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Frugivory and seed dispersal by *Tropidurus torquatus* (Squamata: Tropiduridae) in southern Brazil

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We investigated frugivory of *Tropidurus torquatus* in a rocky outcrop in the Pampa biome, southern Brazil over the course of one year. We quantified the number of seeds consumed, seed germination potential and the distance over which the seeds were dispersed, as observed through the analysis of faeces collected. Fruits of *Chomelia obtusa*, *Ficus luschnathiana* and two species of the genus *Smilax* were consumed, but only the former was effectively dispersed, since passage through the digestive tract did not affect its germination and the lizard deposited the seeds away from the mother plant. We discuss the ecological role of seed dispersal by *T. torquatus* between rocky outcrops.

Key words: Chomelia obtusa, disperser effectiveness, herbivory, seed dispersal

INTRODUCTION

Seed dispersal by animals favours the reproduction and dispersal of plants while providing food for animal species (Jordano, 2000). It is also an important factor in the structuring of plant populations, through its influence on the spatial distribution and trophic structure of species (Yamamoto et al., 2007; Schupp et al., 2010). Furthermore, natural regeneration is strongly dependent upon seed dissemination by animals (Jordano, 2000). Seed dispersal decreases intraspecific competition and herbivory under the mother plant, and increases seed recruitment, germination success and seedling establishment, especially in the case of species that require passing through the digestive tract of animals (Howe & Smallwood, 1982; Willson & Traveset, 2000; Rodríguez-Pérez & Traveset, 2010).

The consumption of fruit and its role for efficient seed dispersal depends on a quantitative component (the number of seeds consumed), as well as a qualitative component (substrate type on which the seeds are deposited, distance from the mother plant and the effect on seed germination of passing through the digestive tract; Schupp, 1993; Traveset, 1998; Jordano et al., 2006). Although birds and mammals are the best known vertebrate seed dispersers, reptiles and amphibians may also perform this function (Iverson, 1985; Silva et al., 1989; Fialho, 1990; Olesen & Valido, 2003). Many reptiles are omnivores, with fruit as a regular part of their diet (Olesen & Valido, 2003, Dutra et al., 2011). Although few lizards are truly herbivorous, their role as seed dispersers has attracted considerable attention since the 1980s (Whitaker, 1987; Olesen & Valido, 2003).

Tropidurus torquatus (Tropiduridae) is a medium-sized lizard that inhabits rocky outcrops in open areas of Brazil, Argentina and Uruguay, including the Cerrado, Caatinga, Atlantic forest, high altitude grasslands and Pampas (Rodrigues, 1987; Arruda et al., 2008). It employs a ‘sit-and-wait’ foraging behaviour, in addition to frugivory and the ability of seed dispersal (Silva & Araújo, 2008). The family Tropiduridae tends to have a generalist diet (Colli et al., 1992). *Tropidurus torquatus* feeds primarily on invertebrates, especially ants and beetles, and also consumes flowers and fruits (Teixeira & Giovanelli, 1999; Fialho et al., 2000; Carvalho et al., 2007).

In open areas used for livestock, such as the Pampa biome, the dispersal of seeds from shrubs and herbaceous species is crucial to plant regeneration. Seed dispersal in open areas is less studied than in forest environments, and zoochory in lizards is poorly investigated in comparison with zoochory in birds and mammals (Iverson, 1985; Traveset, 1998). This study investigated the consumption of fruits by *T. torquatus* and its effectiveness in dispersing seeds in a rocky outcrop in the Pampa biome, southern Brazil.

METHODS

The study area is an open sandstone outcrop approximately one hectare in size, in the middle of an area used for grazing and dominated by shrubs (e.g., *Chomelia obtusa*, *Vassobia breviflora* and *Myrsine*

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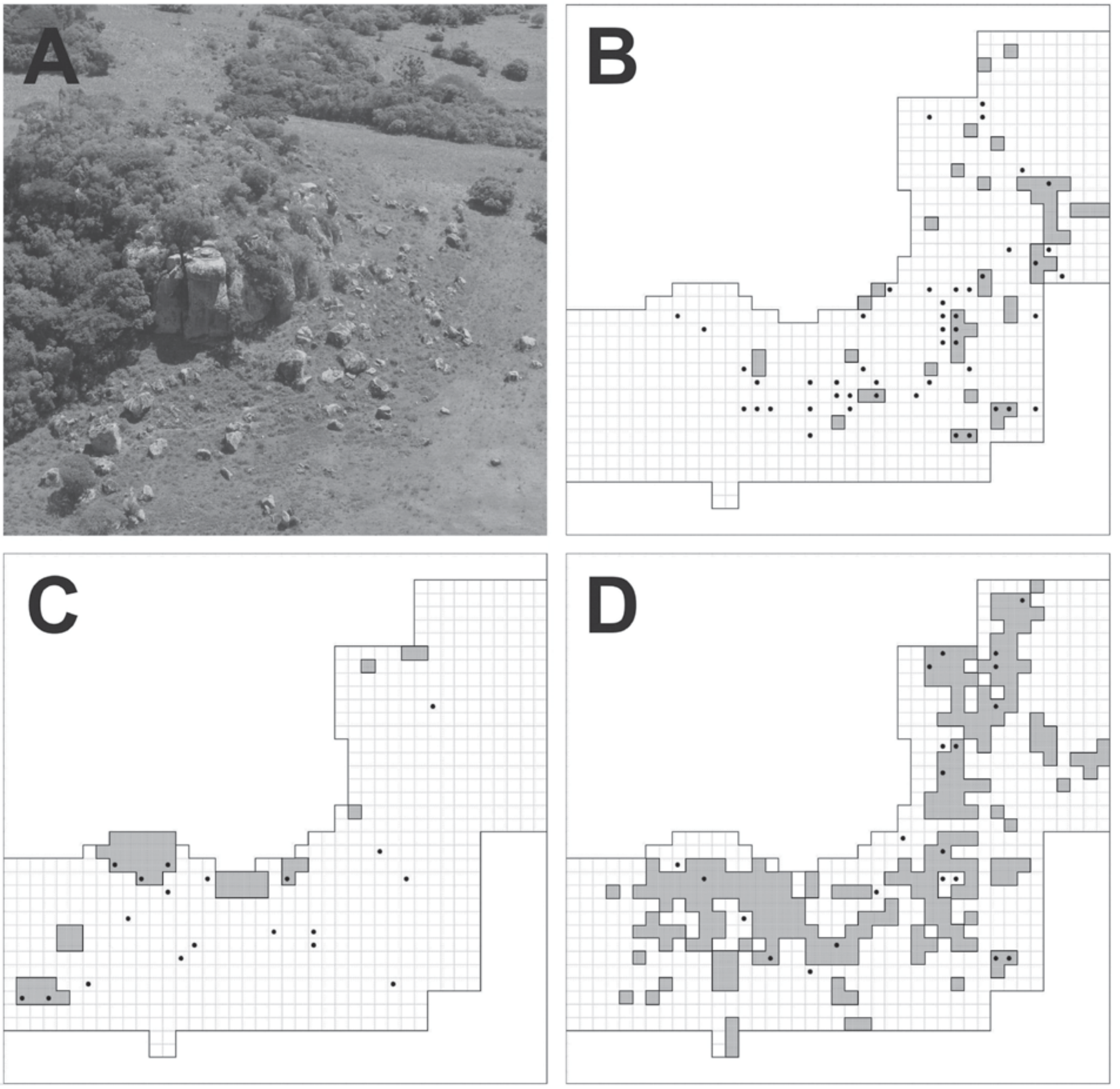

Fig. 1. Study area (A) and location of plant species with fruit consumed by *Tropidurus torquatus* in Pampa Biome, southern Brazil (B: *Chomelia obtusa*, C: *Ficus luschnathiana*, D: *Smilax* spp.); shaded area: coverage of the species, ●: location of faeces with seeds of the species consumed.

umbelata), herbs (e.g., *Solanum* sp. and *Smilax spp.*), cacti (*Cereus* sp. and *Notocactus* sp.), grasses and sparse tree vegetation (e.g., *Ficus luschnathiana*, *Nectandra megapotamica*, *Casearia sylvestris*, *Vitex montevidensis*). Located in the Pampa biome (Santa Maria, Rio Grande do Sul, 29°37'S, 53°52'W), the study site has a humid subtropical climate with rainfall fairly equally distributed throughout the year. The annual mean temperature is 19.2°C, the mean temperature of the coldest month is 13.8°C and the annual precipitation is 1708 mm (Maluf, 2000).

Four other lizard species are also found in the study area: *Teius oculatus* and *Tupinambis merianae* (Teidae), *Cercosaura schreibersii* (Gymnophalmidae) and *Mabuya dorsivittata* (Scincidae). Of these four, only *T. merianae* consumes fruit in a sufficient quantity to be considered a potential seed disperser (Vrcbradic & Rocha, 1995; Cacciali & Bauer, 2003; Castro & Galetti, 2004; Rocha et al., 2004; Cappelari et al., 2007; Caicedo-Portilla et al., 2010). *Tropidurus torquatus* is the only lizard in the study area which uses rocky substrates.

Fruit consumption was verified by analysis of *T. torquatus* faeces collected by hand from the rocks on which the species spend most of their day. Seeds found in faeces were identified by comparison with seeds from fruit collected on site. Field work took place from April 2009 to April 2010. The phenology of plant species was recorded, considering the species producing ripe fruit potentially consumed by lizards (Van der Pijl, 1982; Vasconcellos-Neto et al., 2000). The study area was divided into quadrants (4 x 4 m) and locations of the faeces and plant species were determined based on the quadrant in which they were found (Fig. 1). Minimum seed dispersal distances were calculated by measuring the distance between the quadrant where the seeds were found and the quadrant containing the nearest plant producing such seeds.

Table 1. Number of *Tropidurus torquatus* faeces samples collected for each month (*n*) and % of faeces samples with seeds of each consumed species.

	Chomelia obtusa		*Ficus luschnathiana*		*Smilax* spp.		Nº of faeces samples collected
	n	%	*n*	%	*n*	%	
Apr-09	6	13.64	1	2.27	0	0.00	44
May-09	53	17.85	3	1.01	20	6.73	297
June-09	5	6.49	1	1.30	1	1.30	77
July-09	5	7.46	0	0.00	1	1.49	67
Aug-09	0	0.00	0	0.00	0	0.00	41
Sept-09	0	0.00	0	0.00	0	0.00	60
Oct-09	4	2.07	4	2.07	0	0.00	193
Nov-09	2	4.88	0	0.00	0	0.00	41
Dec-09	0	0.00	1	2.94	0	0.00	34
Jan-10	0	0.00	0	0.00	0	0.00	44
Feb-10	4	14.81	6	22.22	0	0.00	27
Mar-10	25	22.52	5	4.50	1	0.90	111
Apr-10	27	18.88	5	3.50	4	2.80	143
Total	131	11.11	26	2.21	27	2.29	1179

The effect of seed passage through the digestive tract of lizards was analyzed by comparing the germination of seeds collected from faeces and ripe fruit (collected at the same period as those consumed by lizards). All seeds were treated with antiseptic treatment (with 20% hypochlorite for five minutes and 1% antifungal solution for ten minutes), and germination was conducted in Petri dishes under controlled conditions in an incubator at 25°C, 60% relative humidity and photoperiod of 12 hours. Data normality was verified by a Shapiro-Wilk (W) test. The difference in percentage and seed germination between defecated seeds and those extracted from fruits was verified by a Mann–Whitney test.

RESULTS

The species consumed and potentially dispersed by *T. torquatus* were *Chomelia obtusa* Cham. & Schultdl. (Rubiaceae), *Ficus luschnathiana* Miq. (Moraceae) and two species of *Smilax* Linnaeus (Smilacaceae). *Ficus luschnathiana* was available for consumption throughout the sampling period, *C. obtusa* from April–July 2009 and October 2009–April 2010, and *Smilax* spp. from April–July 2009 and January–April 2010.

We collected a total of 1179 faeces samples, of which 184 (15.61%) contained seeds. Only the minimum seed dispersal distance of *Smilax* spp. was smaller than the size of the quadrants, indicating that the seeds may be defecated near the mother plants. For *F. luschnathiana* and *C. obtusa*, the minimum seed dispersal distance was more than four metres (Table 2).

The successful germination of *C. obtusa* and *Smilax* spp. was not affected by passage through the digestive tract, that is, the proportion of germinated seeds and the germination rate of those found in faeces did not differ significantly from seeds taken from fruits (Table 3). Seeds of *F. luschnathiana* that had passed through the digestive system had a reduced germination potential and increased germination time compared to seeds taken directly from fruit (Table 3).

DISCUSSION

Tropidurus torquatus is a 'sit-and-wait' forager, which relies on visual cues to detect its prey, so sight is important for locating fruit (Cooper, 1994). Vasconcellos-Neto et al. (2000) reported that the perception and capture of fruit depends on the level of contrast with

Table 2. Number of seeds per faeces sample and the minimum seed dispersal distance of each plant species consumed by the lizard *Tropidurus torquatus*.

	Mean±SE	Range	*n*
Chomelia obtusa			
Nº seeds per faeces sample	2.737±1.818	1–8	130
Dispersal distance (m)	4.826±5.211	0–26.94	130
Ficus luschnathiana			
Nº seeds per faeces sample	10.961±9.564	2–40	26
Dispersal distance (m)	11.664±12.116	0–46.67	26
Smilax spp.			
Nº seeds per faeces sample	2.333±1.732	1–8	27
Dispersal distance (m)	2.923±4.165	0–20	27

Table 3. Germination test - number of seeds of each plant species tested and effect of passage through the digestive tract of *Tropidurus torquatus* on the germination of the plant species consumed.

	Germination (median)		Mann-Whitney test	
	%	Speed (seed /day)	%	Speed (seed /day)
Smilax spp.			Z(U)=1.071; *P*=0.284	Z(U)=1.703; *P*=0.088
Defecated seeds (70)	62.00	0.033		
Fruit seeds (200)	97.50	0.042		
F. luschnathiana			Z(U)=3.780; *P*=0.0002	Z(U)=4.555; *P*<0.001
Defecated seeds (600)	71.50	0.125		
Fruit seeds (232)	100.00	0.857		
C. obtusa			Z(U)=1.079; *P*=0.280	Z(U)=0.366; *P*=0.714
Defecated seeds (300)	21.50	0.027		
Fruit seeds (310)	18.00	0.029		

the substrate. The species therefore acts as a seed disperser, the effectiveness of which is dependent on the plant species concerned. Following the criteria of Schupp (1993), the lizard consumed a low number of seeds of *Smilax* spp. and *F. luschnathiana*, with less than 5% present in the faeces. Furthermore, in the case of *F. luschnathiana*, the number of seeds per faeces sample was less than the amount present in a fruit. On the other hand, *C. obtusa* was present in approximately 15% of the collected faeces, and is therefore potentially dispersed by *T. torquatus*. Traveset (1998) stated that, in tropical and sub-temperate climates, tree species are more affected by passage through the digestive tract than shrubs, which may explain the difference in the effect between the studied species.

The deposition of the seeds of *C. obtusa* occurs at an average of only about five metres from the original plant. However, this is a short distance which still enables improved germination compared to under the mother plant (Chapman & Chapman, 1995). Seed dispersal to microhabitats preferred by the plant (outcrop areas used by *T. torquatus*) is furthermore advantageous.

The location of seed deposition may further benefit germination. Since *T. torquatus* defecates on rocks, the seeds are deposited in crevices, edges and ground near rocks. As the area is used for grazing, seed dispersal by *T. torquatus* could benefit the regeneration of native vegetation. It may also benefit *T. torquatus* because it creates a more secure environment and serves to attract insects.

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