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DIVERSITY, NATURAL HISTORY, AND DISTRIBUTION OF SNAKES IN THE MUNICIPALITY OF SÃO PAULO

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ABSTRACT. Information on snake assemblages in Brazilian biomes has increased in the last decade. However, detailed studies on snake composition and natural history in urban fragments have never been conducted. The municipality of São Paulo has 150,900 ha and only 16% of forested areas, distributed in small and scattered fragments. Throughout 44 months of sampling, we registered in this municipality 38 snake species belonging to five families. Terrestrial frog-eater species were predominant. The number of recorded snakes was higher during the rainy season. Annual seasonality in captures might be related to prey availability and reproductive cycles. The most abundant species was *Oxyrhopus guibei*, with 24% of dominance, followed by *Sibynomorphus mikanii* (21%), and *Bothrops jararaca* (16%). Three species, *Philodryas patagoniensis*, *Tomodon dorsatus*, and *Liotyphlops beui*, were also common; six others were of intermediate abundance; and 23 were considered rare. Historically, the municipality of São Paulo showed a mosaic of different vegetational physiognomies. Nowadays, despite being fragmented due to the urban growth, these fragmented formations still enclose together a high richness of snake species.

KEY-WORDS. snakes, diversity, natural history, distribution, municipality of São Paulo.

INTRODUCTION

Natural history studies are fundamental for many areas of biology, including ecology, evolutionary biology, and conservation (Greene and Losos, 1988; Hillis, 1995). Natural history focuses on organisms, where they are, and what they do in their environments, including interactions among them (Greene, 1994).

Detailed studies in recent decades with species from southeastern Brazil (e.g., Jordão, 1996; Marques, 1992, 1996a,b, 1998; Oliveira, 2001; Sazima, 1992; Hartmann and Marques, 2005; Marques and Puorto, 1991, 1994; Pizzatto and Marques, 2002; Bizerra, *et al.* 2005; Laporta-Ferreira *et al.*, 1986; Marques, *et al.* 2000, 2004, 2006; Martins, *et al.* 2002; Outeiral *et al.*, 2003) have improved our knowledge about the natural history of neotropical snakes, but much of the basic information on many species is still fragmented and/or limited.

The use of preserved snakes housed in scientific collections has enabled us to acquire data on feeding, reproduction, and body shape, helping to improve our knowledge about the natural history of some species (e.g., Marques, 1998; Oliveira, 2001; Sawaya 2004; Nogueira *et al.*, 2003; Marques *et al.*, 2006; Sawaya *et al.* 2008).

Feeding and reproduction have been widely studied among snakes (e.g., Mushinsky, 1987; Seigel and Ford, 1987; Marques, 1998), providing important information for systematics, ethology, and evolutionary ecology (Stearns, 1992), as well as being related to morphological, behavioral, physiological, and phylogenetic aspects (Pough and Groves, 1983; Vitt and Vangilder, 1983; Martins, 1994; Martins *et al.*, 2001). Snakes show a great diversity of feeding habits (Mushinsky, 1987; Greene, 1997). In addition to many groups of invertebrates, they may also feed on vertebrates, including fish, amphibians, amphisbaenians, lizards, snakes, birds, and mammals (Greene, 1997). The reproductive traits of snakes are closely related to their feeding habits, since reproductive success depends on the energy reserves obtained from food intake (Stearns, 1992).

Snakes in tropical areas are more difficult to characterize with regard to their reproductive seasonality (Fitch, 1970, 1982) which is to some extent due to the complexity of tropical climates (Greene, 1997). Although temperatures fluctuate less in tropical regions than in temperate areas, some regions may have one or more cycles of dry and rainy seasons. Altitudinal differences also have noticeable effects on the climate of nearby locations (Greene, 1997).

With the exception of studies directed exclusively to the examination of snake communities in Brazil (*e.g.*, Amazon: Martins, 1994; Caatinga: Vitt and Vangilder, 1983; Campos Sulinos: Cechin, 1999; Cerrado: Sawaya, 2004, Sawaya *et al.*, 2008; Atlantic Rainforest: Marques, 1998, Hartmann *et al.*, 2009a, b; Araucaria Forest: Di-Bernardo, 1998; Pantanal: Strüssmann and Sazima, 1993), there are no detailed

studies on snake communities in urban forest fragments. For the municipality of São Paulo, the knowledge on the snake fauna begins with a list of 26 species received at Instituto Butantan between 1989 and 1990 (Puerto, *et al.* 1991). Later, Barbo (2008b) discusses the current conservation status of reptiles in the city, emphasizing the importance of conservation of the remaining native areas. Marques *et al.* (2009) present

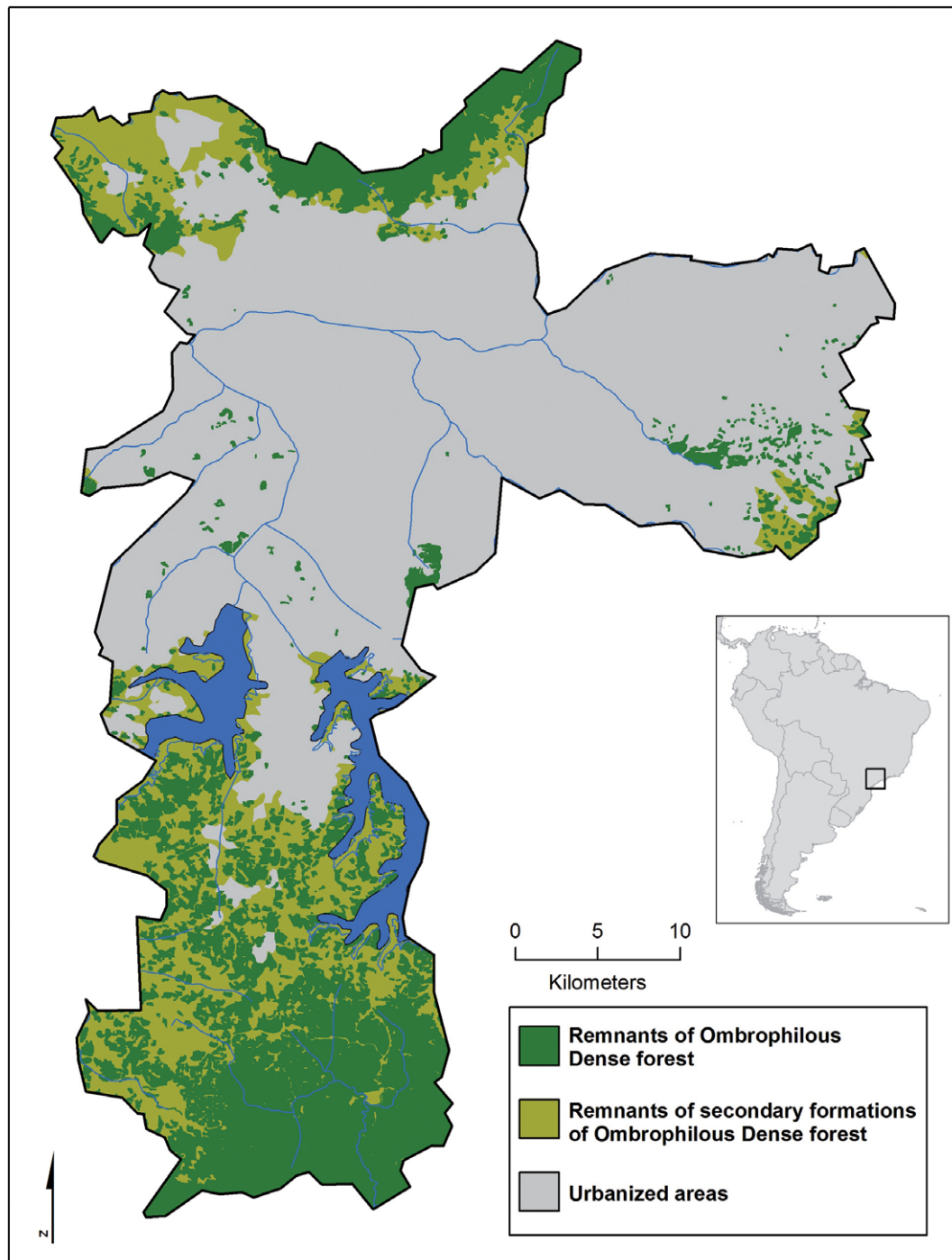


FIGURE 1. Map of Municipality of São Paulo (MSP), highlighting the remnants of dense rainforest in green and olive, the urbanized areas in grey, and main rivers and dams in blue.

a historical survey of reptiles found in the city, which includes a total of 68 species, half of which seems to have disappeared due to urban growth. Herein we present detailed information on natural history, diversity, and geographic distribution of snakes from municipality of São Paulo, based on snakes obtained along 44 months from 2003 to 2007.

MATERIAL AND METHODS

Study Area

The municipality of São Paulo (hereafter MSP) has a total area of 150,900 ha. Of these, 87,522 ha (58%) have been urbanized and altered, and are inhabited by approximately 10 million people (Prefeitura do Município de São Paulo, 2002). Among the total area of the city, only 16.36% (24,687 ha) are occupied by forested areas, of which 10.24% (15,452 ha) are found in urban areas and 6.1% (9,204 ha) in rural areas (Silva, 1993). These numbers reflect the scarcity of remaining forested areas and the decreasing of rural areas that may significantly affects the biodiversity of the municipality.

Currently, the city of São Paulo has fragments of secondary vegetation, which have resisted the process of urban sprawl. Native forest stands are confined within the limits of the municipality: to the south, mainly in Curucutu area, Serra do Mar State Park, the Capivari-Monos Area of Environmental Protection (AEP), on Bororé peninsula on the right margin of the Guarapiranga Reservoir, where dense ombrophilous forest and cloud forest formations remain, as well as open fields and floodplains; to the north, in the Jaragua and Cantareira State Parks, and the Municipal Park of Anhanguera, montane ombrophilous forests and high altitude fields still persist (Prefeitura do Município de São Paulo, 2002); and in the extreme east of the municipality there are still remnants corresponding to the Areas of Environmental Protection of Carmo and Iguatemi (Fig. 1).

The Fontes do Ipiranga State Park is notable for being completely surrounded by urban areas and is an island of vegetation with formations characteristic of dense ombrophilous forest, seasonal forest, and cerrado (Prefeitura do Município de São Paulo, 2002).

Two seasons can be observed throughout the year. A dry season between April and September and a rainy season between October and March (Fig. 2A). In the sampling period, between August 2003 and March 2007, during the dry season, the monthly rainfall ranged between 2.7 mm and 141.2 mm, the

minimum temperature between 6.9°C and 13.7°C and the maximum between 26°C and 35.3°C. During the rainy season, the monthly rainfall varied from 31 mm to 193 mm, the minimum temperature between 6.2°C and 18.3°C and the maximum temperature between 30.7°C and 35.3°C (Fig. 2B).

Data Collection

Our sample included the records of all snakes recorded in MSP brought each day to the Instituto Butantan, São Paulo, Brazil, mostly by lay people, throughout 44 months between August 2003 and March 2007 (Fig. 3).

To characterize the natural history of the species, we obtained information on body size, substrate use, daily and seasonal activity, diet, and reproduction. For each freshly killed specimen the following data was taken: snout-vent length (SVL) and tail length (TL) to the nearest millimeter (with rigid ruler), mass to the nearest gram (with spring scales), sex, gut contents (prey items measured and weighed when intact or little digested.), diameter of largest ovarian follicle or presence of oviductal embryos (with calipers, 0.01 mm, cf. Shine, 1977). Number of follicles in secondary vitellogenesis (fully grown follicles), or eggs/embryos in the oviducts were recorded (cf. Shine, 1977, Marques *et al.*, 2006). Occasional data of birth/hatching of young (recruitment) were also recorded. Information on substrate use and daily activity were also obtained from data available in the literature, by the authors and other researchers.

Data Analysis

The seasonal activity pattern of each species was inferred from the number of snakes brought each month to the Instituto Butantan (see Marques *et al.* 2000). We inferred the seasonal activity pattern only for the most abundant species ($N > 50$ individuals).

The species were also categorized regarding their abundance relative to the total number of recorded individuals of all species (Fig. 4). Species with 114 to 413 individuals recorded (or 6.5 to 24% of the total number of individuals) were considered “dominant”; between 74 and 115 individuals (or 4.2 to 6.6%) were considered “common”; between 28 and 58 individuals (or 1.6 to 3.3%) were considered “of intermediate abundance”; and those between one and 17 individuals (or less than 1%) were considered “rare”.

Taxonomic comments

We used the taxonomic arrangement of Zaher *et al.* (2009) for the major groups, considering the observation of Forlani *et al.* (2010) on the priority of

Erythrolamprus over *Liophis*. For the viperids, we used the taxonomic proposal of Wüster *et al.* (2002), keeping the genus *Bothrops* for *B. jararaca*, rather than *Bothropoides* as suggested by Fenwick *et al.* (2009). For the rattlesnakes, the traditional nomenclature was adopted

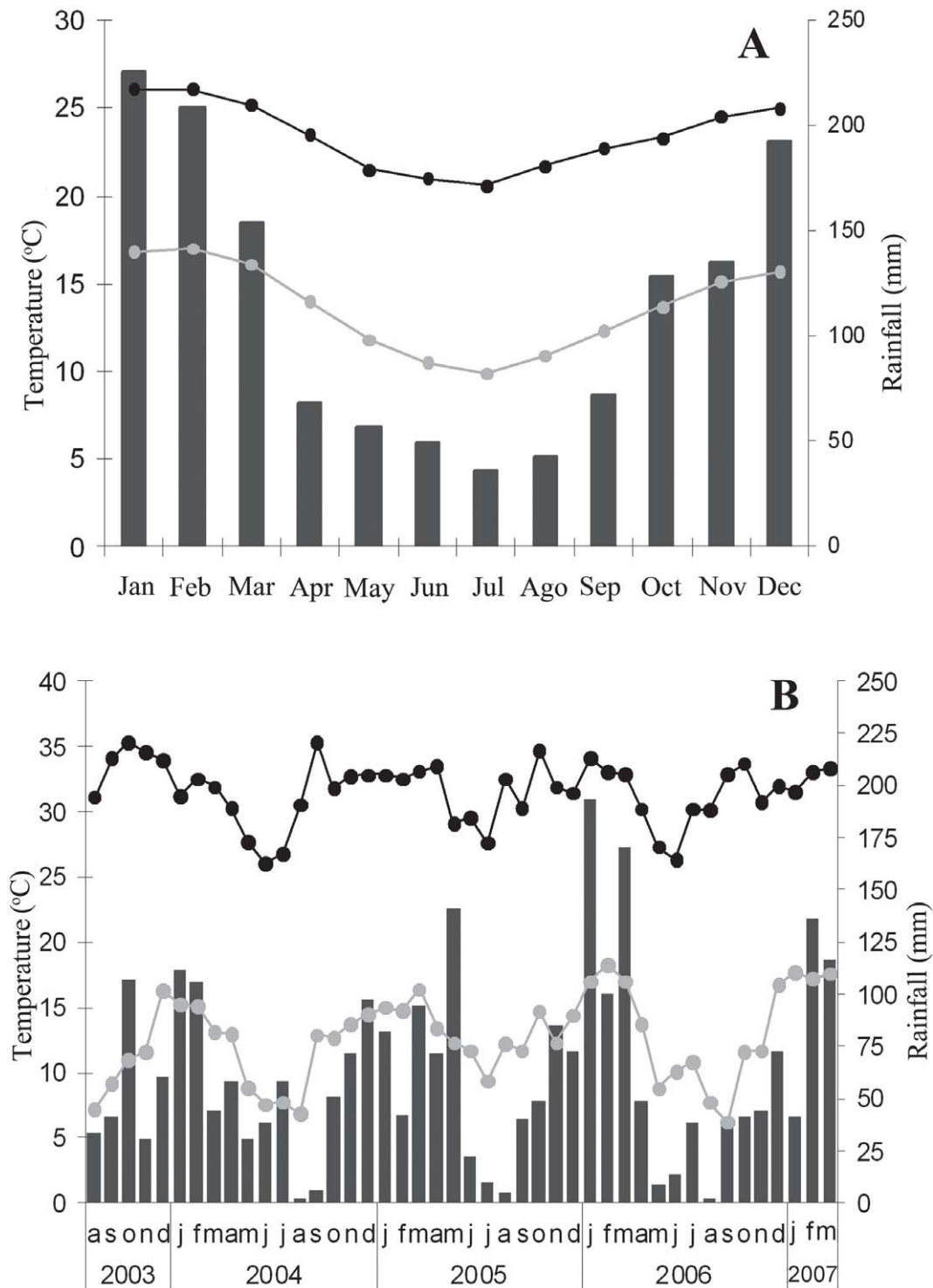


FIGURE 2. A. Historical averages (1950-2000) of maximum (black line) and minimum temperatures (gray line), and rainfall (bars) in Municipality of São Paulo. B. Monthly rainfall variation (bars), and maximum monthly (black line), and minimum temperatures (gray line), between August 2003 and March 2007.

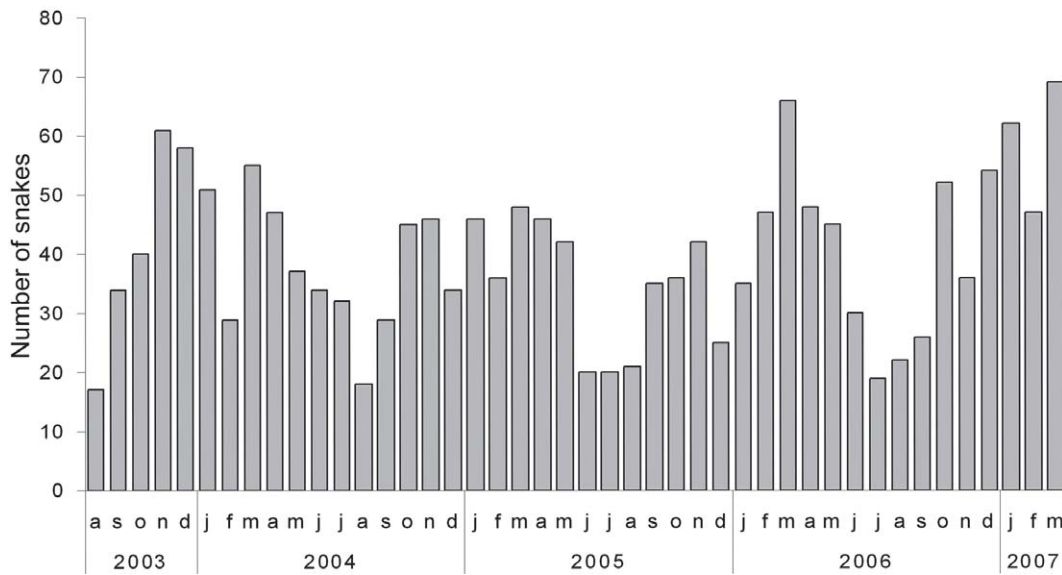


FIGURE 3. Seasonal abundance of juvenile and adult snakes from MSP received at Instituto Butantan between August 2003 and March 2007.

(*Crotalus*), as suggested by Wüster and Bérnills (2011), rather than *Caudisona* as suggested by Hoser (2009).

RESULTS

Species Composition

Between August 2003 and March 2007, we recorded 1741 snakes, distributed among six families, 23 genera, and 38 species (Table 1). During the 44 sampling months there was a peak in abundance during the rainy season, usually between October and March (Fig. 3).

Natural History

Family Anomalepididae Taylor, 1939

Liotyphlops beui (Amaral, 1924), “Pale-headed Blindsnake”, (Fig. 5.1)

A common species in the MSP (N = 74), it was recorded in the north, central and western regions (Fig. 6.1). This burrowing snake is nocturnal (Parpinelli and Marques, 2008) and feeds on larvae and pupae of ants, especially of the genus *Solenopsis* sp. (Parpinelli, 2008).

Pale-headed blindsnakes are oviparous. One female (SVL = 280 mm), received in September, contained seven eggs in its oviduct, the largest reaching 8.3 mm. Another female (SVL = 314 mm), received in late October, had four vitellogenic follicles, the largest reaching 12.8 mm. The specimens were

collected during the rainy season, with peaks in October and March (Fig. 7.1).

Family Tropidophiidae Brongersma, 1951 (1894)

Tropidophis paucisquamis (Müller, 1901), “Brazilian Dwarf-boa” (Fig. 5.2)

A rare species in the MSP (N = 1). The only individual received was found in January in the western regions of the city in a forest fragment of the Lapa neighborhood (Fig. 6.2).

Endemic to the Atlantic Forest, this species seems to be more common in certain localities of the Serra do Mar mountain range (*e.g.*, Carlos Botelho State Park and the Tourist State Park of Alto Ribeira). Due to its small body size (~ 150 mm), arboreal habit and nocturnal activity (Marques *et al.*, 2004, FEB *pers. obs.*), which hinder its encounter in nature, this species has been poorly studied. Field records reported the occurrence of a few individuals found very close to one another, active on nights with high humidity. The diet consists of small frogs and reproduction is viviparous (Carvalho, 1951 A. Mendes, *pers. comm.*).

Family Colubridae Oppel, 1811

Chironius bicarinatus (Wied, 1820), “Two-keeled Whipsnake”, (Fig. 5.3)

A species with intermediate abundance in the MSP (N = 35), recorded throughout the city, but always associated with forest fragments (Fig. 6.3).

This arboreal snake is active during the day and is often found in the Serra do Mar mountain range (Marques *et al.* 2004; FEB *pers. obs.*). Two-keeled Whipsnake feeds on anurans, including hylids (N = 1) and leptodactylids (Marques and Sazima, 2004; Rodrigues, 2007). One individual had insect shells in its intestine which were probably secondary prey items, having been present in the gut of the anurans it had eaten. The reproductive mode is oviparous, and two females (SVL = 864 mm and 967 mm), received in December and January, had six and 10 eggs in their oviducts, the largest measuring 40.5 mm. This species was abundant at the end of the rainy season in March (N = 7), and in May (N = 6).

Chironius exoletus (Linnaeus, 1758), “Common Whipsnake”, (Fig. 5.4)

A rare species in the MSP (N = 1), recorded only in the western regions (Fig. 6.4). This arboreal snake (Marques and Sazima, 2004; Rodrigues, 2007) is active during the day and feeds on anurans (Marques *et al.*, 2004). The species is often found throughout the Serra do Mar mountain range

(Marques *et al.*, 2004), but seems to be more restricted to its slopes.

Spilotes pullatus (Linnaeus, 1758) “Tiger Ratsnake” (Fig. 5.5)

A rare species in the MSP (N = 5), recorded only in the central and western regions (Fig. 6.5). This semi-arboreal snake is active during the day (Marques and Sazima, 2004). Its diet consists of small mammals, birds and lizards (Marques *et al.*, 2004). A specimen from the central region contained traces of a phyllostomid bat in its stomach. The predation of bats has been recorded in 10 species of colubrids (Esbérard and Vrcibradic, 1997), including *Pseustes sulphureus*, a phylogenetically close species (Rufino and Bernardi, 1999). These species forage actively and may inspect into shelters to capture bats. In the city, the shelters can also be trees and ceilings which are not only used by snakes, but also by birds and opossums.

The reproductive mode is viviparous (Hauzman *et al.*, 2005). Two females (SVL = 472 mm and 470 mm), received in August, had seven and four vitellogenic follicles, the largest measuring 49.7 mm.

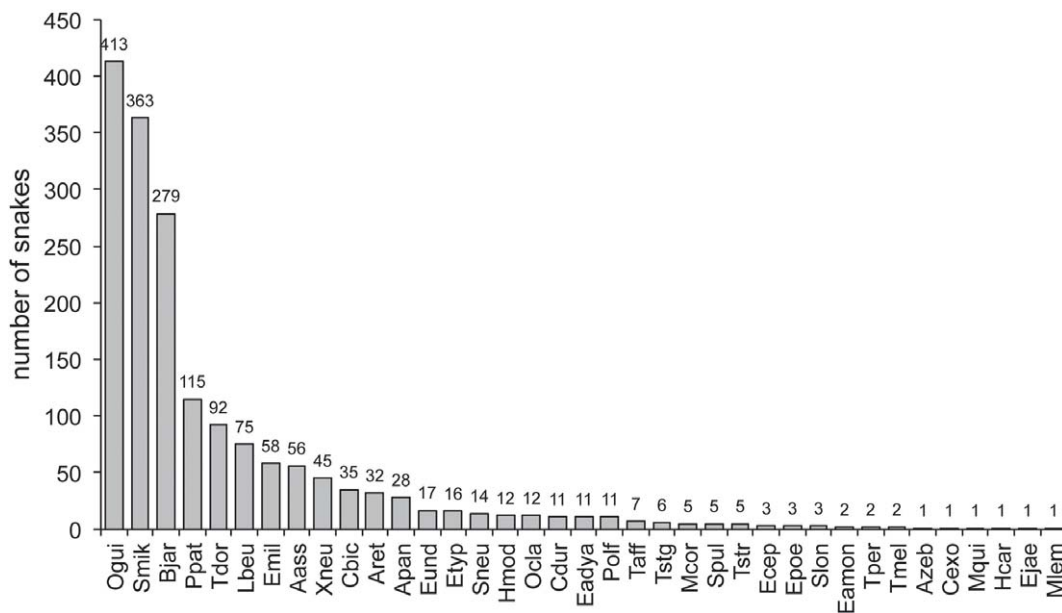


FIGURE 4. Relative abundance of 1741 snakes of Municipality of São Paulo received at Instituto Butantan between August 2003 and March 2007. Number of individuals above bars.

Abbreviations: Aass = *Apostolepis assimilis*; Apan = *Atractus pantostictus*; Aret = *A. reticulatus*; Azeb = *A. zebrinus*; Bjar = *Bothrops jararaca*; Cbic = *Chironius bicarinatus*; Cexo = *C. exoletus*; Cdur = *Crotalus durissus*; Ecep = *Echianthera cephalostriata*; Eund = *E. undulata*; Eamon = *Erythrolamprus aesculapii* (monad pattern); Eadya = *E. aesculapii* (dyad pattern); Ejae = *E. jaegeri*; Emil = *E. miliaris*; Epoe = *E. poecilogyrus*; Etyp = *E. typhlus*; Hcar = *Helicops carinicaudus*; Hmod = *H. modestus*; Lbeu = *Liotyphlops beui*; Mcor = *Micrurus corallinus*; Mlem = *M. lemniscatus*; Mqui = *Mussurana quimi*; Ocla = *Oxyrhopus clathratus*; Ogui = *O. guibei*; Polf = *Philodryas olfersii*; Ppat = *P. patagoniensis*; Slon = *Siphophis longicaudatus*; Smik = *Sibynomorphus mikanii*; Sneu = *S. neuwiedii*; Spul = *Spilotes pullatus*; Taff = *Taeniophallus affinis*; Tper = *T. persimilis*; Tmel = *Tantilla melanocephala*; Tstg = *Thamnodynastes strigatus*; Tdor = *Tomodon dorsatus*; Tpau = *Tropidophis paucisquamis*; Tstr = *Tropidodryas striaticeps*; Xneu = *Xenodon neuwiedii*.

TABLE 1. Species recorded in Municipality of São Paulo. N = number of individuals.

Família	Espécie	N	%
Anomalepididae	<i>Liotyphlops beui</i> (Amaral, 1924)	74	4,2
Tropidophiidae	<i>Tropidophis paucisquamis</i> (Müller, 1901)	1	0,1
Colubridae	<i>Chironius bicarinatus</i> (Wied, 1820)	35	2,0
	<i>Chironius exoletus</i> (Linnaeus, 1758)	1	0,1
	<i>Spilotes pullatus</i> (Linnaeus, 1758)	5	0,3
	<i>Tantilla</i> cf. <i>melanocephala</i> (Linnaeus, 1758)	2	0,1
Dipsadidae	<i>Apostolepis assimilis</i> (Reinhardt, 1961)	56	3,2
	<i>Atractus pantostictus</i> Fernandes and Puerto, 1993	28	1,6
	<i>Atractus reticulatus</i> (Boulenger, 1885)	32	1,8
	<i>Atractus zebrinus</i> (Jan, 1862)	1	0,1
	<i>Echinanthera cephalostriata</i> Di-Bernardo, 1996	3	0,2
	<i>Echinanthera undulata</i> (Wied, 1824)	17	1,0
	<i>Erythrolamprus aesculapii</i> *	2	0,1
	<i>Erythrolamprus aesculapii</i> **	11	0,6
	<i>Erythrolamprus jaegeri</i> (Günther, 1858)	1	0,1
	<i>Erythrolamprus miliaris</i> (Linnaeus, 1758)	58	3,3
	<i>Erythrolamprus poecilogyrus</i> (Wied, 1824)	3	0,2
	<i>Erythrolamprus typhlus</i> (Linnaeus, 1758)	16	0,9
	<i>Helicops carinicaudus</i> (Wied, 1825)	1	0,1
	<i>Helicops modestus</i> Günther, 1861	12	0,7
	<i>Mussurana quimi</i> (Franco, Marques and Puerto, 1997)	1	0,1
	<i>Oxyrhopus clathratus</i> Duméril, Bibron and Duméril, 1854	12	0,7
	<i>Oxyrhopus guibei</i> Hoge and Romano, 1977	413	23,7
	<i>Philodryas olfersii</i> (Lichtenstein, 1823)	11	0,6
	<i>Philodryas patagoniensis</i> (Girard, 1857)	114	6,5
	<i>Sibynomorphus mikanii</i> (Schlegel, 1837)	362	20,8
	<i>Sibynomorphus neuwiedi</i> (Ihering, 1911)	14	0,8
	<i>Siphlophis longicaudatus</i> (Andersson, 1907)	2	0,1
	<i>Taeniophallus affinis</i> (Günther, 1858)	7	0,4
	<i>Taeniophallus persimilis</i> (Cope, 1869)	2	0,1
	<i>Thamnodynastes strigatus</i> (Günther, 1858)	6	0,3
	<i>Tomodon dorsatus</i> Duméril, Bibron and Duméril, 1854	92	5,3
	<i>Tropidodryas striaticeps</i> (Cope, 1869)	5	0,3
	<i>Xenodon neuwiedii</i> (Günther, 1863)	44	2,5
Elapidae	<i>Micrurus corallinus</i> (Merrem, 1820)	5	0,3
	<i>Micrurus lemniscatus</i> (Linnaeus, 1758)	1	0,1
Viperidae	<i>Bothrops jararaca</i> (Wied, 1824)	279	16
	<i>Crotalus durissus terrificus</i> Laurenti, 1768	11	0,6

*monad pattern

**dyad pattern

Tantilla cf. *melanocephala* (Linnaeus, 1758)
“Crowned-snake” (Fig. 5.6)

A rare species in the MSP (N = 2), recorded only in the northern region of the city (Fig. 6.6). This cryptozoic snake is active at night (Marques and Puerto, 1998), and feeds on centipedes, especially *Otostigmus* sp. (Scolopendridae) (Puerto and Marques, 1998).

The reproductive mode is oviparous. The reproductive cycles is seasonal with vitellogenesis from the beginning to the middle of the rainy season (Puerto

and Marques, 1998). A female (SVL = 267 mm) received in November contained three vitellogenic follicles, the largest measuring 11 mm.

Family Dipsadidae Bonaparte, 1838

Apostolepis assimilis (Reinhardt, 1872), “False Coralsnake” (Fig. 5.7)

A species of intermediate abundance in the MSP (N = 56) recorded in the north, east and western regions (Fig. 6.7). This fossorial and cryptozoic snake



FIGURES 5.1-5.8. Snakes received at Instituto Butantan between August 2003 and March 2007. 5.1. *Liotyphlops beui*; 5.2. *Tropidophis paucisquamis*; 5.3. *Chironius bicarinatus*; 5.4. *C. exoletus*; 5.5. *Spilotes pullatus*; 5.6. *Tantilla melanocephala*; 5.7. *Apostolepis assimilis*; 5.8. *Atractus pantostictus*. Photo 5.1: Antonio C. O. R. da Costa.



FIGURE 5.9-5.16. (Continued) Snakes received at Instituto Butantan between August 2003 and March 2007. 5.9. *Atractus reticulatus*; 5.10. *A. zebrinus*; 5.11. *Echinanthera cephalostriata*; 5.12. *E. undulata*; 5.13. *Erythrolamprus aesculapii* (monad pattern); 5.14. *E. aesculapii* (dyad pattern); 5.15. *E. jaegeri*; 5.16. *E. miliaris*.



FIGURE 5.17-5.24. (Continued) Snakes received at Instituto Butantan between August 2003 and March 2007. 5.17. *Erythrolamprus poecilogyrus* (adult); 5.18. *E. poecilogyrus* (juvenile); 5.19. *E. typhlus* (adult); 5.20. *E. typhlus* (juvenile); 5.21. *Helicops carinicaudus*; 5.22. *H. modestus*; 5.23. *Mussurana quimi*; 5.24. *Oxyrhopus clathratus*. Photo 5.23: Giuseppe Puerto.



FIGURE 5.25-5.32. (Continued) Snakes received at Instituto Butantan between August 2003 and March 2007. 5.25. *Oxyrhopus guibei*; 5.26. *Philodryas olfersii*; 5.27. *P. patagoniensis*; 5.28. *Sibynomorphus mikanii*; 5.29. *S. neuwiedi*; 5.30. *Siphlophis longicaudatus*; 5.31. *Taeniophallus affinis*; 5.32. *T. persimilis*. Photo 5.32: Claudio Zamprogno



FIGURE 5.33-5.40. (Continued) Snakes received at Instituto Butantan between August 2003 and March 2007. 5.33. *Thamnodynastes strigatus*; 5.34. *Tomodon dorsatus*; 5.35. *Tropidodryas striaticeps*; 5.36. *Xenodon neuwiedii*; 5.37. *Micrurus corallinus*; 5.38. *M. lemniscatus*; 5.39. *Bothrops jararaca*; 5.40. *Crotalus durissus terrificus*. Photo 5.33: Ivan Sazima.

(Ferrarezzi, 1993; Ferrarezzi, *et al.*, 2005) apparently is active during the day and at night and feeds on amphibia and other elongate fossorial reptiles (Savitzky, 1979; Ferrarezzi *et al.*, 2005). In the stomachs of two specimens of *A. assimilis* we found a whole individual of *Liotyphlops beui*. In one of them, the prey had a SVL of 215 mm, equivalent to 96% of its length and 133% of its mass.

The reproductive mode is oviparous. Two females (SVL = 518 mm and 645 mm) found in November and March had four and six vitellogenic secondary follicles, measuring 12.4 mm and 30.9 mm, respectively. The seasonal abundance was bimodal with peaks in December (N = 11) and March (N = 13) (Fig. 7.2).

Atractus pantostictus Fernandes and Puorto, 1993, “Speckled Earthsnake” (Fig. 5.8)

A species of intermediate abundance in the MSP (N = 28), distributed in the northern, western and central regions (Fig. 6.8), in open areas and forests. This fossorial and cryptozoic snake is active at night (Sawaya *et al.*, 2008), and feeds on earthworms (N = 2) (Marques *et al.*, 2004, Sawaya *et al.*, 2008, FEB *pers. obs.*).

The reproductive mode is oviparous. Three females (SVL = 365 mm, 320 mm and 363 mm) contained three eggs each, with diameters ranging from 28.7 to 32.9 mm, respectively. Another individual (SVL = 374 mm) had four eggs, the largest reaching 31.4 mm. The peak of abundance was during the early rainy season in November (N = 4) and December (N = 3).

Atractus reticulatus (Boulenger, 1885), “Reticulate Earthsnake”, (Fig. 5.9)

A species of intermediate abundance in the MSP (N = 32), distributed in the eastern, central and southwestern regions (Fig. 6.9). Like the previous species, it has fossorial and cryptozoic habits, nocturnal activity and feeds on earthworms (Marques *et al.*, 2004). Two individuals contained fragments of earthworms in their guts.

Two females (SVL = 314 mm and 364 mm), received in November and December, contained three eggs in each oviduct, the largest reaching 39.5 mm, while another female (SVL = 278 mm) received in January, had only one egg with a diameter of 49.3 mm. A peak of abundance was observed during the rainy season between October and March (N = 22).

Atractus zebrinus (Jan, 1862), “Zebrine Earthsnake”, (Fig. 5.10)

A rare species in the MSP (N = 1). The only individual recorded was collected in a forest, in the extreme southern region of the city (Curucutu, Fig. 6.10), close to the altitude grasslands (L. Malagoli, *pers. comm.*). It is probably cryptozoic and fossorial, nocturnal and feeds on earthworms, similar to the two previous species (Marques *et al.*, 2004).

Echinanthera cephalostriata Di-Bernardo, 1996, “Line-headed Forest Racer” (Fig. 5.11)

A rare species in the MSP (N = 3) recorded in forests in the extreme northern (Cantareira State Park) and southern (Curucutu) parts and also in the central region (Jardim João XXIII) (Fig. 6.11). It is probably a cryptozoic and diurnal snake (Marques *et al.*, 2004, FEB *pers. obs.*) which feeds on small anurans (Marques *et al.*, 2004). The reproductive mode is oviparous (Marques *et al.*, 2004), but no information on reproduction was obtained during this study.

Echinanthera undulata (Wied, 1824), “Undulated Forest Racer” (Fig. 5.12)

A rare species in the MSP (N = 17), recorded in the forests of the northern and central regions (Fig. 6.12). It is probably a cryptozoic and diurnal snake, which feed on small anurans (N = 2) (Marques *et al.*, 2004). An individual had insect remains in its gut, probably a secondary item of an anuran. The reproductive mode is oviparous. A female (SVL = 465 mm) received in January had five vitellogenic follicles, the largest with 18 mm. Individuals from the collection of the Instituto Butantan had vitellogenic follicles between October and December, and eggs in the oviducts between September and January, indicating that this species has a seasonal reproductive cycle and recruitment of young occurs during the rainy season (Marques, 1998). The highest abundance was recorded during the rainy season between October and March (N = 13).

Erythrolamprus aesculapii (Linnaeus, 1766), “Southern Mock False Coralsnake”

Two color patterns, until recently treated as subspecies, are found in the MSP. Curcio (2008) states that the two subspecies may be recognized as a single

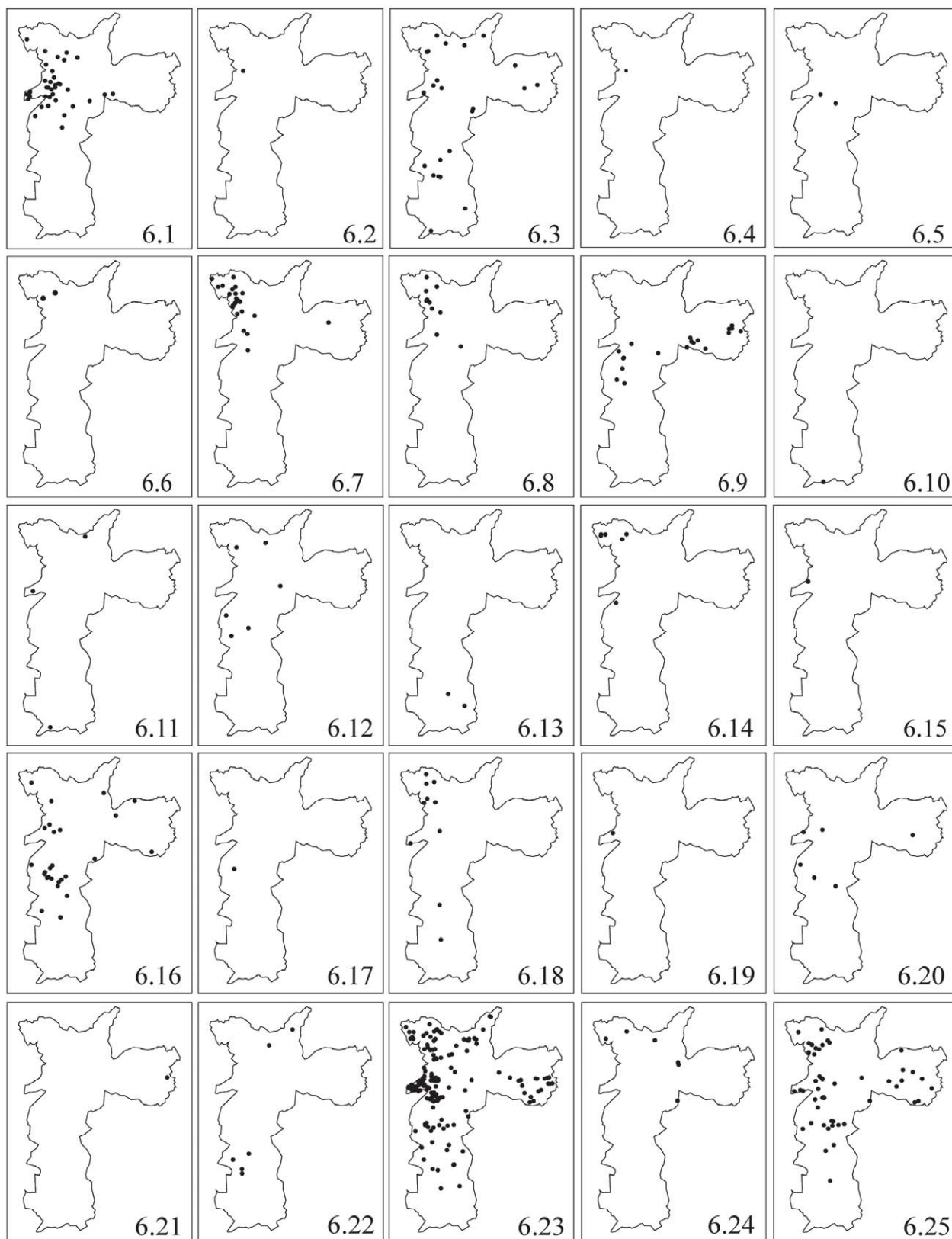


FIGURE 6.1-6.25. Geographic distribution records of species received at Instituto Butantan between August 2003 and March 2007 from Municipality of São Paulo: 6.1. *Liotyphlops beui*; 6.2. *Tropidophis paucisquamis*; 6.3. *Chironius bicarinatus*; 6.4. *C. exoletus*; 6.5. *Spilotes pullatus*; 6.6. *Tantilla cf. melanocephala*; 6.7. *Apostolepis assimilis*; 6.8. *Atractus pantostictus*; 6.9. *A. reticulatus*; 6.10. *A. zebrinus*; 6.11. *Echinanthera cephalostriata*; 6.12. *E. undulata*; 6.13. *Erythrolamprus aesculapii* (monad pattern); 6.14. *E. aesculapii* (dyad pattern); 6.15. *E. jaegeri*; 6.16. *E. miliaris*; 6.17. *E. poecilogyrus*; 6.18. *E. typhlus*; 6.19. *Helicops carinicaudus*; 6.20. *H. modestus*; 6.21. *Musurana quimi*; 6.22. *Oxyrhopus clathratus*; 6.23. *O. guibei*; 6.24. *Philodryas olfersii*; 6.25. *P. patagoniensis*.

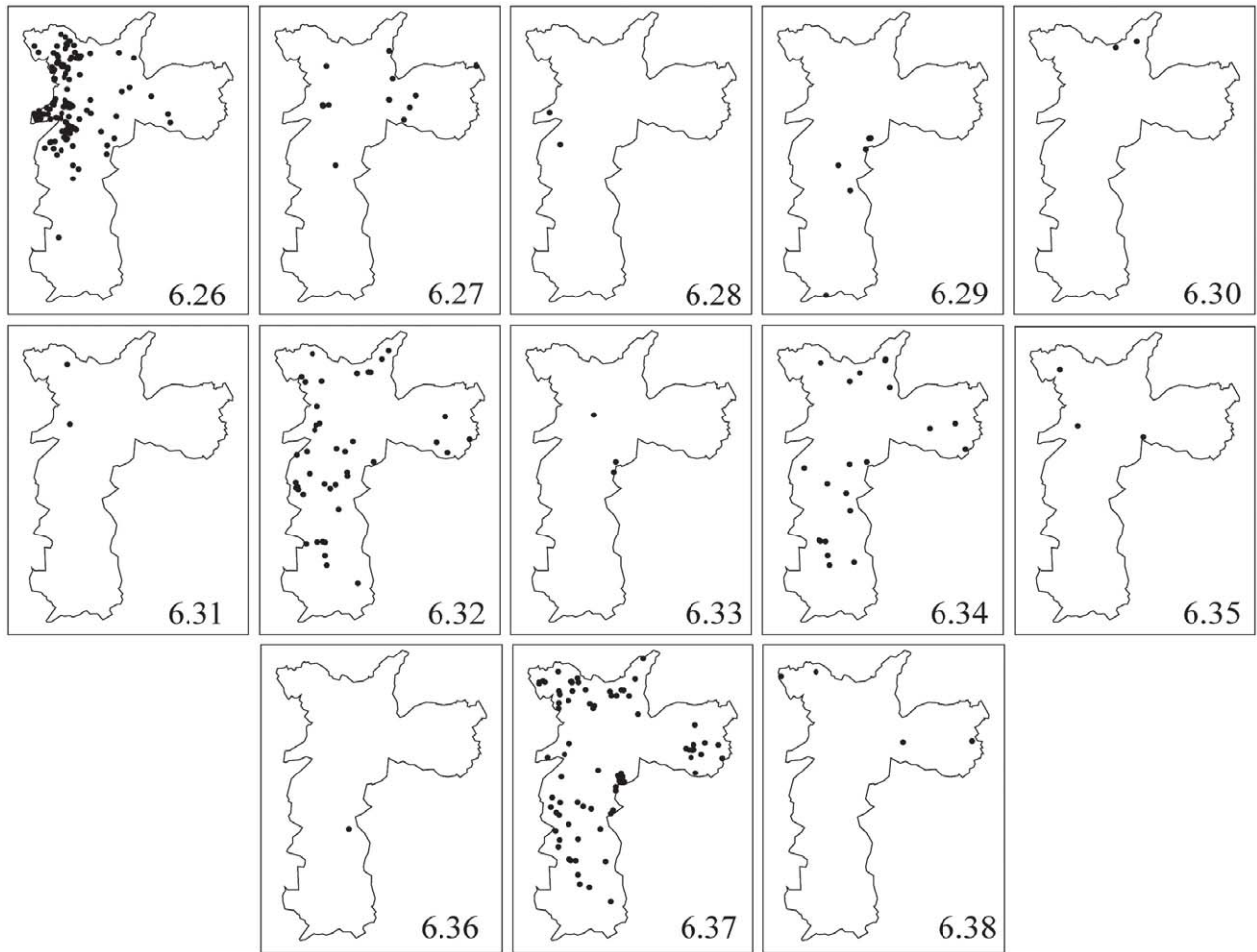


FIGURE 6.26-6.38. (Continued) Geographic distribution records of species received at Instituto Butantan between August 2003 and March 2007 from Municipality of São Paulo: 6.26. *Sibynomorphus mikanii*; 6.27. *S. neuwiedi*; 6.28. *Siphlophis longicaudatus*; 6.29. *Taeniophallus affinis*; 6.30. *T. persimilis*; 6.31. *Thamnodynastes strigatus*; 6.32. *Tomodon dorsatus*; 6.33. *Tropidodryas striaticeps*; 6.34. *Xenodon neuwiedii*; 6.35. *Micrurus corallinus*; 6.36. *M. lemniscatus*; 6.37. *Bothrops jararaca*; 6.38. *Crotalus durissus terrificus*.

species, but one has not yet been described and the other one has problems related to nomenclatural priority. To avoid misunderstandings and also the dissemination of unpublished taxonomic data, both forms were treated separately based only on color pattern.

Monad pattern (Fig. 5.13)

This pattern has broad red rings separated by a black ring flanked by two narrow white rings. This black ring may eventually also have a central white ring (Fig. 5.13), which may or may not be complete dorsally.

This form is rare in the MSP (N = 2). This terrestrial snake is active during the day, and feed upon snakes; juveniles also feed on small gymnophthalmid lizards (Marques and Puerto, 1994). An individual had colubrid or dipsadid scales in its gut.

The reproductive mode is oviparous, but no information on its reproduction was obtained during this study. The reproductive cycle is continuous (Marques, 1996a). A female, found dead on a trail in the Serra do Mar range in Cubatão, in June 2002, contained five eggs (FEB *pers. obs.*).

The only two distribution records are from the southern region (Fig. 6.13), connected to the Serra do Mar range, where it occurs in sympatry with *Micrurus corallinus*, which appears to be its mimetic model (Puerto and Marques, 1991).

Dyad pattern (Fig. 5.14)

Individuals with a pattern of rings arranged in dyads belong to a species that have not yet been described (Curcio, 2008). The red rings are narrower compared to those seen in monad patterns, and are contiguous with the black rings on both sides. The

black rings are always separated by a narrow white ring.

It was rare in the MSP (N = 11), recorded in the north and west of the city (Fig. 6.14). Similar to the species with the monad patterns, this species is terrestrial, diurnal and feed upon snakes (Marques and Puerto, 1994). One individual contained the remains of a *Sibynomorphus mikanii* in the gut, and another had unidentified colubrid scales.

The reproductive mode is oviparous. Two females, received in September and October, had five and three follicles in secondary vitellogenesis, the largest reaching 30.4 mm and 14.5 mm, respectively. Both specimens had vitellogenic follicles at the beginning of the rainy season, indicating that the reproduction is continuous (Marques, 1996a).

Erythrolamprus jaegeri (Günther, 1858), “Jaeger’s Smoothsnake” (Fig. 5.15)

A rare species in the MSP (N = 1). This terrestrial snake is active during the day and feeds on small anurans (Dixon, 1989).

The reproductive mode is oviparous. The specimen recorded in the MSP is a juvenile (SVL = 204 mm), collected in May, near a small remnant of forest (Fig. 6.15). This species was very abundant in the MSP in the 1950s and 1960s, when it was often found in wetlands adjacent to the Pinheiros River (J. Cavalheiro, *pers. comm.*). Outside MSP, it is rare in areas of preserved Cerrado associated with gallery forests (Sawaya *et al.*, 2008).

Erythrolamprus miliaris (Linnaeus, 1758), “Water Smoothsnake” (Fig. 5.16)

A common species in the MSP (N = 58), distributed in the northern, eastern and western regions, but mostly in the southern region (Fig. 6.16), close to reservoirs.

This semi-aquatic snake is active during the day and at night (Marques *et al.*, 2004). In two dissected specimens, an anuran and a fish were recorded, and in four other specimens insect remains were recorded, probably secondary items from amphibians. The reproductive mode is oviparous. A female (SVL = 905 mm) collected in December had 20 vitellogenic follicles, the largest measuring 17.8 mm. The species shows continuous reproduction in the northern portions of its range (Vitt and Vangilder, 1983), but in southeast Brazil (São Paulo) its reproduction is seasonal (Pizzatto and Marques, 2006).

It was more abundant during January (N = 9), February (N = 11) and March (N = 21) (Fig. 7.3). The recruitment of young occurred late in the rainy season.

Erythrolamprus poecilogyrus (Wied, 1824), “Ground Smooth Snake” (Figs. 5.17 and 5.18)

A rare species in the MSP (N = 3), recorded in the southwest region of the city (Fig. 6.17).

This terrestrial snake is active during the day and at night (Marques *et al.* 2004; Sawaya *et al.*, 2008) and feeds upon anurans (Dixon, 1989, Sawaya *et al.*, 2008).

The reproductive mode is oviparous. One female (SVL = 536 mm) collected in October contained eight eggs in the oviduct, the largest measuring 25.8 mm. Another female (SVL = 580 mm), collected in November, had three vitellogenic follicles, the largest measuring 20.7 mm.

Erythrolamprus typhlus (Linnaeus, 1758), “Green Smoothsnake” (Figs. 5.19 and 5.20)

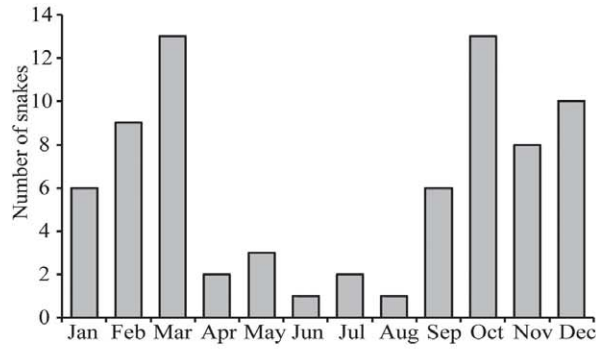
A rare species in the MSP (N = 16), recorded in the north, west and south of the city (Fig. 6.18).

This terrestrial snake is active during the day and feeds upon anurans (Marques *et al.*, 2004). One individual had anuran legs (*Rhinella* sp.) in its gut. Another individual had insect remains in the gut, probably secondary items from an amphibian. *Rhinella* sp. is found in approximately 50% of the food items of *L. typhlus* (E. Cinaqui-Filho, *pers. comm.*).

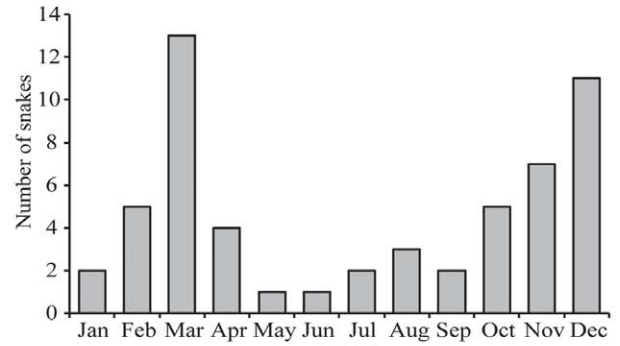
The reproductive mode is oviparous. A female collected in December (SVL = 790 mm) had seven vitellogenic follicles, the largest measuring 33.7 mm. Two other females collected in January (SVL = 535 mm and 674 mm) had four and seven vitellogenic follicles, the largest measuring 15.3 mm and 20.9 mm, respectively. A female collected in June (SVL = 595 mm) had eight vitellogenic follicles, the largest measuring 14.2 mm. These data suggest that the reproductive cycle of females is continuous in the southeast region, with a predominance of breeding females in summer and autumn.

Helicops carinicaudus (Wied, 1825), “Rough-tailed Watersnake” (Fig. 5.21)

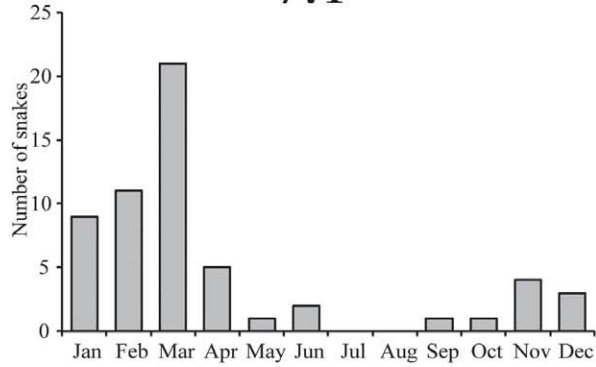
A rare species in the MSP (N = 1), recorded in the western region (Fig. 6.19). This aquatic snake is active during the day and at night (Marques,



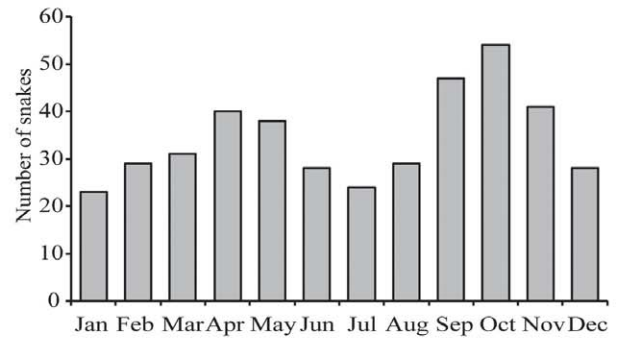
7.1



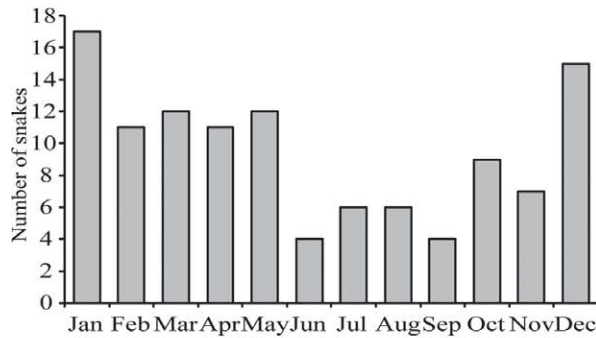
7.2



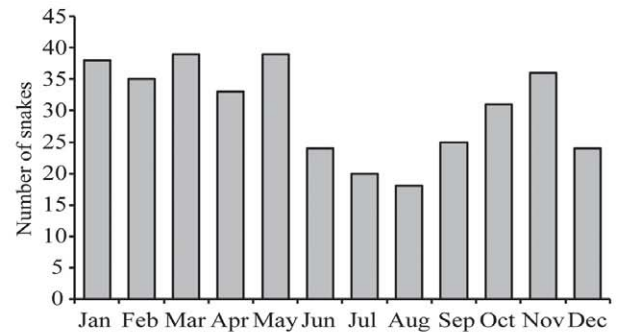
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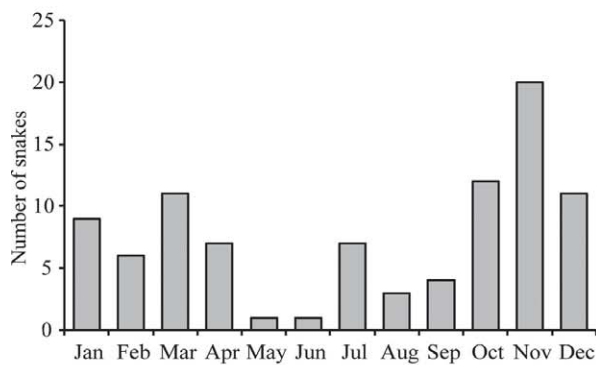
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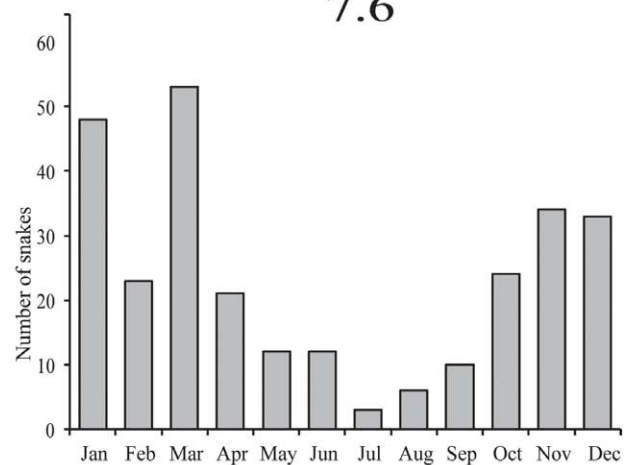
7.5



7.6



7.7



7.8

FIGURE 7.017.08. Seasonal abundance of most abundant species (> 50 specimens) received at Instituto Butantan between August 2003 and March 2007. 7.1. *Liotyphlops beui*; 7.2. *Apostolepis assimilis*; 7.3. *Erythrolamprus miliaris*; 7.4. *Oxyrhopus guibei*; 7.5. *Philodryas patagoniensis*; 7.6. *Sibynomorphus mikanii*; 7.7. *Tomodon dorsatus*; 7.8. *Bothrops jararaca*.

1998, Marques *et al.*, 2004, Scartozzoni, 2005). It is often found along the Serra do Mar range (Marques *et al.*, 2004). Analysis of preserved specimens from southeastern Brazil showed the presence of fish and amphibians in the gut (Scartozzoni, 2010).

The reproductive mode is viviparous. Analysis of several preserved specimens from southeastern Brazil shows that reproduction is seasonal with vitellogenesis occurring from September to December, embryos from November to March and recruitment from the end of the rainy season to the beginning of the dry season (Scartozzoni, 2010).

Helicops modestus Günther, 1861, “Common Water-snake” (Fig. 5.22)

A rare species in the MSP (N = 13) reported in some neighborhoods with green areas in the west, east and south (Fig. 6.20), probably due to the presence of water bodies. In cerrado areas, this species has been recorded on the edges of gallery forests and water bodies (Sawaya *et al.*, 2008). Similar to *H. carinicaudus*, it is an aquatic snake with both diurnal and nocturnal activity (Marques, 1998).

The diet consists of fish and occasionally small anurans (Scartozzoni, 2010). The reproductive mode is viviparous and one female gave birth to 20 young in March (FEB *pers. obs.*). The reproductive cycle is similar to that of *H. carinicaudus*, with seasonal reproduction, vitellogenesis occurring from September to December, embryos from November to March and recruitment from the end of the rainy season to the beginning of the dry season (Scartozzoni, 2010).

Mussurana quimi (Franco, Marques and Puerto, 1997), “Quim’s Mussurana” (Fig. 5.23)

A rare species in the MSP (N = 1), recorded at the extreme east of the city, in an area where there are still large forest remnants (Fig. 6.21). This terrestrial snake is active at night, and feeds on mammals, lizards and snakes (Franco *et al.*, 1997).

Oxyrhopus clathratus Duméril, Bibron and Duméril, 1854, “Atlantic Calico Coralsnake” (Fig. 5.24).

A rare species in the MSP (N = 12) recorded in the north and south of the city (Fig. 6.22).

This terrestrial snake is active at night (Marques *et al.*, 2004). Adults feed on rodents whereas juveniles

feed on lizards (Marques and Sazima, 2004, FEB *pers. obs.*). The reproductive mode is oviparous.

Oxyrhopus guibei Hoge and Romano, 1977, “Common False Coralsnake” (Fig. 5.25)

This is the dominant species in the MSP (N = 413), it is widespread in the city (except in the deepest forests of the southern region of the city), especially in highly urbanized areas, even those with little or no vegetation cover (Fig. 6.23).

This terrestrial snake is active at night (Sazima and Abe, 1991). However, some collectors have found individuals supposedly active during the day (N = 18). Juveniles feed upon lizards whereas adults feed upon rodents (Andrade and Silvano, 1996). Of the 413 individuals analyzed, 47 (11.4%) contained prey in the gut. Of these, 13 (27.6%) contained whole or vestiges of rodents in the stomach, 23 (49%) contained rodent hair in the intestine, six (12.7%) contained geckos (*Hemidactylus mabouia*) in the stomach, one contained fragments of insects in the intestine, probably secondary food content, one contained the tail of an unidentified lizard, and three contained scales of a lizard (*Ophiodes* sp.).

The reproductive mode is oviparous and, based on a sample of 53 females, vitellogenic follicles or eggs occurred in several months of the year, suggesting that the species has a continuous reproductive cycle in São Paulo, as reported for the southeast of Brazil (Pizzatto and Marques, 2002). We observed two abundance peaks throughout the year, the first in April (N = 40) and May (N = 38) and the other at the beginning of the rainy season in September (N = 47), October (N = 54) and November (N = 71) (Fig. 7.4).

Philodryas olfersii (Lichtenstein, 1823), “Eastern Green Whiptail” (Fig. 5.26)

A rare species in the MSP (N = 11), recorded in the central and northern regions of the city (Fig. 6.24). This semi-arboreal snake is active during the day, feeds on small vertebrates such as rodents, lizards, amphibians and birds (Hartmann and Marques, 2005). Two specimens had rodent hair in the gut.

It is an oviparous species. Three females (SVL = 885 mm, 788 mm and 1020 mm) received in September, October and January contained between seven and 11 vitellogenic follicles, the largest measuring 30 mm. A female received in November contained seven eggs in the oviduct, the largest measuring 50 mm.

Philodryas patagoniensis (Girard, 1857) “Patagonian Whiptail” (Fig. 5.27)

A common species (N = 114), recorded throughout MSP except in the more forested extremes to the north and south of the city (Fig. 6.25). This terrestrial snake is active during the day, feeds on mammals, anurans, small lizards, birds and eventually snakes (Hartmann and Marques, 2005).

Of the total of 114 specimens received, 12 (~10%) had prey in the gut. One individual contained two rodents in the stomach, five had rodent hair in their intestines and one contained the tail of the gecko *Hemidactylus mabouia*. Three individuals contained anurans: *Leptodactylus marmoratus* (N = 1), *Physalaemus* sp. (N = 1), and an unidentified species, in addition to insect remains in their intestines. Two specimens ingested snakes (one had the tail of the snake *Sibynomorphus mikanii* in the stomach and the other contained a juvenile *Oxyrhopus guibei*).

The reproductive mode is oviparous. Thirteen females contained vitellogenic follicles with diameters ranging from 5.4 mm to 32 mm. One female collected in November had six eggs in the oviduct, the largest measuring 44 mm. Two other females received in December had 13 and 14 eggs in the oviduct, the largest measuring 40.5 mm. One female had 11 vitellogenic follicles, as well as eggs, the largest measuring 5.4 mm. It was most abundant in December (N = 15) and January (N = 17), as well as at the end of the rainy season (February and March) and at the beginning of the dry season (April and May) (Fig. 7.5).

Sibynomorphus mikanii (Schlegel, 1837) “Western Slug-eater” (Fig. 5.28)

This was the second most abundant species (N = 362) and, except for the deepest forests to the south of the city, it occurred in all regions of the MSP, especially in the western and northern regions (Fig. 6.26). This terrestrial snake is active at night (Oliveira, 2001). However, some collectors have found individuals supposedly active during the day (N = 25). This snake feeds on Veronicellidae slugs (N = 36). Due to the low caloric value and the rapid digestion of this type of prey, this snake can eat many slugs in a short period of time. Two specimens had more than one slug in the gut.

The reproductive mode is oviparous (Oliveira, 2001). Forty-two females contained vitellogenic

follicles and 15 contained eggs in the oviduct. The species was abundant throughout the year (Fig. 7.6). Mating of this species was observed at the end of rainy season (C. Rojas, *pers. comm.*).

Sibynomorphus neuwiedi (Ihering, 1911) “Eastern Slug-eater” (Fig. 5.29)

A rare species in the MSP (N = 14), recorded mainly in the west, north and east of the city (Fig. 6.27). This semi-arboreal snake is active at night and feeds on slugs (N = 2) (Oliveira, 2001).

The reproductive mode is oviparous. A female (SVL = 602 mm) collected in October contained five vitellogenic follicles, the largest measuring 31 mm. Another female (SVL = 705 mm), received in March, contained nine eggs in the oviduct, the largest measuring 29 mm.

Siphlophis longicaudatus (Andersson, 1907) “Long-tailed Treesnake” (Fig. 5.30)

A rare species (N = 3), recorded in the western region of the city (Fig. 6.28), associated with areas of preserved vegetation. This arboreal snake is active at night, and feeds on lizards (Prudente *et al.*, 1998, Marques *et al.*, 2004).

The reproductive mode is oviparous, but no information was obtained about its reproduction in the MSP.

Taeniophallus affinis (Günther, 1858) “Black-Headed Forest Racer” (Fig. 5.31)

A rare species (N = 7), recorded in the southern region of the MSP (Fig. 6.29). Apparently, it is a cryptozoic and diurnal snake (Marques *et al.* 2004; FEB *pers. obs.*). The diet consists of small anurans and lizards (Marques *et al.*, 2004, Zacariotti and Gomes, 2010).

An individual collected at Parque Estadual das Fontes do Ipiranga had an amphisbaenian (*Amphisbaena dubia*) in the gut (Barbo and Marques, 2003; Barbo and Sawaya, 2008). In southern Brazil, two specimens of this species were found with amphisbaenians (*Amphisbaena mertensi*) in the gut (E. Sanches, *pers. comm.*), indicating that this species has a cryptozoic habit.

The reproductive mode is oviparous (Marques *et al.*, 2004), but no information was recorded about its reproduction in the MSP.

Taeniophallus persimilis (Cope, 1868) “Brown Forest Racer” (Fig. 5.32)

A rare species in the MSP (N = 2). It was recorded in the north, on the edge of the forest of the Cantareira State Park (Fig. 6.30). Their habits are similar to the previous species (Marques *et al.*, 2004). The diet consists of small anurans and lizards (Marques *et al.*, 2004, Zacariotti and Gomes, 2010).

The reproductive mode is oviparous (Marques *et al.*, 2004), but no information about its reproduction was recorded for the MSP.

Thamnodynastes strigatus (Günther, 1858) “Common Frog-eater” (Fig. 5.33)

A rare species (N = 6), recorded in the northern and western regions of the city (Fig. 6.31). This snake is terrestrial, but also uses vegetation to rest (Bernarde *et al.* 2000a). It is active at night and feeds on anurans, small mammals, fish and lizards (Bernarde *et al.* 2000a,b). No data were obtained on the diet of this species in the MSP.

The reproductive mode is viviparous. A female (SVL = 571 mm) collected in February, had 15 vitellogenic follicles, the largest measuring 14.4 mm. Another female (SVL = 598 mm) received in November had 24 embryos in the oviducts, the largest measuring 23.3 mm.

Tomodon dorsatus Duméril, Bibron and Duméril, 1854 “Slug-eating Mockviper” (Fig. 5.34)

A common species in the MSP (N = 92), recorded in all regions (Fig. 6.32). This terrestrial snake is active during the day and feeds on slugs (N = 2) (Marques *et al.* 2004, Bizerra *et al.*, 2005, FEB *pers. obs.*).

The reproductive mode is viviparous. A female received in October (SVL = 412 mm) contained one vitellogenic follicle with a diameter of 10.5 mm. Two other females (SVL = 474 mm and 530 mm), received in December, had 10 vitellogenic follicles each, the largest measuring 17.7 mm. Two females received in January (SVL = 551 mm and 514 mm) contained 11 and 14 vitellogenic follicles, the largest measuring 18.1 mm.

Births occurred in June (N = 1, 11 offspring), January (N = 2, 13 and 14 offspring), February (N = 2, 12 and 17 offspring) and March (N = 4, 10, 13, 13 and 14 offspring). This species was most abundant in October (N = 12), November (N = 20), December (N = 11) and March (N = 11) (Fig. 7.7).

Tropidodryas striaticeps (Cope, 1869) “Highland Tail-luring Snake” (Fig. 5.35)

A rare species in the MSP (N = 5), recorded in forested areas of the southern and central regions (Fig. 6.33). This semi-arboreal snake is active during the day (Sazima and Puerto, 1993). Juveniles feed upon small lizards whereas adults feed upon mammals (Sazima and Puerto, 1993, Marques 1998, Marques *et al.*, 2004, Stender-Oliveira, 2008).

No information was obtained about its reproductive biology, but specimens preserved in collections from southeastern Brazil show that this species is oviparous with seasonal reproduction. Vitellogenesis occurs during the rainy season and births in the beginning of the dry season (Stender-Oliveira, 2008).

Xenodon newwiedii (Günther, 1863) “Forest False Pitvipers” (Fig. 5.36)

A common species in the MSP (N = 44), recorded in all regions except the central and western ones (Fig. 6.34). This terrestrial snake is active during the day, and feeds on anurans, especially the family Bufonidae (Jordan, 1996). Of the 11 food contents analyzed, four were remains of anurans and seven were fragments of insects, probably secondary items from amphibians.

The reproductive mode is oviparous. A female received in June (SVL = 652 mm) contained 12 vitellogenic follicles, the largest measuring 23.8 mm. Two females received in October and November (SVL = 640 mm and 479 mm, respectively) contained nine and eight vitellogenic follicles, the largest measuring 27.5 mm. Three other individuals received in February, March and April (SVL = 823 mm, 632 mm and 625 mm) contained eight, three and six vitellogenic follicles, respectively, the largest measuring 27 mm. These data confirm the continuous reproduction of the species (Jordão, 1996, Marques 1998).

Family Elapidae Boie, 1827

Micrurus corallinus (Merrem, 1820) “Atlantic Coral-snake” (Fig. 5.37)

A rare species in the MSP (N = 5), found only in areas with forest remnants located in the north, west and east (Fig. 6.35). Despite being very common in the forests of the Serra do Mar range, no record was obtained for the forested areas in the south of the city during the sampling period. This semi-fossorial snake is predominantly active during the day, and feeds

on elongate vertebrates, especially amphisbaenians and caecilians, and occasionally snakes and lizards (Marques *et al.*, 2004, Marques and Sazima, 1997).

No data were obtained on the reproduction of the species in the MSP. However, in coastal populations vitellogenic follicles occur in September and December, and births in March and April (Marques, 1996b).

Micrurus lemniscatus (Linnaeus, 1758) “South American Coralsnake” (Fig. 5.38)

A rare species in the MSP (N = 1), recorded in the south of the city in a forest area near the Billings reservoir (Fig. 6.36). This semi-burrowing snake is active during the day and at night, and feeds on elongate vertebrates, but may include elongated fish (*e.g.*, *Synbranchus* spp.) (Cunha and Nascimento, 1978, 1982, Sazima and Abe, 1991), indicating that it can forage in water bodies.

Family Viperidae Laurenti, 1768

Bothrops jararaca (Wied, 1824), “Jararaca Lance-head” (Fig. 5.39)

The third most abundant species in the MSP (N = 279), recorded in the forest remnants in all regions of the municipality, except in the central region. Very common in forest parks in the city, such as Parque do Estado and Parque do Carmo (Fig. 6.37). This pitviper is predominantly terrestrial and nocturnal (Sazima, 1992; Marques *et al.*, 2004). Juveniles are frequently found on vegetation. A few specimens were collected while active during the day (N = 11). Juveniles feed upon ectothermic prey such as small anurans and lizards whereas adults feed upon rodents (Martins *et al.*, 2002). Of the total analyzed, 54 had gut contents, including rodents (76%), the gecko *Hemidactylus mabouia* (11%) and amphibians (0.5%), as well as insect remains in 11% of the specimens, probably secondary contents from amphibians.

The reproductive mode is viviparous. Vitellogenic follicles were recorded in almost all months of the year, with diameters ranging from 5.2 mm to 38.6 mm. The presence of fully-developed embryos was recorded between October and March. The number of embryos ranged from 11 and 40 (N = 14). Reproduction is seasonal and births occur at the end of the rainy season (Almeida-Santos and Solomon, 2002). This snake was more abundant during the rainy season in November (N = 34), December (N = 31), January (N = 31) and March (N = 48) (Fig. 7.8)

Crotalus durissus terrificus Laurenti, 1768, “Neotropical Rattlesnake” (Fig. 5.40)

A rare species in the MSP (N = 11), recorded in the north and east, always associated with open areas (Fig. 6.38). This terrestrial snake is active at night, despite having been recorded in activity during the day by Sawaya *et al.* (2008). The diet consists of rodents (N = 1, FEB *pers. obs.*).

The reproductive mode is viviparous. Two females received in August and December contained 13 and nine vitellogenic follicles, the largest measuring 34.2 mm. Reproduction is seasonal and births occur at the end of the rainy season (Almeida-Santos and Orsi, 2002).

This pitviper is typical of the cerrado, and in recent years it has been found more frequently in the MSP. One hypothesis for this fact is the dispersion through corridors of deforestation occurring in the surrounding towns, as suggested by Bastos *et al.* (2005) for Rio de Janeiro. The high rate of deforestation due to urbanization, coupled with the abundance of rodents in the city, probably facilitated the colonization of this species in areas where it did not previously occur.

Summary of Information on Natural History

The terrestrial habit was the most common (53%), whereas fossorial and cryptozoic habits accounted for 18% of the species, semi-arboreal for 13%, arboreal for 8%, aquatic for 5%, and fossorial habits for 3%.

Of the 38 recorded species of snakes, 39% feed exclusively or predominantly on anurans, 21% on mammals, and 21% on invertebrates (earthworms, molluscs, and arthropods), as well as snakes and amphisbaenas (11%), fish (5%), and lizards (3%).

DISCUSSION

Currently, at least 38 species of snakes occur in the municipality of São Paulo. This corresponds to slightly more than half (56%) of the 68 species which have been recorded historically, in the last 100 years (Marques *et al.*, 2009; see discussion below).

The seasonal abundance of snakes, as observed in other assemblages, peaked during the rainy season, which in this case corresponded to the period from October to March. Abiotic factors such as humidity and temperature (Lillywhite, 1987, Marques *et al.*, 2000, Sawaya, 2004) and biotic factors such as reproduction

(Gibbons and Semlitsch, 1987, Marques *et al.*, 2004, Sawaya, 2004) are important determinants for the activity of snakes. Low temperatures may decrease metabolism and consequently the activity of the snakes (Marques *et al.*, 2004, Sawaya, 2004, Sawaya *et al.*, 2008). From April to September there is a significant drop in temperature in the municipality of São Paulo, which may be one of the factors responsible for the decrease in activity during these periods (Lillywhite, 1987, Marques *et al.* 2004).

Another factor related to the seasonal abundance of snakes is the incorporation of new individuals into the population through juvenile recruitment (Henderson *et al.* 1978, Marques *et al.*, 2004, Sawaya *et al.*, 2008). For most species, juvenile recruitment occurs during the rainy season, between October and March. The birth of amphibians and lizards, important prey for about 40% of the sampled species of snakes, also occurs during the rainy season.

The ability to thrive in a wide variety of environmental condition, the predominance of nocturnal habits and the diet consisting of invertebrates or rodents (both abundant in urban areas) may be considered as relevant factors that influence the relatively high abundance of six species, apparently common in the urban environment (cf. Puerto *et al.*, 1991). The two most common species in São Paulo (*Oxyrhopus guibei* and *Sibynomorphus mikanii*) are nocturnal. *Oxyrhopus guibei* feeds on rodents as well as lizards, including the house gecko (*Hemidactylus mabouia*). This gecko is an important item in diet of *O. guibei*, as shown by the contents of the specimens analyzed in this study. *Sibynomorphus mikanii* feeds on Veronicellidae slugs (Pizzatto and Marques, 2002; Oliveira, 2001, this study), abundant in disturbed environments (Thomé *et al.*, 1999). Moreover, these two snakes can occur in various habitats, including the interior and edges of forests, open areas, disturbed areas, and even cultivated areas (Sazima and Abe, 1991, Sawaya *et al.*, 2008, FEB and OAVM *pers. obs.*). Both species are widely distributed in the more urbanized areas of the city, and can even be found in vacant lots. Thus, these two dipsadid snakes can be considered as synanthropic species.

Bothrops jararaca, the third most common species in the MSP, is also nocturnal and feeds on frogs, lizards, and rodents (Martins *et al.* 2002; Sazima, 1992). It was always associated with forest fragments (e.g., Parque do Estado and Cantareira; Barbo, 2008a,b).

Philodryas patagoniensis and *Tomodon dorsatus* are diurnal. The former has a generalist diet, feeding on frogs, small lizards, birds, and rodents (Hartmann

and Marques, 2005), and the latter has a specialized diet, feeding exclusively on slugs (Bizerra *et al.*, 2005). Both species are terrestrial. *Tomodon dorsatus* is associated with forested areas, whereas *P. patagoniensis* occurs predominantly in open areas (cf. Bizerra, 1998, Hartmann and Marques, 2005).

The availability of prey may be an important factor influencing the abundance of the five species above. The proliferation of rodents is certainly associated with the excessive production of waste in the city. In addition, many of the snakes' ectothermic prey feed on urban arthropods and the populations of these invertebrates are favored by waste production. Species such as *Physalaemus* spp., *Leptodactylus marmoratus*, and the house gecko *Hemidactylus mabouia* are very efficient in colonizing urban habitats, and they are often found in the digestive tracts of juveniles of *B. jararaca*, *O. guibei* and *P. patagoniensis*. Veronicellidae slugs are synanthropic mollusks (Thomé *et al.*, 1999) with nocturnal habits, and they are very abundant in moist and shady environments, such as home gardens and land with minimal vegetation cover, which almost certainly explains the abundance of *S. mikanii* in the city. This snake species can also perform communal egg-laying, in which several individuals lay eggs almost simultaneously in common nests, presumably ensuring the success of a greater number of youngs (Albuquerque and Ferrarezzi, 2004, Braz *et al.*, 2008).

Liotyphlops beui is active mainly at night (Parpinelli and Marques, 2008) and it is the only snake with a strictly fossorial habit among the common species. The abundance of *L. beui* is probably associated to its diet as this snake feeds on larvae of *Solenopsis* spp. (a very common ant in the city), as well as its time of activity and micro-habitat use (cf. Barbo and Sawaya 2008). Due to its extremely secretive habit, it is possible that this snake is much more common than any of the other five most common species sampled in this study. A study involving other forms of sampling (e.g., use of pitfall traps) could help to clarify the actual abundance of this snake in the MSP.

The low collection effort of most of the specimens brought by residents of the city suggests that the greater abundance of certain species is associated with occasional encounters. Collectors tend to capture more frequently snakes with conspicuous coloration, diurnal activity and terrestrial habits, and which are less prone to escape (cf. Zanella and Cechin, 2006). This may be one of the reasons for the relatively low sample of snakes with arboreal habits (see Marques, 1998). In the same way, the low availability

of arboreal substrates in the city can limit the occurrence of arboreal species. Likewise, the low occurrence of aquatic snakes may also be a result of the low quality of the water in most water bodies (polluted and uninhabitable) within MSP. The few water bodies that could still provide resources for these species are found within the forest reserves and the reservoirs of the southern region, although the groundwater in this region is also polluted and contaminated.

The predominance of terrestrial and frog-eating snakes seems to be determined by historical factors, with a large proportion of species from the South American xenodontine lineage in this assemblage (see Cadle and Greene, 1993). In addition to the historical factors that may have structured this fauna, ecological factors may also be responsible for the observed patterns, such as the environmental heterogeneity of the area, which originally included forest and open physiognomies of Cerrado and Atlantic Forest (Barbo, 2008a, b, Marques *et al.*, 2009).

During the twentieth century, almost all of the forest vegetation in the city was removed or disturbed due to urban growth (Prefeitura do Município de São Paulo, 2002). The same occurred with other phytophysiognomies in the municipality, including remnants of Cerrado and of open fields, such as high altitude grasslands, unique ecosystems that have been poorly studied. The loss of these environments probably caused the disappearance of species that occur in these formations (Sawaya *et al.*, 2008, Marques *et al.*, 2009), explaining in part the apparent decrease in species richness along the last decades.

Despite the extensive process of urbanization of the city, its snake fauna is very diverse. A few species (synanthropic ones) seem to have benefited from this process. However, although quite diverse, the current richness of snake species is half of what is known historically (cf. Marques *et al.*, 2009). This decrease in richness provides evidence for the disappearance of several species, including some that were common a few years ago, due to the loss of natural habitats in the municipality.

RESUMO

As informações disponíveis sobre taxocenoses de serpentes em biomas brasileiros têm aumentado nas últimas décadas, porém estudos detalhados sobre composição e história natural de serpentes em fragmentos urbanos nunca foram realizados. O município de São Paulo possui 150.900 ha e apenas 16% de

áreas verdes, distribuídas em fragmentos pequenos e dispersos. Ao longo de 44 meses de amostragem, registramos 38 espécies de serpentes de cinco famílias em São Paulo. Houve predominância de espécies terrícolas e batracófagas. Um maior número de serpentes foi registrado na estação chuvosa. Essa sazonalidade anual de captura deve estar relacionada à maior disponibilidade de presas e ao ciclo reprodutivo das espécies. A espécie mais abundante foi *Oxyrhopus guibei*, com 24% de dominância, seguida de *Sibynomorphus mikanii* (21%) e *Bothrops jararaca* (16%). Outras três espécies, *Philodryas patagoniensis*, *Tomodon dorsatus* e *Liotyphlops beui*, foram consideradas comuns; seis tiveram abundância intermediária; e 23 foram consideradas raras. Historicamente, a região do município de São Paulo apresentava um mosaico de diferentes fisionomias vegetais. Atualmente, apesar dessas formações encontrarem-se bastante fragmentadas devido ao crescimento urbano, ainda abrigam conjuntamente grande riqueza de espécies de serpentes.

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