Seasonal activity of snakes in the Atlantic forest in southeastern Brazil

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Abstract. Seasonal abundance of some snake species from the Atlantic forest in southeastern Brazil was inferred from collection data gathered throughout twelve years at the Instituto Butantan in São Paulo, Brazil. The number of collected individuals of *Chironius* spp., *Liophis miliaris*, *Spilotes pullatus*, *Tropidodryas* spp., *Micrurus corallinus*, and *Bothrops jararaca* was significantly higher during the rainy season, whereas the number of *Sibynomorphus neuwiedi* was higher during the dry season. *Erythrolamprus aesculapii*, *Xenodon neuwiedii*, *Tomodon dorsatus* and *Bothrops jararacussu* did not show significant differences in the number of individuals collected at each of these seasons. Seasonality in captures may result from seasonal activity patterns. Food availability, tolerance to climatic conditions, reproductive cycle, and phylogenetic constraints are considered the main factors responsible for the observed patterns. A multivariate approach is recommended for analysis of annual activity.

Introduction

Seasonal occurrence peaks of snakes are well-known in several species from temperate areas (e.g. Moore, 1978; Phelps, 1978; Gannon and Secoy, 1985; Seigel, 1986; see Gibbons and Semlitsch, 1989 for assembled references), but there is little information about tropical species in South America (e.g. Sazima, 1988; Jordão and Bizerra, 1996; Marques, 1996; Marques and Puorto, 1998). In this region, most data refers to assemblages studied at a particular site (e.g. Henderson and Hoever, 1977; Henderson et al., 1978; Silva et al., 1985; Strüssmann, 1992; Martins, 1994; Marques, 1998).

Based on the diversity of seasonal patterns recorded for species from temperate areas, Gibbons and Semlitsch (1989) suggested that the activity pattern of tropical snakes should be analyzed individually for each species. Nevertheless, it is difficult to evaluate the annual activity of each species in studies undertaken during a short period of time in a restricted area due to the low number of individuals sampled for most of the species. During several

years, thousands of snake specimens belonging to many species from southeastern Brazil have been collected by field dwellers and sent to Instituto Butantan.

The present paper describes the seasonal abundance of eleven species from the southeastern Atlantic forest based on specimens sent to Instituto Butantan. Here, we discuss the factors that may affect the patterns observed for each species.

Material and methods

Study area. The studied specimens came from the coastal lowlands and the sea slope of the Serra do Mar in the State of São Paulo, southeastern Brazil (fig. 1). This area is covered by Atlantic forest, and has a homogeneous climate throughout (Nimer, 1989; Silva, 1989), which may be characterized by high rainfall levels throughout the year (fig. 2). However, it is possible to define a rainy season (between October and May, with a higher incidence of rains and higher temperatures) and a dry season (between June and September, with less rainfall and lower temperatures) (fig. 2).

Data collection. We used records of snake arrivals at the reception of the Laboratório de Herpetologia of the Instituto Butantan in São Paulo, southeastern Brazil, to document the number of snakes collected by field dwellers each month throughout a twelve-year period

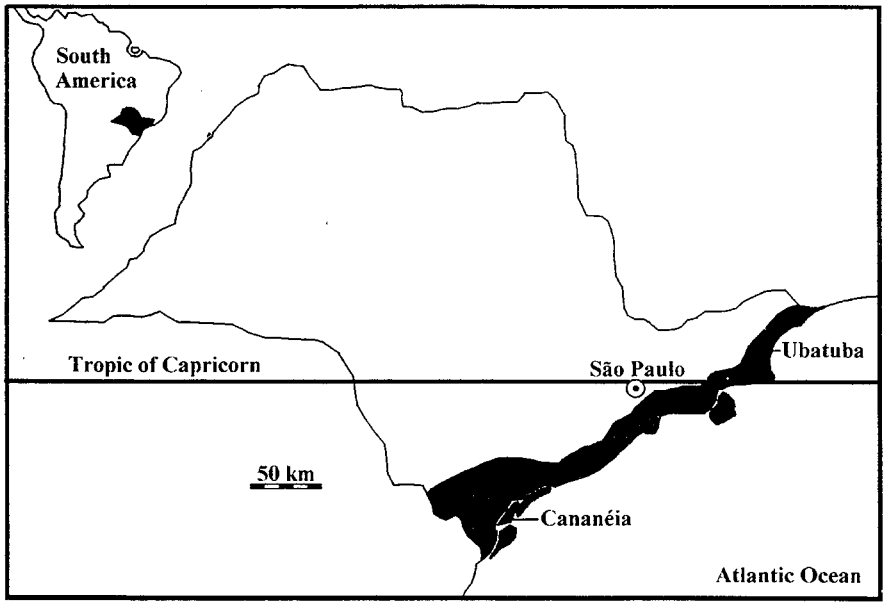

Figure 1. The coastal lowlands and the sea slope of the Serra do Mar. Area covered by Atlantic forest from southeastern Brazil, where snakes of the present study were collected. Localities of Ubatuba and Cananéia were used as examples of climate of entire area.

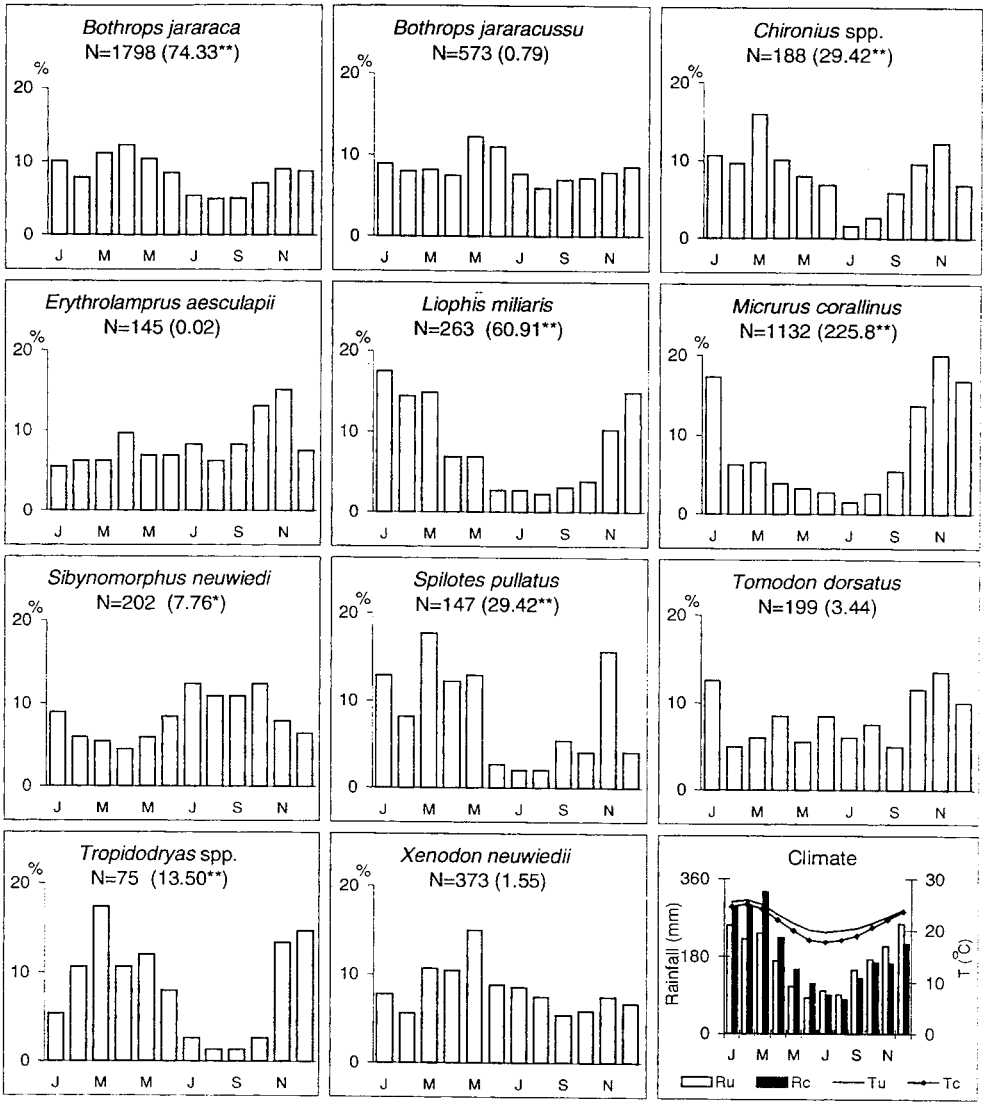

Figure 2. Seasonal activity of 11 species of snakes in the Atlantic Forest, southeastern Brazil. Percentage values at each month correspond to the number of adult individuals (n) sent to Instituto Butantan from 1985 to 1996. X^2 values (in parenthesis: * significant, $P < 0.05$, ** highly significant, $P < 0.01$) result from comparison of abundance in rainy (October-May) and dry (June-September) seasons. The lower graph right presents monthly average rainfall and temperature (1980-1988) in extreme sites of the study area: north — Ubatuba and south — Cananéia (data from Silva, 1989). Ru: rainfall in Ubatuba, Rc: rainfall in Cananéia, Tu: temperature in Ubatuba, Tc: temperature in Cananéia.

(1985 to 1996). All specimens are from the coastal lowlands and sea slope of the Serra do Mar. We choose 11 taxa arbitrarily, that include some of the species most frequently

found in Atlantic Forest areas (Marques, 1998), and species with secure determination by technicians. In two cases (*Chironius* and *Tropidodryas*), identification of the genus by the technicians was unequivocal, but not to the species level, leading to clustering of these species in the analysis. In the records of the Laboratório de Herpetologia of the Instituto Butantan the snakes are classified as adults or juveniles. The latter category generally is used to define newborns (pers. obs.). Juveniles were not used in our study in order to avoid interference due to recruitment. To compare the number of snakes collected at each season we used a chi-square test. A classification analysis (UPGMA) was done based on similarities (Morisita-Horn standard index) between the monthly relative abundance of each species.

Results

Most of the snakes species, *Chironius* spp. (*C. bicarinatus*, *C. exoletus*, *C. fuscus*, *C. laevicollis* and *C. multiventris*), *Liophis miliaris*, *Spilotes pullatus*, *Tropidodryas* spp. (*T. serra* and *T. striaticeps*), *Micrurus corallinus* and *Bothrops jararaca*, were collected in significantly lower numbers during the dry season (fig. 2). One species (*Sibynomorphus neuwiedi*) was more frequently collected during the dry season, and four species (*Erythrolamprus aesculapii, Xenodon neuwiedii, Tomodon dorsatus* and *Bothrops jararacussu*) showed no significant difference in the number of individuals collected during either of the two seasons (fig. 2). Three clusters of species (up to 90% of similarity between monthly abundance) result from the classification analysis: a) *B. jararaca*, *B. jararacussu*, and *X. neuwiedi*; b) *E. aesculapii*, *T. dorsatus*, and *S. neuwiedi* and c) *Chironius* spp., *S. pullatus*, and *Tropidodryas* spp. *Liophis miliaris* and *M. corallinus* do not take part in any of these groups (fig. 3).

Discussion

Three possible factors may influence the number of snakes collected in the different months of the year: (1) seasonal difference in collection effort, (2) seasonal difference in number, and (3) seasonal difference in activity (see Henderson et al., 1978).

Recent studies undertaken in tropical areas quantified the monthly collection effort in a precise way, thus reducing or excluding the first factor (Sazima, 1988; Strüssmann, 1992; Martins, 1994). In the present study, collection effort during each month cannot be quantified, since the snakes were collected by various collaborators of the Instituto Butantan. However, most of these collectors live in the area and, therefore, we assume that the number of hours they spend in the field every month does not vary substantially (see Shine, 1982 for discussion about collecting effort influence on quantitative ecological data). The only species whose data on seasonal abundance with equal collection effort are available, *B. jararaca* in southeastern Brazil, presents a pattern similar to the one here

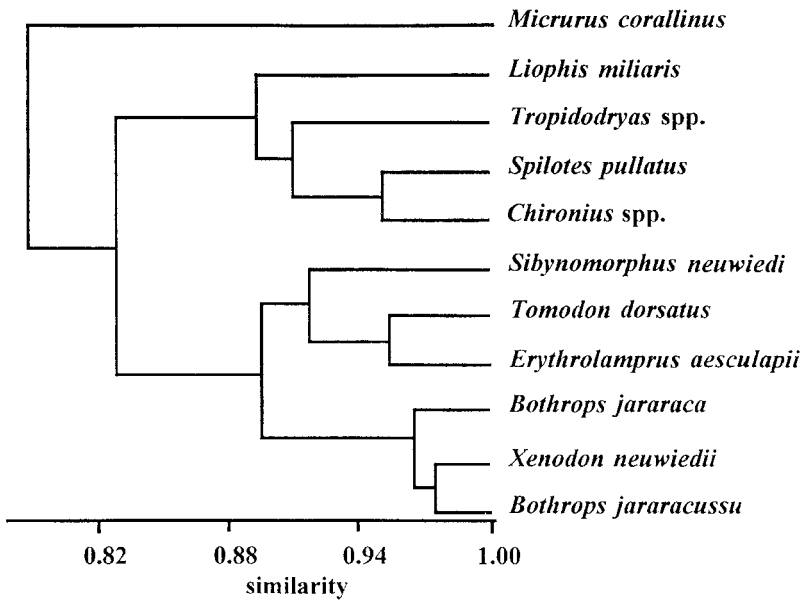

Figure 3. Classification analysis (UPGMA) based on similarities (Morisita-Horn standard index) between the monthly relative abundance of eleven snake species from Atlantic rainforest from southeastern Brazil. Clusters were assumed when similarity was higher than 90%.

obtained (Sazima, 1988), justifying our risk assumption on homogeneous effort. Thus, the influence of the first factor should be small in our study.

The monthly oscillation in the number of collected snakes caused by greater abundance is due basically to the incorporation of new individuals as a function of species recruitment (Henderson et al., 1978). Since newborns were removed from our analysis, this factor can be disregarded. Therefore, we suggest that snake activity is the main factor that produces the differences in abundance recorded throughout the year (see Shine, 1982). The data indicate the existence of different patterns of seasonal activity among the snake species.

Factors related to climatic conditions may be responsible for certain observed patterns. Food availability throughout the year, that may or may not be related to the climate, has been considered as one of the main factors explaining snake activity patterns (Henderson et al., 1978; Gibbons and Semlitsch, 1989; Martins, 1994). The availability of various rodents, a potential prey of *S. pullatus*, *Tropidodryas* spp., *B. jararaca* and *B. jararacussu* (Sazima, 1992; Sazima and Haddad, 1992; Sazima and Puorto, 1993; Marques, 1998) does not seem to vary much throughout the year at several sites of the Atlantic forest (Cerqueira et al., 1993; Olmos, 1991; Bergallo, 1994). However, among the four snake species whose diet is based on rodents, only *B. jararacussu* does not change its activity throughout the year. Thus, prey availability itself not explain the seasonality of *S. pullatus*, *Tropidodryas* spp., and *B. jararaca*.

However, the availability of most frog species, an important food source for *Chironius* spp., *L. miliaris* and *X. neuwiedii* (cf. Dixon et al., 1983; Michaud and Dixon,1989; Jordão, 1988; Marques, 1998) seems to be higher during the first half of the rainy season, due to their reproductive activity during this period in the Atlantic forest (Bertoluci, 1998; Heyer et al., 1990; C.F.B. Haddad and J.P. Pombal-Júnior, pers. comm.). The differential availability of frogs throughout the year may explain the seasonal differences in number of individuals of *Chironius*, a genus specialized in this type of prey (Dixon et al., 1993; Marques, 1998). Data obtained for *C. fuscus* and *C. exoletus* in the upper Amazon river shows that the collection peak for these snakes also occurs during the rainy period (Dixon et al., 1993), when frogs are most active (Aichinger, 1987; Moreira and Lima, 1991). On the other hand, the frog-eating snake *X. neuwiedii* does not seem to decrease its activity during the dry season (fig. 2). Species of the genus *Chironius* prey mainly on hylids and leptodactylids (Dixon et al., 1993; Marques, 1998), whereas *X. neuwiedii* is specialized on toads of the genus *Bufo* (Jordão, 1996; Marques, 1998). Several species of *Bufo* are abundant on the forest floor during any time of the year, unlike most of the other frog species belonging to Hylidae and Leptodactylidae (C.F.B. Haddad, and J.P. Pombal-Júnior, pers. comm.; pers. obs.). Therefore, the year-round availability of *Bufo* spp. may explain the non-seasonal activity of *X. neuwiedii*. However, *L. miliaris*, that can also prey on this amphibian type, besides several other types of prey (Michaud and Dixon, 1989; Marques, 1998), seems to present a clear fall in activity during the dry season (fig. 2). The higher availability of temporary ponds during the wet season (which are common foraging sites in *L. miliaris*, Marques and Souza, 1993; Marques, 1998) may explain their higher abundance in rainfall. However, other factors may determine these activity patterns, which we discuss below. Other factors should also be considered to explain the differences in activity patterns of *T. dorsatus* and *S. neuwiedii*, since both species are malacophagous (Laporta-Ferreira, 1986; Bizerra, 1998; Marques, 1998).

For most snake species, the period in which the least number of snakes was taken corresponds to lowest periods of rainfall and temperature (fig. 2). Abiotic factors, such as humidity and temperature, directly influence the metabolism of snakes and consequently their activity (Lillywhite, 1987). Although there are periods with less rainfall (fig. 2), the relative humidity within the forest changes little throughout the year (Silva, 1989). Nevertheless, the temperature is considerably lower in most of the available forest microhabitats during the dry season (pers. obs.), reducing the chance of finding an adequated site for thermoregulation. Low temperatures may considerably reduce the metabolic rate of snakes and consequently constrain their activity (Lillywhite, 1987). Therefore, it is possible that many snakes may show a decrease in activity at lower temperatures. Some species, such as *B. jararacussu*, *E. aesculapii*, *X. neuwiedii*, *T. dorsatus* and *S. neuwiedi* may be more tolerant to lower temperatures and this may explain their activity during the dry season.

Phylogenetic relationship is a possible factor that constrains the patterns of activity. Despite this, the supposed differences in temperature tolerance may not be associated only with phylogenetic lineages. When comparing abundance in dry and wet season,

clear differences exist between closely related species, such as the viperids *B. jararaca* (seasonal) and *B. jararacussu* (aseasonal) and the xenodontini *L. miliaris* (seasonal) and *X. neuwiedii* (aseasonal). However, when the abundance is analyzed month by month (as in the clustering procedure), the historical influence emerges in two cases: the species of *Bothrops* and the colubrines *Chironius* spp. and *S. pullatus*.

Another factor that may influence snake activity is the reproductive cycle (Shine, 1979; Gibbons and Semlitsch, 1987). In some species such as *M. corallinus*, males are mainly active at the onset of the rainy season, probably because they are searching for females (Marques, 1996a). The females, however, are more active during vitellogenesis (when they may be searching for appropriate thermoregulation sites), which occurs in the early part of the rainy season (Marques, 1996a). Except for *E. aesculapii* and *X. neuwiedii*, the species studied here seem to have a seasonal reproductive cycle (Marques, 1996b, 1998; Jordão, 1996). Thus, reproductive conditions may determine an increase in locomotory activity for most of the snakes here studied during the rainy period. The higher number of *S. neuwiedi* individuals collected during the dry season may be explained in the same way, since vitellogenesis of this species starts in the dry season (Laporta-Ferreira et al., 1986; Marques, 1998).

Other factors not discussed here (such as predator and parasite seasonality) may also influence the observed activity patterns. Therefore, only a multivariate approach permits a accurate comprehension of this problem. However, no information is available for many of these variables. The results reinforce the need of a single-species approach in snake community analysis (Gibbons and Semlitsch, 1989). Abundance surveys in tropical areas have to be conducted during a given season, allowing robust comparisons between studies and avoiding bias due to the annual rhythms of each species.

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