), we quickly scouted the location, then concentrated our surveys on areas that appeared suitable based on habitat descriptions available (Means 1974, 1975; Petranka 1998). The study areas chosen are biased toward those that appeared relatively intact and with enough habitats to search for at least an hour; several sites scouted appeared to us unsuitable for finding most wildlife (e.g., clear-cuts, etc.) and were not searched. Search methods were consistent with previous studies (Folkerts 1968; Means 1975; Means and Travis 2007), and consisted of 1–3 individuals lifting and searching under coarse woody debris and other cover objects, and thick accumulations of wet leaf litter and coarse woody debris (piles of sticks). We performed timed surveys of at least one hour (1–6 person hours), and all salamander species (and their larvae in some cases) were identified and counted at each site. We searched the edges of creeks and their floodplains ~ 200 m upstream and downstream of bridge crossings to include the collecting point of historical sites. We searched most sites only once; however, we searched Alabama historical sites up to five times for three consecutive years. We noted the habitat for each site and categorized it according to the scheme of Wharton (1978). We collected a representative series of *Desmognathus* salamanders (six or fewer) from each site and euthanized them with cutaneous administration of Orajel® (benzocaine; Church and Dwight Co., Princeton, NJ, USA; Brown et al. 2004), fixed them in formalin, and stored them in 70% EtOH. We collected tail or liver tissue before fixation for molecular analyses underway by D. Beamer (East Carolina University; see Beamer and Lamb 2008). We collected liver tissue in most cases to preserve tail morphology. We deposited all specimens in the Georgia Museum of Natural History (GMNH) or AUM.

TABLE 2. Scoring values for categorical data in ANCOVA morphological analyses of *Desmognathus* salamanders.

Score	Portholes	Tail Morphology	Sinuate Jaw Commissure
0	No evidence	No evidence of keel	Straight jaw commissure
0.5	Flecks on side	Weakly to moderately keeled	Weakly sinuate
1	Large, fully circular spots	Large, bladelike keel	Strongly sinuate

Data analysis.—*Desmognathus* salamanders are notoriously difficult to identify (Conant and Collins 1991); therefore we attempted to use an integrative approach combining morphological features and preliminary genetic information to group salamanders and provide a morphological analysis that may be useful for future research conducted on Coastal Plain species of *Desmognathus*. Each *Desmognathus* salamander was identified using information in Means (1974), Means and Karlin (1989), Conant and Collins (1991), and Petranka (1998; Table 1). Measurements, recorded from preserved salamanders (nearest 0.1 mm) using vernier calipers included snout to posterior edge of vent length (SVL), tail height at posterior edge of vent (TH), and tail width at posterior edge of vent (TW). In addition, we noted meristic and subjective characters (see Table 2 for categorical scores), e.g., number of costal grooves between adpressed limbs, presence or absence of a sinuate jaw commissure (Means 1974; also see Conant and Collins 1991, p. 260), presence or absence of "portholes" (large or small lateral spots; Conant and Collins 1991), and the nature of the tail keel (heavily keeled, weakly keeled, or not keeled and with an attenuate tip).

To assess morphological differences among *Desmognathus* salamanders, we identified salamanders following Table 1. We identified *D. auriculatus* using this combination of characters: dorsum dark with no

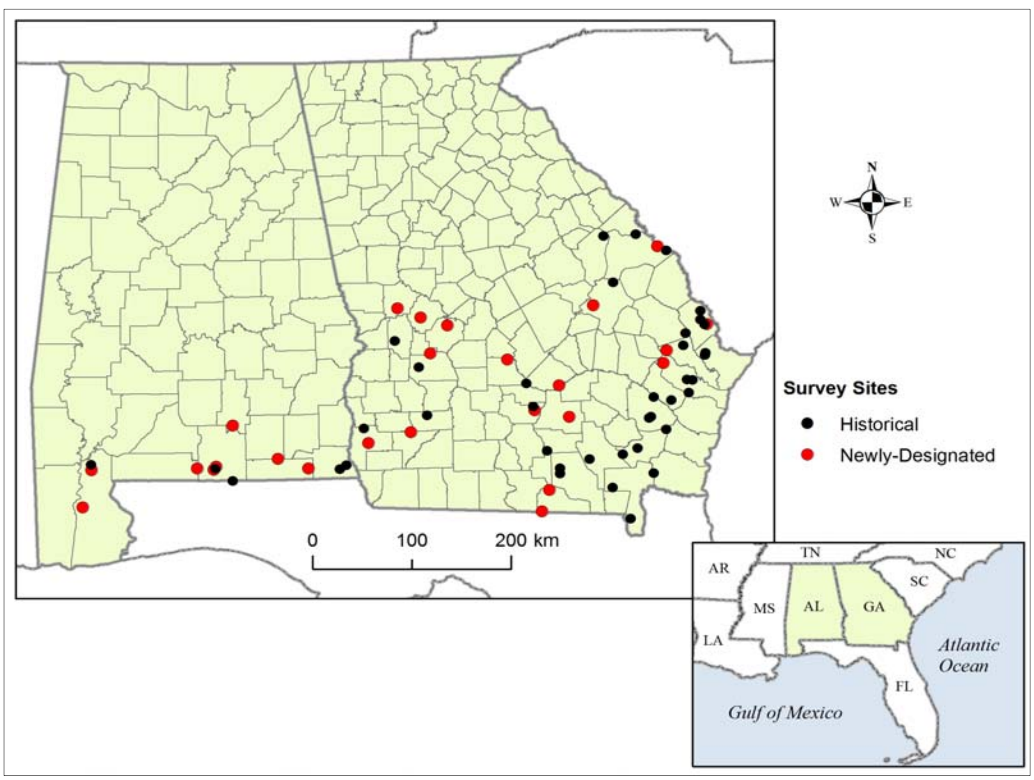

FIGURE 1. Map of 39 historical collection localities (black dots) and 25 newly-designated sites (red dots) searched for *Desmognathus auriculatus*.

discernable pattern, venter dark with or without light flecks, large spots (e.g., “portholes”) along sides and tail, greater than four costal grooves between adpressed limbs, and tail with distinct keel. In addition, we confirmed the identity of specimens freshly collected using a preliminary phylogenetic analysis of representative specimens (n = 37; Beamer and Lamb 2008; David Beamer, pers. comm.). It should be noted that these analyses are ongoing and possibly subject to change; we interpreted these data based upon current taxonomy. We supplemented our dataset with specimens in the GMNH and AUM collections (Appendix 1). Museum specimens lacked *a priori* molecular information. We first tested all morphological variables to conform to assumptions of normality for parametric statistics. Tail height was log transformed to achieve normality. We compared SVL against log TH, TW, number of costal grooves between adpressed limbs, and TH/TW using linear regression for all salamanders. These variables were significantly correlated; therefore, we compared SVL using ANOVA and other morphological characters with ANCOVA using species identifications as grouping variables and SVL as the covariate. We scored categorical variables (Table 2). We also compared the mean number of costal grooves between adpressed limbs as a categorical variable. We compared mean scores for each species using a Kruskal-Wallis test.

Because some of the same characters compared in our analysis contributed to the definition of the grouping variables, the above analysis is admittedly circular. Therefore, we repeated the ANCOVA analyses using no *a posteriori* species identification, but instead used habitat at the collection site (seepage-associated or blackwater associated; see descriptions in Wharton 1978) as the grouping variable with SVL as the covariate. Grouping salamanders by these habitat associations was based upon observations by Valentine (1963), Means (1975), and Beamer and Lamb (2008) that *D. auriculatus* prefers blackwater (rather than seepage) habitat, and was intended to serve as an unbiased control for the above analysis that included *a posteriori* species identifications. We considered seepages as those areas with shallow sheet flow derived from subterranean sources, most often in areas of steep relief, such as at the base of bluffs or steapheads (Wharton 1978). In contrast, blackwater habitats are not derived from local subterranean (spring) sources and instead derive from rainwater leaching through flat sandy terrain. Blackwater creeks and swamps are oligotrophic habitats and support a unique flora and fauna (Wharton 1978). These habitats are easily recognized by the deep black mucks and leaf accumulations found within them. We used Wilcoxon tests to compare these groups using the keel, porthole, costal groove, and sinuate jaw commissure scores. Analyses were performed using JMP 8.0.1 (SAS Institute, Cary, NC, USA) with α set at 0.05.

TABLE 3. Salamanders encountered during 94 person hours of searching 64 potential *Desmognathus auriculatus* localities in Georgia and Alabama, USA. We include all specimens morphologically identified as *D. auriculatus*.

Species	Total Encountered	
	Transformed	Larvae
Amphiuma means	7	
A. pholeter	2	
Siren intermedia	5	
Ambystoma maculatum	1	
A. opacum	1	
Stereochilus marginatus	2	
Eurycea cirrigera	85	
E. quadridigitatta	46	34
E. quadridigitatta sp. nov.	3	
E. guttolineata	65	
Plethodon cf. glutinosus	30	
Pseudotriton ruber	28	40
P. montanus	3	20
Desmognathus conanti	41	
D. apalachicolae	15	
D. auriculatus	8	

RESULTS

We sampled 64 localities (39 historical and 25 newly designated), representing a total sampling effort of more than 94 person hours in Georgia and Alabama (Fig. 1; Appendix 2). We located *Desmognathus* salamanders at 19 of these sites (Appendix 2), and morphological identifications indicated that eight salamanders at three sites were *D. auriculatus* (Appendix 2). Many collection sites where salamanders were catalogued as *D. auriculatus* (Williamson and Moulis 1994) contained other *Desmognathus* species outside of their known range (Appendix 2). We examined specimens from these localities at GMNH and believe these sites were catalogued incorrectly based on misidentified salamanders. Preliminary genetic analyses (David Beamer, pers. comm.; Beamer and Lamb 2008) further restricted the number of *Desmognathus* identified as *D. auriculatus* to seven salamanders found at two sites (Appendix 2). *Desmognathus* salamanders were present at 21% (n = 8) of historical sites, with *D. auriculatus* present at only 5% (n = 2; Table 3). We found

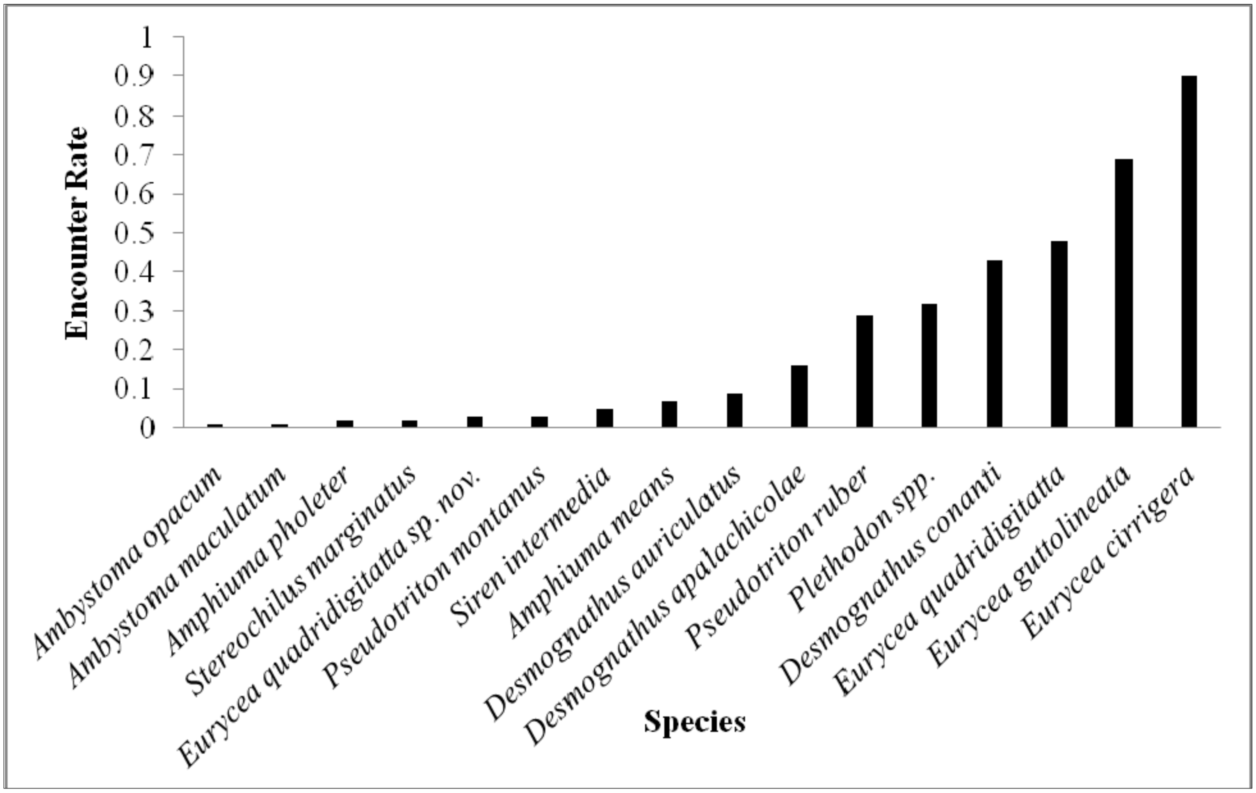

FIGURE 2. Encounter rate (individuals per person hour) of salamanders detected by our study in Georgia and Alabama, USA.

Desmognathus salamanders at 44% (n = 11) of the newly designated sites, but *D. auriculatus* at only one of these sites (Table 3). The relative abundance of *D. auriculatus* is low compared to some salamander species present in its habitat, and comparable to the abundance of others (Table 4; Fig. 2).

Coastal Plain *Desmognathus* species were clearly segregated morphologically (Table 4). Mean SVL (F = 4.67, df = 2, 79, P = 0.01), log TH (F = 10.11, df = 2, 79, P < 0.001), TH/TW (F = 27.43, df = 2, 79, P < 0.001) and costals between adpressed limbs (χ^2 = 39.46, df = 2, 79, P < 0.001) were significantly different among species (Table 4). *Desmognathus auriculatus* tails were more heavily keeled (χ^2 = 29.12, df = 2, 79, P < 0.001) and had well-defined portholes (χ^2 = 36.99, df = 2, 79, P < 0.001) compared to other dusky salamanders (Table 4). The sinuate jaw commissure was more prevalent in *D. apalachicolae* (χ^2 = 24.63, df = 2, 79, P < 0.001; Table 4). Grouping salamanders by habitat alone revealed similar patterns: Blackwater swamp-dwelling Coastal Plain *Desmognathus* species exhibit significantly greater mean SVL (F = 4.47, df = 1,80, P = 0.041), mean log TH (F = 16.36, df = 1,80, P < 0.001), TH/TW (F = 9.72, df = 1, 80, P < 0.001), and more costals between adpressed limbs (χ^2 = 28.31, df = 1, 80, P < 0.001) than seepage-associated Coastal Plain *Desmognathus* species (Table 4). Portholes (χ^2 = 15.11, df = 1, 80, P < 0.001) and keeled tails (χ^2 =14.29, df = 1, 80, P < 0.001) were more prevalent in blackwater-associated *Desmognathus* than seepage associated *Desmognathus* (Table 4). The sinuate jaw commissure score was significantly different between these groups (χ^2 = 3.57, df = 1, 80, P = 0.05; Table 4).

DISCUSSION

Previous research and species accounts vary in their descriptions of the relative abundance of *D. auriculatus,* and published accounts of this species are mostly anecdotal. This species was considered abundant in Virginia (Martof et al. 1980), North Carolina (Eaton 1953), Florida (the Devil's Millhopper Geological Site, and ravine and swamp sites sampled by D.B. Means for several studies; Means 1975; Dodd 1998; Means 2005), Georgia cypress ponds and the Magnolia Bluffs seepage site (Wharton 1978), and sites in Louisiana (Chaney 1949). In South Carolina (the Savannah River Site; Gibbons and Semlitsch 1991), Alabama (Folkerts 1968), and in Florida (Means 1975), this species was not considered as common as other *Desmognathus* species. In Mississippi, it was recognized that two species occurred in the Coastal Plain and were segregated by habitat with *Desmognathus fuscus* (= *conanti*) occupying seepages, and *D. auriculatus* occupying

TABLE 4. Morphological features of *Desmognathus* species encountered during the surveys, supplemented by museum specimens (Appendix 1). Specimens are grouped by tentative identifications based on a suite of gross morphological features (see Tables 1 and 2) guided by preliminary molecular data (e.g., "species"), and by habitat of collection site (e.g., "habitat"). Values are mean ± standard deviation. SVL = snout vent length, TH = tail height (at posterior vent; non-log transformed values presented), TW = tail width (posterior vent), CGAL = number of costal grooves between adpressed limbs, keel = keeled tail, porthole = large round spots on sides, sinuate = sinuate jaw commissure. For keel, porthole, and sinuate features, means represent a three level categorical score (see Materials and Methods); values approaching 1 = feature strongly apparent, values approaching 0 = feature not present. *Desmognathus auriculatus* refers to specimens identified as species based on morphology. *Indicates these features were significantly different between groups.

	MORPHOLOGICAL FEATURES							
SPECIES	SVL (mm)*	TH (mm)*	TW (mm)	TH/TW*	CGAL*	Keel*	Porthole*	Sinuate*
Desmognathus auriculatus (N = 33)	48.46 ± 5.94	5.23 ± 1.02	4.67 ± 0.68	1.09 ± 0.06	5.2 ± 1.1	1 ± 0.0	0.8 ± 0.38	0.03 ± 0.12
Desmognathus conanti (N = 26)	44.03 ± 6.01	4.34 ± 0.67	4.05 ± 0.7	1.08 ± 0.06	3.76 ± 0.78	0.71 ± 0.37	0.14 ± 0.31	0
Desmognathus apalachicolae (N = 23)	45.43 ± 4.6	4.42 ± 0.52	4.81 ± 0.86	0.96 ± 0.05	3.43 ± 0.96	0.54 ± 0.37	0.15 ± 0.32	0.39 ± 0.45
HABITAT	*	*		*	*	*	*	*
Blackwater (N = 32)	47.96 ± 5.92	5.21 ± 1.02	4.8 ± 0.88	1.08 ± 0.06	5.15 ± 1.21	0.95 ± 0.2	0.66 ± 0.44	0.03 ± 0.12
Seepage (N = 50)	45.15 ± 5.64	4.42 ± 0.66	4.36 ± 0.75	1.02 ± 0.08	3.7 ± 0.81	0.67 ± 0.37	0.25 ± 0.41	0.18 ± 0.36

blackwater swamps (Valentine 1963). Numbers collected from sites where both species occurred syntopically suggest *D. auriculatus* may have been more common than *D. conanti* in Mississippi (e.g., 32 *D. fuscus* [= *conanti*] were collected, versus 64 *D. auriculatus*; Valentine 1963).

Determining if the current status of *Desmognathus auriculatus* has changed with respect to its previous abundance is difficult. However, the low number of historical sites currently occupied by *D. auriculatus* combined with the low encounter rate of 0.09 salamanders/person hour compared to 8.65 salamanders/person hour for surveys in the Florida Panhandle in the 1970s (Means and Travis 2007) provide qualitative evidence that this may be the case. Because most sites were searched only once in the present study, we cannot determine whether lack of success at finding *D. auriculatus* was caused by natural population fluctuations, unsuitable weather or hydrological conditions, population declines, or various other factors (Pechman et al. 1991). Our total search effort is comparable in time and methods to other recent studies attempting to locate *D. auriculatus* (Beamer 2005; Means and Travis 2007).

We encountered multiple individuals of smaller, and therefore less detectable species (e.g., *Eurycea quadridigitatta*), and fewer individuals of many species that are presumably difficult to find using these collection methods (e.g., *Amphiuma means*, *A. pholeter*, *Siren intermedia*, and *Pseudotriton montanus*; Fig. 2). In Alabama, we encountered no *D. auriculatus*, yet were able to collect two *Amphiuma pholeter* (considered highly rare in this state; Mirarchi 2004) in a county where they had not been previously documented (Graham 2007). Additionally, at several sites (including Five Runs Creek, Conecuh National Forest, Alabama, and Lake Jackson, Florala, Alabama), up to five return visits during three consecutive years yielded no *Desmognathus* salamanders where they were collected in the past. These are not sites where extensive collections were made (only 1–3 salamanders were collected), so it is unlikely that over collection at these sites is responsible for the trends observed.

Our morphological analysis, using at least one grouping scheme that required no *a posteriori* morphological categorization, is the first of its kind for Coastal Plain *Desmognathus* species. This suggests at least three species are widespread in the Georgia-Alabama Coastal Plain, that clear morphological features can discriminate them, and that they are usually segregated by habitat (Fig. 3). We suggest that some characters used in the past to distinguish *D. auriculatus* (Folkerts 1968; Conant and Collins 1991; Petranka 1998) may be unreliable or too subjective, and can also be found in other Coastal Plain *Desmognathus* species, most importantly the presence or absence of portholes. Although *D. auriculatus* certainly exhibits well-defined lateral light spots, many *D. conanti* and *D. apalachicolae* have small flecks along their sides that could be referred to as portholes. Dark coloration is also an unreliable characteristic, especially given the propensity for color change in Coastal Plain members of this genus (Means 1974). Most specimens of *D. auriculatus* encountered by us in the field, and those examined at the GMNH and AUM, exhibited heavily keeled tails reminiscent of the tails of *D. monticola* or even *D. quadramaculatus*. The number of costal grooves between the adpressed limbs (4–6 in *D. auriculatus* versus ≤ 3 for other species found within its range) appears to be a reliable field characteristic as well.

Unfortunately, a more thorough morphological-genetic analysis of Coastal Plain *Desmognathus* species is difficult due to the current rarity of *D. auriculatus* (Beamer 2005; Beamer and Lamb 2008). We recommend future researchers rely on the suite of characteristics we used to identify Coastal Plain *Desmognathus* sp. (rather than relying on a single character), and that those interested in working with these species consult museum collections (especially those identified by D.B. Means) before field work commences.

Current range maps suggest the Georgia Coastal Plain is occupied largely by *Desmognathus auriculatus*, with minimal penetration of *D. conanti* from the north into this region, and small pockets of *D. apalachicolae* occurring within it (Conant and Collins 1991; Lannoo 2005). The present study indicates that: (1) other *Desmognathus* species may occupy localities purported to be *D. auriculatus* sites; (2) the current understanding of the range and habitat associations of *D. auriculatus* and other Coastal Plain *Desmognathus* is flawed or incomplete; and (3) there is a general trend of habitat partitioning between locally abundant, ravine/seepage-dwelling *Desmognathus* species (e.g., *D. conanti*, *D. apalachicolae*, and possibly others) and blackwater swamp-dwelling *D. auriculatus,* which historically may or may not have been common. Valentine (1963), Means (1975), and Beamer and Lamb (2008) also describe habitat partitioning between seepage/ravine associated species (*D. conanti, D. apalachicolae*) and the blackwater associated *D. auriculatus*.

Our study therefore supports the findings of a recent phylogeography of Coastal Plain *Desmognathus* (including samples from this study), which suggests that current taxonomy vastly underestimates species-level diversity in southeastern Coastal Plain *Desmognathus* (Beamer and Lamb 2008). Beamer and Lamb (2008) demonstrate that *D. auriculatus* (as currently recognized) is paraphyletic, with eastern Atlantic Coastal Plain populations referable to several independent lineages. A lineage associated with populations collected near the type locality was identified, and includes populations surveyed in this paper (Beamer and Lamb 2008; David Beamer, pers. comm.). It is likely, therefore, that the entire area we surveyed (the Georgia and Alabama Coastal Plain) was within the range of the lineage that will retain the taxonomic status of *D. auriculatus*, and which is considered to be in decline (Dodd 1998; Means 2005; Means and Travis 2007). The sole exception to this was a single salamander collected in Chatham County, Georgia, which we identified morphologically as *D. auriculatus*, that was nested within an Atlantic Coastal Plain lineage that is morphologically similar to *D. auriculatus* (e.g., the C2 lineage of Beamer and Lamb 2008), but is exclusive of topotypic *D. auriculatus*. The difficulty involved in identifying members of the genus *Desmognathus* is notorious (Conant and Collins 1991), and although we attempt to provide a morphological basis for identifying *D. auriculatus*, we also recognize that, pending future phylogeographic analyses and taxonomic revisions, this may prove futile.

FIGURE 3. Blackwater branch swamp habitat of *Desmognathus auriculatus* at Fort Stewart, Georgia, site of our largest collection of this species during this survey. Six salamanders were encountered in two person hours. Note thick accumulations of dark, damp leaf litter and coarse woody debris, and lack of understory vegetation. No seepage habitat was present. Author's footprint in left foreground. (Photographed by Sean P. Graham)

These observations greatly increase the difficulty in interpreting past estimates of the abundance and distribution of *D. auriculatus*, and our results should also be viewed with caution. We conclude that *Desmognathus* species referable to descriptions of either *D. conanti* or *D. apalachicolae* occur in or near seepages along major river drainages in the Coastal Plain of Alabama and Georgia. These species often occur in high densities, and misidentifications may have inflated past estimates of the abundance of *D. auriculatus*. Our identifications of many of these populations were corroborated by others (John Jensen and D. Bruce Means), are supported by molecular sequence data (Beamer and Lamb 2008), and represent range extensions for *D. conanti* and *D. apalachicolae* (Graham et al. 2007). However, despite the growing evidence that *D. auriculatus* may never have occurred in the large geographic range it was presumed to have occupied, individuals referable to *D. auriculatus* once occurred in blackwater branches, creeks, or cypress ponds in south Georgia and Alabama. We had great difficulty finding *Desmognathus* salamanders in these habitats at dozens of sites where they were once present and collected in the past.

Although it is possible *Desmognathus auriculatus* may not have been especially common in the past, this study and others (Dodd 1998; Beamer 2005; Means 2005; Means and Travis 2007; Beamer and Lamb 2008) support the conclusion that *D. auriculatus* has likely experienced population declines. Two studies have documented declines in sites where they were once common, in seemingly pristine habitat (Dodd 1998; Means and Travis 2007). A general decline of all ravine-inhabiting species in the Florida Panhandle was also described by Means and Travis (2007) and attributed to habitat modification by feral hogs. Beamer (2005) commented on the difficulty in conducting a phylogeographic analysis of *D. auriculatus* due to insufficient material available throughout the historical range of this species, and his inability to find specimens at the type locality. Beamer and Lamb (2008) suggested local extirpation may have been responsible for their inability to find more than three populations of topotypic *D. auriculatus.* Interestingly, Beamer (2005) commented on declines of blackwater swamp-associated *Desmognathus* sp. throughout the historic range of *D. auriculatus*, despite that these salamanders belong to independent lineages.

We recommend that additional studies be conducted to determine the systematic affinity of Coastal Plain *Desmognathus* sp., and when possible, these studies should incorporate morphological information to make them useful for land managers, field biologists, and conservation biologists. In addition, repeated visits to sites located in this study should be conducted to estimate population densities and develop detectability models that will be invaluable for future efforts to evaluate this species' conservation status.

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Sean P. Graham earned his B.A. and M.S. from Georgia State University, His M.S. research involved field endocrinology of the Cottonmouth, *Agkistrodon piscivorus*. He is currently a Ph.D. candidate at Auburn University studying under the advisement of Craig Guyer, His dissertation research involves hormone/immune interactions in the Cottonmouth. However, he is also interested in many other herpetological topics, and collaborates with Elizabeth Timpe on phylogeographic studies of the Brownback Salamander (*Eurycea aquatica*) and Webster's Salamander (*Plethodon websteri*). Sean often crosses the state of Alabama on rainy nights in hopes of discovering new herpetological range extensions. With help from his friends, Sean has documented ~ 200 new county records for amphibians and reptiles in Alabama and Georgia in the last few years. Sean likes to focus on species that have been ignored or overlooked due to funding constraints and a lack of awareness; a perfect example of such a species is the unfortunate and neglected Southern Dusky Salamander. (Photographed by Elizabeth Timpe)

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APPENDIX 1. Museum specimens used to supplement salamanders collected during this study for morphological analyses. Museums were Georgia Museum of Natural History (GMNH) and Auburn University Museum (AUM).

GMNH 612, 17968, 17969, 17970, 17971, 17976, 17977, 17984, 18009, 18010, 18013, 18014, 18015, 18023, 18024, 18031, 18033, 18039, 18040, 20489, 20491, 20493, 20494, 20499, ; **AUM** 245, 5012, 10543, 13009, 13010, 13014, 13015, 18491, 19833, 21452, 21614, 22215, 22216, 22219, 22364, .

APPENDIX 2. Sites searched for *Desmognathus auriculatus* in Georgia and Alabama, USA. *Indicates salamander that was morphologically consistent with *D. auriculatus*, but preliminary molecular sequence data supports its relationship to *Desmognathus* of the North Carolina/South Carolina Coastal Plain rather than topotypic *D. auriculatus* (David Beamer, East Carolina University, pers. comm.). This specimen was not included in morphological analyses.

Site	County, State	*Desmognathus* Species Present	Individuals Encountered	Habitat	Precise Locality
		HISTORICAL SITES			
Suwannoochee Cr. crossing GA 37; 8 mi W of Homerville	Clinch, GA	*auriculatus*	1	blackwater branch and gum swamp	31.03676°N, 82.87966°W
Little Ogeechee Pond; 4.8 mi. SSW of Pooler; Half Moon Lake or Little Ogeechee Pond	Chatham, GA	*auriculatus**	1	blackwater branch behind impoundment	32.052972°N, 81.280722°W
Altamaha River Bluff; 5.5 mi. NNE of Jesup	Wayne, GA	*conanti*	3	bluff seepage	31.675972°N, 81.849667°W
30 mi. W Americus; Kinchafoonee Creek	Marion, GA	*apalachicolae*	5	gum swamp adjacent to seepage	32.306917°N, 84.583806°W
Kolomoki Park Near Blakely	Early, GA	*apalachicolae*	3	ravine seepage and creek swamp	31.47232°N, 84.93567°W
Vicinity of McBean Cr.	Burke, GA	*conanti*	4	gum swamp with seepage	33.240778°N, 81.946333°W
7.5 mi E of Girard, Little Sweetwater Cr. and River Rd.	Burke, GA	*conanti*	2	blackwater swamp	33.069056°N, 81.626361°W
Co. Rd. #329; Reedy Cr.; 2.2 mi. N-NNE of Matthews	Jefferson, GA	*conanti*	1	ravine seepage	33.238222°N, 82.297306°W
Mill Cr.; 6.1 mi SW of Eden	Bryan, GA			blackwater branch	32.15763°N, 81.50723°W
Small creek entering Ogeechee R.; 4.5 mi SW Guyton (Sweeten Water Branch)	Bulloch, GA			blackwater branch	32.27204°N, 81.47126°W
7.3 mi S Clyo	Effingham, GA			blackwater branch	32.39192°N, 81.30527°W
"the runs"; Ebenezer Cr.; 3.5 mi. W Clyo	Effingham, GA			blackwater branch	32.47789°N, 81.30200°W
U.S. 21; Little Ebenezer Cr.; 3 mi SE Springfield	Effingham, GA			blackwater branch	32.34429°N, 81.26570°W
Bay and creek swamp NE of Featherhead Bay	Atkinson, GA			Carolina bay	31.2055°N, 83.00472°W; 31.240556°N, 82.958944°W

Laura Walker SP, Big Creek nature trail; along Big Creek from Laura Walker Lake behind dam	Ware, GA	blackwater branch	31.14201°N, 82.20713°W
GA 136; 3.6 mi NW midway; Fleming Station Rd.	Liberty, GA	blackwater swamp	31.82988°N, 81.48834°W
Riceboro (Type Locality). LeConte Woodmanston Historical Site	Liberty, GA	blackwater swamp	31.70020°N, 81.47607°W
GA 94; 6 mi. W of St. George	Charlton, GA	blackwater swamp	30.52338°N, 82.16177°W
First creek on Gillionville Rd. W of Albany (Cooleewahee Cr.)	Dougherty, GA	creek swamp	31.58482°N, 84.26436°W
3.2 mi E of Plains (Muckaloochee Cr. and U.S. 280)	Stewart, GA	seepage	32.04995°N, 84.33685°W
2 mi E of Bowen's Mill Fish Hatchery	Wilcox, GA	spring run	31.859639°N, 83.197056°W
Anderson Creek Run; 1–1.25 mi S of Osierfield	Irwin, GA	blackwater branch	31.634944°N, 83.133167°W
Suwanoochee Creek crossing U.S. 84/GA 38; 0.5 mi SW of Dupont	Clinch, GA	blackwater creek	30.98585°N, 82.87906°W
McKinney's Pond; 3 mi. S Midville	Emanuel, GA	spring run	32.79132°N, 82.21902°W
Quacco Rd.; 0.2 mi E of I-95; Quacco Rd. 3 mi. S Pooler	Chatham, GA	flatwoods, cypress ponds	32.07472°N, 81.27497°W
U.S. 17 at Baker Swamp; 0.95 mi. N Midway	Liberty, GA	cypress swamp	31.82171°N, 81.42955°W
GA 99 (now GA 57); 7.8 mi. S of Ludowici; Goose Run Cr.	Long, GA	blackwater branch	31.64059°N, 81.66876°W
S-1920 at Penholloway Cr.; E of U.S. 301 at Broadhurst.	Wayne, GA	blackwater creek	31.47715°N, 81.91194°W
S-1920 crossing Little Cr.	Wayne, GA	blackwater branch	31.49111°N, 81.89123°W
"Bella Vista", Glynn Co.	Wayne, GA	gum swamp	31.363806°N, 81.738972°W
U.S. 82; 9.5 mi. E of Ware Co. line; 5.4 mi E-ENE of Hoboken; (Caney Bay)	Brantley, GA	Carolina bay	31.19386°N, 82.05019°W
Camp Branch Cr. (Greasy Branch) crossing U.S. 84; 14 mi. WSW of Waycross.	Ware, GA	blackwater branch	31.10913°N, 82.56256°W
Billy’s Island	Charlton, GA	cypress swamp	30.83146°N, 82.33352°W
Magnolia Bluff; E bank of Satilla R. N of GA 252 bridge.	Camden, GA	bluff seepage	30.95054°N, 81.89177°W

Rocky Cr. Bridge	Houston, AL			blackwater creek	31.090012°N, 85.199073°W
Depression N "Hogfoot Cr." crossing at Co. Rd. 24 (refined to Five Runs Cr. at County Rd. 24)	Covington, AL			cypress swales near blackwater creek	31.10961°N, 86.51699°W
Lake Jackson at Florala	Covington, AL			cypress sink lake	30.988876°N, 86.334738°W
3 air mi SW Gordon (T2N R29E S21)	Houston, AL			cypress pond	31.126220°N, 85.134422°W
5 mi SW Tensaw, approx 2 mi E bend in Alabama R., on Ft Pierce Hunt Club.	Baldwin, AL			hardwood swamp	31.14903°N, 87.83029°W
NEWLY-DESIGNATED SITES					
Fort Stewart; FS Rd. 43 and small trib. of Canoochee R. (Otter Hole Cr.).	Bryan, GA	*auriculatus*	6	blackwater branch	32.11528°N, 81.68929°W
Tributary of Whitewater Cr.	Taylor, GA	*apalachicolae*	2	seepage	32.52387°N, 84.3029°W
Seepages along S bank of Ebenezer Cr; 1 mi. E of SR 21/GA 225 intersection; .25 miles E of GA 225; E of RR	Effingham, GA	*conanti*	22	seepage	32.344806°N, 81.244944°W
Sweetwater Cr. at Bumphead Rd. seepages on S of creek, E of road	Schley, GA	*apalachicolae*	6	seepage	32.17375°N, 84.211583°W
Steephead near Pond Cr.	Covington, AL	*conanti*	3	steephead	31.0962°N, 86.53986°W
Seepage near Pond Cr.	Covington, AL	*conanti*	3	seepage	31.09785°N, 85.53544°W
Ravine near Lake Fox downstream impoundment	Geneva, AL	*conanti*	3	ravine seepage	31.19382°N, 85.85742°W
Red Hill Spring	Baldwin, AL	*conanti*	2	ravine seepage	31.094173°N, 87.832696°W
Blakely State Park	Baldwin, AL	*conanti*	2	ravine seepage, bottomland swamp	30.736888°N, 87.924285°W
U.S. 29, Three Mile Cr.	Crenshaw, AL	*conanti*	1	seepage, gum swamp	31.520517°N, 86.335433°W
GA 127, Flint River, upstream ~ 200m	Macon, GA	*apalachicolae*	1	seepage	32.43681°N, 84.01910°W
Yuchi WMA, Toblers Cr., River Rd.	Burke, GA			seepage, first order creek	33.11164°N, 81.72502°W
Small trib. of Alapaha R. at U.S. 129, just E of Mayday	Echols, GA			blackwater creek, mucky seepage	30.82763°N, 83.00308°W
Small trib. of Alapahoochee R. just N of FL state line; N and S of GA 135 brige; along seepages S of bridge	Echols, GA			seepage	30.62654°N, 83.09123°W

Blue Cr. and U.S. 27 S of Blakely	Early, GA	blackwater creek	31.33132°N, 84.89724°W
Small Cr. and U.S. 80 just N of Oakgrove. Searched Cr. both sides W of hwy to its source	Talbot, GA	first order creek	32.61632°N, 84.54812°W
Cedar Cr. and U.S. 129	Wilcox, GA	blackwater branch	32.09076°N, 83.39014°W
Satilla River and GA 32	Irwin, GA	blackwater creek	31.59601°N, 83.12470°W
Horse Creek WMA; Searched swamps and seepages along boat ramp Rd. about 1 mi. N of Ocmulgee R.	Telfair, GA	hardwood swamp	31.82813°N, 82.85485°W
General Coffee SP, along Seventeen Mile Cr. swamp E campground; along seepages just S of campground	Coffee, GA	blackwater swamp, seepages	31.52031°N, 82.76297°W
Ohoopee Dunes SNA; Along small trib. and floodplain of Little Ohoopee R., N of U.S. 80	Emanuel, GA	blackwater branch	32.57698°N, 82.44913°W
FS Rd. 23 and Canoochee Cr.	Liberty, GA	blackwater branch	31.993252°N, 81.733114°W
At “seven bridges” over Spring Cr. and Chickasawhatchee Cr. (Chickasawhatchee Rd. from GA 37)	Baker, GA	hardwood swamp	31.42478°N, 84.44628°W
Conecuh NF, Hog Foot Creek, FS 339	Covington, AL	creek swamp	31.12770°N, 86.51397°W
Conecuh NF, Bear Head Cr., FS 311-D	Escambia, AL	creek swamp	31.11167°N, 86.71329°W