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Aspects of the Life History and Ecology of the Coal Skink, *Eumeces anthracinus*, in Georgia

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The coal skink, *Eumeces anthracinus*, is a medium-sized (maximum snout–vent length approximately 65 mm) lizard that has a highly localized distribution in the midwestern and eastern United States (Walley, 1998). It is uncommonly encountered throughout its range (Mount, 1975; Collins, 1993; Trauth, 1994; Dundee and Rossman, 1996) and is listed as endangered, threatened, or a species of special concern in at least five states (Mitchell, 1994; Ramus, 1998). It is a ground-dwelling form that has a strong affinity for mesic sites and often occurs near water (Collins, 1993; Mount, 1975; Trauth, 1994; Dundee and Rossman, 1996). Other than habitat, very little is known about the ecology of this secretive species. Most information on life history and activity patterns is in the form of scattered anecdotal observations (e.g., Collins, 1974; Mount, 1975; Irwin, 1982). The single exception is Trauth's (1994) study of gonadal development in Arkansas.

Although normally rare, the abundance of coal skinks in a forested area in Habersham County, Georgia, afforded us the opportunity to investigate the ecology of this relatively unstudied species. Our specific objectives were to use nondestructive sampling to collect data on life history and activity patterns.

The study site was an area approximately 5000 m^2 located on the southern side of Lake Demorest, Habersham County, Georgia. This area is north-facing with a gentle slope (< 15°) abutting a marshy swamp on its northern edge. The area is covered by a largely deciduous forest. The most common trees are, in decreasing order of abundance, tulip poplar (*Liriodendron tulipifera*), short-leaf pine (*Pinus echinata*), red maple (*Acer rubrum*), dogwood (*Cornus florida*), beech (*Fagus grandifolia*), and southern red oak (*Quercus falcata*). The area is bisected by a north-flowing swampy stream, whose associated bottoms are dominated by Chinese privet (*Lugustrum sinense*). Much of the forest floor is densely covered with English ivy (*Hedera helix*). The southern end terminates at a south-facing roadbank, which is approximately 45° and has a substrate of mowed grass and exposed soil.

We captured lizards using a drift fence similar to that described by Gibbons and Semlitsch (1981). The fence was 25 cm high with regularly spaced (approximately 5-m intervals) bucket stations. Each bucket station consisted of a pair of four-liter buckets, each of which was placed on the opposite side of the fence from the other. The longest part (100 m) of the fence paralleled the roadbank approximately 10 m inside

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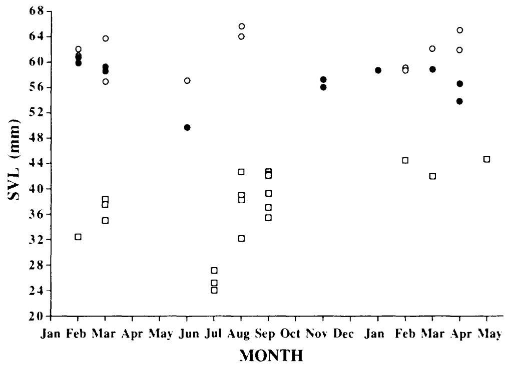

FIG. 1. Dates of capture and SVLs of individual coal skinks. Closed circles = mature males, open circles = mature females, and open squares = immature individuals. The figure starts with January 1998.

TABLE 1. Two-way ANOVA of male versus female SVL and Georgia versus Arkansas SVL for coal skinks. Mean ± standard deviation for Georgia males and females, respectively, were 57.26 ± 3.06 and 61.38 ± 2.96 mm. Mean ± standard deviation for Arkansas males and females, respectively, were 54.72 ± 2.99 and 60.43 ± 3.00 mm. N Georgia = 24; N Arkansas = 41.

Source	df	SS	MS	F	P
State	1	45.59	45.59	5.07	0.0279
Sex	1	363.31	363.31	40.43	0.0001
Interaction	1	9.64	9.64	1.07	0.3045
Error	61	548.12	8.99		

the southern edge of the forest. Other, shorter, sections of fence were placed at various sites throughout the area at angles that were both parallel and perpendicular to the longest section, partially enclosing two rough squares, one on each side of the stream. The entire length of fence was 185 m. The fence was checked daily from 30 January 1998 to 15 May 1999. Most lizards were collected in buckets, although a few were collected by hand on the roadbank.

Individual lizards that were collected in buckets were categorized as immature, adult male, or adult female. Adult males were determined by the presence of red coloration on the inferior and lateral parts of the chin and face (Mitchell, 1994). Because males and females of other *Eumeces* mature at the same size, we judged a lizard to be female if it was at least as large as adult males and did not have the red coloration. Immature coal skinks had a considerably darker body than adults; the smallest individuals were virtually black. On the same day as capture, individual lizards were measured for snout–vent length (SVL), individually marked by clipping toes (following Hasegawa, 1984) and released to the opposite side of the fence. The SVL data were grouped into size categories by visual estimation. These were then used to estimate age at maturity.

A t-test was used to determine whether there was any sexual dimorphism in mean SVL. To determine whether the same relationship holds in other parts of its range, a two-way analysis of variance (Zar, 1984) was performed comparing adult SVLs from our study population to those of a sample of adults from Arkansas reported by Trauth (1994). Although Trauth's (1994) pooling of museum specimens precludes direct interpopulation comparisons, we felt that such an analysis may still indicate trends in geographic variation.

Chi-square analysis was used to determine whether coal-skink activity was similar between warm (April–September) and cool (October–March) months. Numerous bucket captures were also made of the five-lined skink, *E. fasciatus*. Although these lizards were not measured or marked, they were categorized as mature or immature. Their seasonal activity pattern was analyzed in the same way as that of *E. anthracinus* for comparative purposes.

In addition to bucket captures, observations of coal skinks were made along the roadbank. Notes were taken of any behavior (e.g., mating, aggression) observed.

A total of 44 coal skinks was captured during the course of this study. Only five recaptures were made during the course of the study. An additional recapture was made after completion of the study during February 2000. This latter individual was a 35-mm juvenile initially marked in March 1998, and a 57-mm mature male when recaptured.

Twelve of the skinks initially captured were adult females, 12 were adult males, and 20 were immature (Fig. 1). The three smallest animals were collected during July. Because Martof (1955) estimated *Eumeces anthracinus* from northern Georgia to hatch at approximately 20 mm SVL, we considered these to be young-of-the-year (mean SVL = 25.50 ± 1.52 mm). Adult males had a mean SVL of 57.30 ± 3.06 mm, whereas females were 61.38 ± 2.96 mm. Adult males were significantly smaller than adult females (t = 3.35; df = 22; $P < 0.01$). By way of comparison, results of a two-way analysis of variance (Table 1) showed that females were also larger than males in Arkansas. In addition, it indicated that mean SVLs for adult males and females were larger in Georgia than their respective counterparts in Arkansas.

In the largest sample of immature specimens (July–September, Fig. 1), there appeared to be two size classes. If the smaller group were plotted in July 1998, rather than July 1999, the growth trajectory estimated by all plotted immatures would appear linear. Therefore, we used linear regression and associated r^2 to generate a growth model for immature individuals. The model assumes hatching occurs in July. The r^2-value was 0.859. The model is given as size (SVL) = 0.896age + 28.014 (Fig. 2). Based on this model, age at maturity is estimated to be approximately 23–24 months following hatching. The slight discrepancy between the y-intercept given in the model and the mean SVL of presumed hatchlings is the result of the assumption within the model of total synchrony in hatching.

There was no difference in numbers of coal skinks captured between warm (April–September) and cool (October–March) seasons (N = 21 and 22, respectively; χ^2 = 0.023; df = 1; $P > 0.75$). Almost all of the five-lined skinks (60 of 66), however, were captured

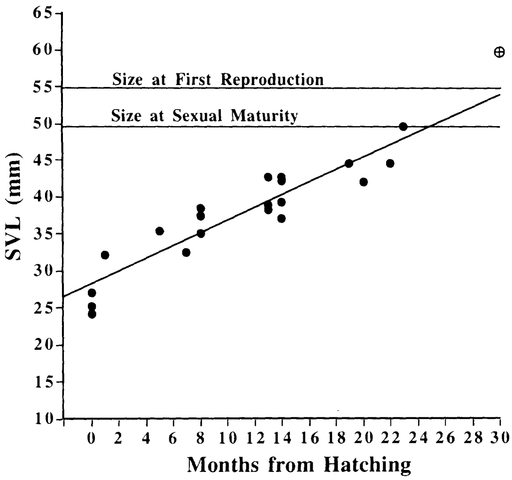

FIG. 2. Regression model of growth for coal skinks. Size at sexual maturity (approximately 50 mm SVL) and first reproduction (approximately 55 mm SVL) are presented. Solid circles represent immature and newly maturing individuals. The hatched circle represents the mean SVL of all sexually mature adults captured from January to April (N = 18; mean = 59.69 ± 2.68 mm).

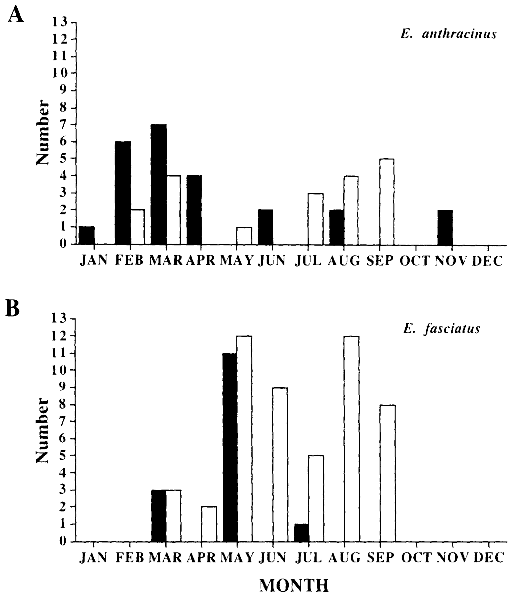

FIG. 3. Monthly activity of skinks as measured by bucket captures. (A) *Eumeces anthracinus.* (B) *Eumeces fasciatus.* Dark bars represent adults. Open bars represent immature individuals.

during warm months ($\chi^2 = 44.182$, df = 1, $P < 0.001$; Fig. 3).

Coal skinks were seen mating on the roadbank in February and March, and aggression was seen between two males in March. Sexually active individuals collected in early April exhibited courtship and mating in the laboratory. We also noted that the red coloration on the face of adult males was most intense during late winter and early spring.

Female coal skinks are larger than males in both Georgia and Arkansas. A similar pattern has been reported for this species in Virginia (Mitchell, 1994). This suggests that this pattern of sexual dimorphism is a specieswide phenomenon. This differs, however, from other southeastern species of *Eumeces*, in which males are as large as, or larger than, respective females (Vitt and Cooper, 1985a, 1986). Our finding that Georgia coal skinks were larger than those from Arkansas is suggestive of population-level divergence, but we note that the Arkansas data were not from a single population.

Our growth model estimates age at maturity of 23–24 months and size at maturity of 50 mm, assuming synchronous hatching in July and an overall linear growth trajectory. Hence, we hypothesize that coal skinks mature during the second summer after hatching. Because of an early-spring mating season, our growth model estimates age and size at first reproduction of 30–32 months and 55 mm, respectively. The 57-mm adult male recaptured during February 2000, provides anecdotal support for the model. A two-year age to maturity is similar to that known for other, larger southeastern *Eumeces* (Vitt and Cooper, 1985b, 1986). Vitt and Cooper (1986) noted the conservative nature of life histories in *Eumeces.* If our hypothesis is correct, then differences in adult body size in *Eumeces* are largely achieved through differences in growth rates (Fitch, 1954; Vitt and Cooper, 1985b), with *E. anthracinus* growing more slowly.

Coal skinks are active year round with mating occurring in late winter and early spring. Trauth (1994) showed that male coal skinks in Arkansas reach maximal sperm production in March, and Mount (1975) observed mating in Alabama during March. This suggests a broad geographic synchrony in breeding season in this species. The activity period of five-lined skinks appears restricted to warmer months. This differential pattern between the two species is further demonstrated by the asynchrony of the spermatogenic cycles of the two species in Arkansas. Peak spermatogenesis in five-lined skinks occurs over a month later than that of coal skinks (Trauth, 1994). Adult activity in both species appears to be greatest during the respective breeding seasons (Fitch, 1954; this study). Variation in the timing of activity and reproductive cycles among syntopic species may influence the structure of lizard communities through temporal shifts in assemblage composition (Fitzgerald et al., 1999).

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Sexual Dimorphism in *Osornophryne guacamayo* with Notes on Natural History and Reproduction in the Species

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Osornophryne guacamayo is distributed between 1800 and 2200 m on the eastern slopes of the Andes and adjacent foothills in central Ecuador. Few specimens have been discovered since the species was described (Hoogmoed, 1987), and information regarding variation within the species and among sexes, habitat preference, reproduction, and diet are limited. Ruíz-Carranza and Hernández-Camacho (1976) included some aspects of the natural history and reproductive biology of *Osornophryne* in their description of the genus. Cannatella (1986), Hoogmoed (1987), and Gluesenkamp (1995) also reported briefly on general habitat attributes and microhabitats in which other species were encountered. Stomach contents were reported for some species by Ruíz-Carranza and Hernández-Camacho (1976) and by Gluesenkamp (1995).

Many species of the genus *Atelopus*, hypothesized to be most closely related to *Osornophryne* (Cannatella, 1986; Graybeal, 1995; Coloma, 1997), have recently undergone drastic population declines the causes of which are still unknown. Understanding the natural histories of these taxa may provide information leading to a better understanding of the causes of these declines. We present for the first time data on male morphology, season of reproduction, vocalization, and reproductive behavior in *Osornophryne guacamayo*. Further data are presented regarding ontogenetic color variation in females, microhabitat preference, sexual dimorphism, and diet of this species.

Individuals were collected primarily on Volcán Sumaco and Volcán Reventador and in the Cordillera de los Guacamayos. A few specimens collected at other localities have been included in this analysis.

Microhabitat data for populations from Volcán Sumaco, Cordillera de los Guacamayos, and Volcán Reventador were recorded in July and August 1992 and March and April 1996. Microhabitat descriptors scored included substrate (leaf, branch, trunk of tree, ground), and perch size. Perch classes were defined as Short = leaf < 15 cm in length; Medium = leaf 15–30 cm; Long = leaf > 30 cm; Bromeliad = arboreal bromeliad of any size. Color pattern and morphometric data were recorded for all available specimens. Some microhabitat descriptors were recorded for individuals that were not collected. These individuals are included as "unknown" in all analyses with the exception of 15 large (> 30 mm SVL) individuals with yellow venters which were assumed to be adult females based on the distribution of these traits among specimens of known sex. Color pattern and size was not recorded for all individuals encountered. Therefore, the unknown class likely contains some adult females. Overall, the observed sex ratio was skewed toward adult females which accounted for 35 of 106 individuals observed (including 17 juvenile females, 20 males, and 34 individuals of unknown gender).

Nearly all specimens were collected on vegetation at night (Fig. 1). Five specimens (four adult females and one male) were encountered walking on the ground during the day. Individuals of both sexes perched at various perch heights with no differences apparent among sex or age classes with the exception that only adults were found on the ground (Fig. 1). A single adult female was collected in an epiphyte 20 m above the ground and two others on the ground under