ELEVATIONAL RANGES AND LOCAL EXTINCTION RISK OF BEETLES OCCURRING IN THE "CAMPOS DE ALTITUDE" IN SOUTHEASTERN BRAZIL

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ABSTRACT

The mountaintops of the Atlantic Rainforest in Southeastern Brazil are dominated by high altitude grasslands, named *Campos de Altitude* (CA). Considering the location and the smaller habitat areas of communities on the mountaintops and the high frequency of endemic species, the assemblages in these habitats are particularly threatened by climate change, and the vulnerability of a species should then be higher if its elevational range is narrow. In this study we aim to describe the elevational range of beetle species occurring in the CA and discuss their vulnerability to local extinction in the context of climate change, also considering their trophic group. We selected beetles in five taxa from three trophic groups in the CA of Serra dos Órgãos National Park (SONP) and Itatiaia National Park (INP): detritivores (Scarabaeidae - INP), herbivores (Chrysomelidae - SONP and INP, and Curculionidae - SONP) and predators (Coccinellidae - SONP, and Lampyridae - SONP). We found different elevational ranges among the studied taxa and among species within each taxon. Herbivores tended to have narrower ranges than the detritivores, and predators were the trophic group with the broadest species range. The relatively high frequency of species with narrow elevational range, particularly within the herbivores, suggests that this entomofauna is particularly endangered due to predicted climate warming and an expected range shift upwards. Considering that many endemic species are expected in the CA and that many undescribed species of insects have been found in this habitat, we may lose many yet unknown species.

Keywords: altitudinal gradient; Atlantic Forest; climate change; Coleoptera; species richness.

INTRODUCTION

Mountain systems are hotspots of biodiversity and endemism (Martinelli 1996, Körner 2002, Martinelli 2007) and occur in all climatic zones of the globe, covering approximately 25% of the planet's surface (Martinelli 2007). Various mountain regions in Brazil are largely degraded or threatened by several factors, including climate change (listed in Martinelli 2007).

Many studies have predicted that climate change will cause mountain species to shift their distribution upslope with concomitant complex changes in assemblage structure (*e.g.* Parmesan 1996, Parkash *et al*. 2013, Menéndez *et al*. 2014). Climate change is predicted to increase temperature in most terrestrial systems, particularly at low and mid-latitude (IPCC 2014). Under this scenario, mountaintop assemblages are

particularly vulnerable: the mountaintops provide a ceiling to further upward movement, whilst the microclimates at the top of the mountain are those most likely to disappear or become smaller in area. The vulnerability of a species should then be higher if its elevational range is narrower. If so, a species living near the top of elevational gradients will face "mountaintop extinction", meaning local extinction if they have disjunct population elsewhere on higher mountains or at cooler latitudes (Colwell *et al*. 2008). Moir *et al*. (2014) reviewed the host-dependent insect groups at greatest risk from extinction through climate change, highlighting that limited environmental tolerances could make it difficult for many insect species to remain *in situ* with global warming.

In the Southeastern Atlantic Rainforest biome in Brazil the mountaintops are dominated by the *Campos de Altitude* (CA) in Serra do Mar and

Serra da Mantiqueira, generally from above 1500 m a.s.l. (Vasconcelos 2011). The CA is set of grass- and shrub-dominated communities which vary according to topography, microclimate and soil resulting in several physiognomies (Vasconcelos 2011). The phytogeographical patterns of the contemporary Brazilian CA are described in Safford (2007). Considering the location of the CA on the mountaintops and the high frequency of endemic species there (*e.g.* Martinelli 1996), the assemblages in these habitats are particularly threatened by climate change, though there are other important threats such as: fire and burning, extraction of attractive floral species, hunting, invasive species and pollution.

In this context we aim to describe the elevational ranges of beetles occurring in the CA and discuss the vulnerability of such species in the context of climate change, also considering their trophic groups.

MATERIAL AND METHODS

Study areas

Serra dos Órgãos National Park (SONP) (22°26'58"S 42°59'07"W) in Rio de Janeiro State, Southeast Brazil, is a mountainous conservation area that ranges from 80 to 2263 m elevation in the Serra do Mar range. It is one of the oldest national parks in the country covering an area of 20,024 ha. The Park encloses four different phytophysiognomies within the domain of the tropical Atlantic Rain Forest: lower montane forest (below 800 m), montane forest (600 to 1500 m), high-montane forest (1500 to 2000 m) and the CA (starting at 2000 m) (Rizzini 1954, Veloso *et al.* 1991). The CA comprises 13.5% of all area at SONP (Cronemberger & Castro 2007). The climate in the region is tropical mesothermic, with a short dry season, mild summers and lower temperature due to the altitude. At 980 m elevation, the mean annual temperature is 17.9°C, the maximum 31°C and the minimum 4.6°C. The mean annual precipitation is 2,842.3 mm, varying from 2,344.4 mm to 3,777.6 mm, with intense rainfall occurring from December to March (climatic data obtained from the National Institute of Meteorology - INMET - for the period of 2007 to 2011).

Itatiaia National Park (INP) (22°27'06"S 44°36'26"W) is located in the Serra da Mantiqueira range, also in southeastern Brazil, presenting around 30,000 ha of area. INP was the first protected area created in Brazil in 1937 and harbors an important Atlantic Forest remnant (Morin 2006). This area presents a large altitudinal variation, ranging from 500 to 2787 m altitude, with the CA above 2000 m, comprising a large extent of the park area, and a dense forest downwards (Silva *et al.* 2009). According to Ururahy *et al.* (1983), the Itatiaia massif has four vegetation types: lower montane forest (below 500 m), montane forest (from 500 to 1500 m), high-montane forest (from 1500 to 2000 m), and the CA (above 2000 m). The climate is tropical mesothermic, with mild summer and rainy season between October and April. Freezing temperatures occur in winter, with some snow events (Tomzhinski *et al*. 2012).

Focal taxa

Beetles (Coleoptera) occupy almost every terrestrial niche and microhabitat and are critical for ecosystem function (Erwin 2004). Besides that, they are the richest group of insects and of animals. So, we selected beetles in five taxa from three trophic groups (*sensu* Marinoni 2001): detritivores (Scarabaeidae), herbivores (Chrysomelidae and Curculionidae) and predators (Coccinelidae and Lampyridae).

All Scarabaeidae species belong to Scarabaeinae and were collected at INP. Most dung beetle species feed on mammalian feces, mostly herbivores and omnivores, but can also feed on other vertebrate and invertebrate feces, dead material and rotting fruits (Gill 1991).

The Chrysomelidae (leaf beetles) studied belong to Eumolpinae and Galerucinae and were collected both at INP and SONP. Species in these two subfamilies have root-feeding larvae and the adults feed on foliage (Jolivet & Hawkeswood 1995). In general the species are polyphagous as larvae and adults feed on hosts from several plant families (Pokon *et al*. 2005).

Curculionidae, Coccinellidae and Lampyridae were collected at SONP. Curculionidae, also known as weevils, are plant feeders, with adults typically found on foliage or flowers, and most

larvae are subterranean or internal feeders (Daly *et al.* 1998). All Coccinellidae species collected belong to Coccidulinae and Scymninae (*sensu* Kovář 1996) and are predaceous (Giorgi *et al.* 2009). The soft-bodied Lampyridae fireflies are predators as larvae, generally feeding in gastropods and other soft-bodied invertebrates, such as earthworms (Branham 2005). Most species are capital breeders, except for the firefly-predators Photurinae (Branham 2005).

Sampling methods

Chrysomelidae (Eumolpinae and Galerucinae), Curculionidae and Coccinelidae were sampled at SONP using yellow sticky traps (Bio Trap®) consisting of a plastic yellow panel (24.5 cm x 10 cm) with adhesive on both sides. A piece of wire was used to attach them to vegetation 1.5 to 2 m above the ground. Seven panels were placed approximately 20 m apart from each other in the vegetation at each of six different elevations, which were chosen facing 90º to the north of the mountain, over an altitudinal gradient of 1,750 m. The first site was located at 350 m in Guapimirim county, and the five latter in Teresópolis county along the *Pedra do Sino* trail: 1280 m, 1480 m, 1680 m, 1880 m, and 2100 m. This last site was located in the CA (22º27'26''S 43º01'24''W). Sampling was conducted every two months from February 2007 to February 2008, resulting in seven sampling months. Placement of new traps, and their retrieval one week later, occurred on a single day and in the same chronological sequence, i.e. the first traps placed were the first to be retrieved. Retrieved panels were placed in plastic containers and separated from each other by small wooden cubes, taken to the laboratory and stored in the freezer. Traps were individually submersed in paint thinner for five minutes to dissolve the glue and insects were carefully removed with a thin brush. This procedure was undertaken in a fume hood with use of a gas mask. All detached material was sifted, washed and stored in 70% ethanol. Adults were separated and counted per morphospecies.

Chrysomelidae (Eumolpinae and Galerucinae) from INP were collected monthly from April 2011 to June 2012 in four different elevations: 800 m, 1000 m, 1750 m and 2450

m. The first two sites were located near the park headquarters and the last two along the main road between *Garganta do Registro* and the *Abrigo Rebouças*. The last site was located in the CA (22º22'20''S 44º42'13''W). In September 2011 and January 2012 there was no sampling due to adverse weather conditions, so there was a total of 13 months of sampling. At each previously selected site the individuals were collected by sweep-netting the vegetation along the main park road using a 38 cm sided triangular sweep-net. Sweeping was synchronized with walking pace and two persons performed sweeping at the same time at both sides of the road, one at each side, for 12 minutes at each elevational site. The same two people were responsible for the sweep-netting in all samples to minimize variability due to collector effect. After 12 minutes, we flicked the sweep-net to knock the insects to the bottom of the net, keeping the opening closed with one hand, and emptied the material into a plastic bag with cotton wool soaked in ethyl acetate. The specimens were then taken to the laboratory and preserved in 70% ethanol to be sorted to morphospecies.

Lampyridae from SONP were sampled monthly from June 2013 to June 2014 using Malaise (flight interception) traps arranged along an elevation gradient from 850 to 2030 m, with seven intervals of approximately 200 m, totaling seven traps each month. The last site, at 2030 m (22º27'35''S 43º01'36''W) was located in the CA. Specimens were kept in vials of 92% ethanol, after sorting under stereomicroscope. Species sampled belong to all-Neotropical subfamilies: Amydetinae, Lampyrinae and Photurinae.

Scarabaeidae were sampled along the altitudinal gradient at INP in January 2012, at every 50 m of altitude from 600 to 2400 m. At each site, Scarabaeinae beetles were sampled using three pitfall traps with a solution of water, detergent and salt, and baited with human feces, 50 m apart from one another. The traps were exposed for 48 hours and the beetles captured were taken to the laboratory and kept in 70% ethanol. All dung beetles collected belong to Scarabaeinae. To compare with the other groups, three-trap-site data were pooled for each 200 m of altitude, and other altitudes excluded. For example, data from traps at 600 m, 650 m, 700 m and 750 m were grouped

(elevation in this study - 700 m) and the data from the 800 m site were excluded; the next elevation was then 950 m from the grouping of sites 850, 900, 950 and 1000 m, excluding the next site at 1050 m, and so on. This resulted in 84 pitfalls and seven elevations: 700 m, 950 m, 1200 m, 1450 m, 1700 m, 1950 m and 2200 m, the last two in the CA (22°24'35''S 44°38'17''W and 22°23'60''S 44°39'10''W, respectively).

Species sorting

In the laboratory all specimens collected were first separated into order, then into family and subfamily, and finally identified to unique categories of morphospecies (Derraik *et al.* 2002) and counted. Scarabaeinae and Lampyridae were identified to species. For simplicity, all morphospecies will be referred to as species. The material was deposited in the collection of the Laboratory of Insect Ecology, Federal University of Rio de Janeiro, Brazil.

Data description

To describe the general patterns of species richness and abundance in the CA all species in the six insect groups studied here were included regardless their abundance. A chi-square test was performed to compare species richness and abundance in the CA in each taxon with the total species and individuals collected.

Only species with six or more individuals, regarded as non-rare, were used to evaluate their elevational range. This number was chosen because four out of the six beetle groups were collected in six or fewer different elevations and the other two groups were sampled in seven elevation sites; so six was the minimum abundance necessary for a species to appear in the majority of the elevations sampled. There may be limitations in using the same abundance criteria for all trophic groups as they are differently represented in the community, but it is a way to standardize when their proportions are not known.

The elevational range of a species was obtained as the difference between the highest elevation the species was collected at and the lowest one (in meters). This range was divided by the maximum possible elevational range (the highest minus the lowest elevation sampled for the group) and multiplied by 100 to obtain a percentage elevational range. These results are presented within each beetle group and the species are arranged from the most to the least abundant species in the CA. A Kruskal-Wallis test was used to test the null hypothesis of equal elevational ranges among different classes of abundances for the Chrysomelidae at SONP: low (1 to 4 individuals, $n = 12$ species); intermediate (5 to 10 individuals, $n = 10$ species) and high (11 to 115 individuals, $n = 11$ species). The same null hypothesis was tested between the two classes of abundances for Chrysomelidae at INP: low (1 to 13 individuals, $n = 9$ species) and high (14 to 98 individuals, $n = 9$ species). Because of sample size this test could only be performed for the Chrysomelidae.

To compare elevational range, species richness and abundance among different trophic groups taxa were arranged in three groups: detritivores (Scarabaeinae), herbivores (Chrysomelidae and Curculionidae) and predators (Coccinellidae and Lampyridae). To avoid duplicating one taxon in the same trophic group, we excluded the Chrysomelidae from INP among the herbivores. This particular group was excluded because it was sampled in a smaller number of elevations and in a smaller elevational range than the other groups. We performed a chi-square test to compare species richness and abundance in the CA among trophic groups in relation to the total number of species and individuals collected in each group.

We chose the temperature-increase scenarios of 2.0°C and 4.0°C, which encompasses the predicted ranges for the low-intermediate and high temperature-increase scenarios (IPCC 2014) for the remainder of the century. These two scenarios were used to estimate the lower elevation limit above which non-rare species occurring in the CA would be faced with local extinction if they moved upwards tracking the climate. Local extinctions would occur if the future range shift uphill due to climate change exceeded the current lower elevation of the species. These 2.0°C and 4.0°C increases in temperature would correspond, respectively, to 300 m and 600 m shift in the elevational distribution of isotherms, which, in turn, would mean, respectively, a *c.* 300

m and 600 m species upwards distribution shift considering that temperature rises *c.* 0.65ºC each 100 m increase in elevation (but see Blandford *et al.* 2008 for criticism). Considering that 2200 m is the mean highest elevation where CA occur in Serra dos Órgãos, the lower limits for a species prone to local extinction, if shifting its distribution upwards, are 1900 m and 1600 m for the two temperature increase scenarios of 2.0ºC and 4.0ºC, respectively, in this mountain range. At INP, where the mean highest elevation for CA is 2400 m, the species' lower distribution limits for these two scenarios are 2100 m and 1800 m, respectively. Thus, the non-rare (n > 6) species which occur in the CA were analyzed considering three categories: 1 - those restricted to above 1600 m (SONP) and 1800 m (INP), which would be local extinction-prone under the 4ºC temperature-increase scenario, 2 - those restricted to above 1900 m (SONP) and 2100 m (INP), which would be prone to local extinction under the 2ºC temperature-increase scenario, and 3 - those restricted to the CA which would be local extinction-prone under any temperature-increase scenario.

RESULTS

General patterns of elevational distribution

A total of 664 species and 9,330 individuals belonging to the five chosen families in Coleoptera were collected. The number of species occurring in the CA in relation to the total of species collected varied significantly among taxa (χ^2 = 29.47; p < 0.0001) as did the abundance among taxa (χ^2 = 1117.68; p < 0.0001). A total of 20.2% of all species and 16.0% of all individuals are found in the CA (Table 1).

Most of the species were rare (n < 6) and only 175 species (26.4%) had six or more individuals collected, out of which 67 (38.3%) were present in the CA. Chrysomelidae had by far the most species occurring in the CA. The other groups varied from 11.1% (Curculionidae) to 25.0% (Lampyridae) of non-rare species in the CA (Figure 1). Chrysomelids (28.8% at SONP and 21.7% at INP) had more species with elevational ranges restricted to above 1600 m (SONP) / 1800 m (INP), followed by curculionids (3.7%) and dung beetles (5.6%). Chrysomelids also had more species restricted to altitudes above 1900 m (SONP) / 2100 m (INP), followed by curculionids and dung beetles. The coccinellids and the lampyrids had no species restricted to higher elevations. Again chrysomelids had the highest proportion of species restricted to the CA (13.6% at SONP and 21.7% at INP) followed by the dung beetles (2.8%). Curculionids, coccinellids and lampyrids had no species occurring exclusively in the CA (Figure 1).

Species elevational ranges

Most of the eight dung beetles species which occurred in the CA had broad (more than

Table 1. Total number of species collected along the elevational gradients, number and percentage of species occurring in the Campos de Altitude (CA), total abundance, and absolute and relative abundance in the CA for the six beetle groups studied at Itatiaia National Park (INP) and Serra dos Órgãos National Park (SONP), Brazil.

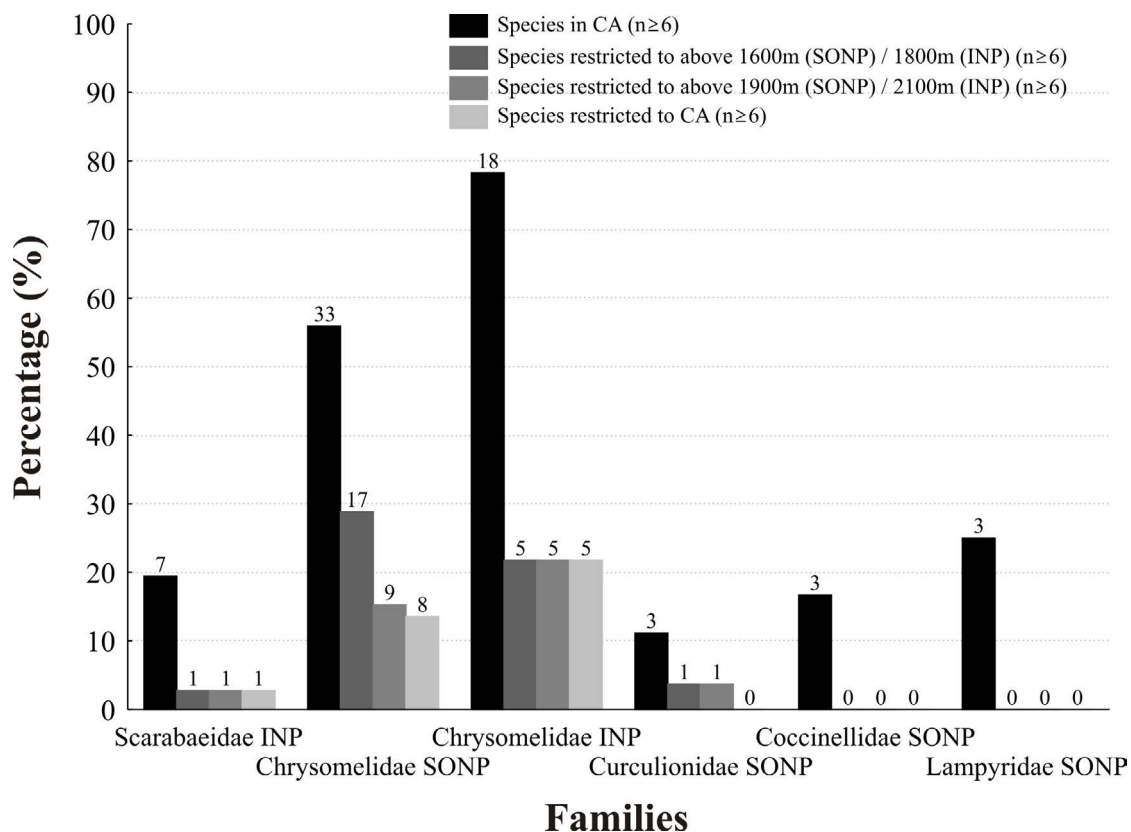| Family	Total species	Species in CA	% Species in CA	Total abundance	Abundance in CA	% Abundance in CA
Scarabaeidae INP	51	8	15.7	2,548	306	12.0
Chrysomelidae SONP	300	61	20.3	3,095	560	18.1
Chrysomelidae INP	59	27	45.8	1,018	482	47.3
Curculionidae SONP	194	31	16.0	673	58	8.6
Coccinellidae SONP	32	4	12.5	1,665	10	0.6
Lampyridae SONP	26	3	11.5	331	75	22.7
TOTAL	662	134	20.2	9,330	1,491	16.0

Figure 1. Percentage of non-rare species (n ≥ 6) in each group occurring in the CA, restricted to elevations above 1600 m (SONP) / 1800 m (INP), restricted to elevations above 1900 m (SONP) / 2100 m (INP), and occurring exclusively in the CA. Numbers of species are presented above the bars. INP = Itatiaia National Park; SONP = Serra dos Órgãos National Park; CA = Campos de Altitude.

750 m) elevational ranges (Figure 2A) and only *Canthidium* sp. was restricted to the CA at INP. Chrysomelids from SONP, besides having a great number of species with narrow elevational ranges, exhibit a tendency for less abundant species in the CA to have broader ranges than those most abundant (Figures 2B and 3) ($p < 0.05$ by K-W test). The same pattern was not observed for the chrysomelids from INP ($p > 0.05$; M-W test) as the species were either broad-ranged or restricted to the CA regardless their elevational range (Figure 2C). The other group of herbivores, the curculionids, cannot be evaluated in this respect as only three species occurred in the CA, but it is noteworthy that the most abundant of these three species in the CA had the narrowest elevational range and the least abundant one exhibited the broadest range (Figure 2D). The predaceous coccinellids (Figure 2E) and lampyrids (Figure 2F) were similar in that CA-occurring-species were

broad-ranged. The relative frequency of species with a narrow elevational range, considered as a quarter of the total elevational range sampled, decreases in the following order: Chrysomelidae SONP > Curculionidae > Chrysomelidae INP > Scarabaeinae > Lampyridae = Coccinellidae (Figure 4).

Trophic groups and elevational ranges

The total numbers of species and individuals in the CA were different among trophic groups (Table 2). However, the difference among trophic groups was not significant for species numbers in the CA ($x^2 = 1.93$; $p > 0.05$), but was significantly different for abundance in the CA ($x^2 = 180.44$; $p < 0.0001$), greater in herbivores and lower in predators.

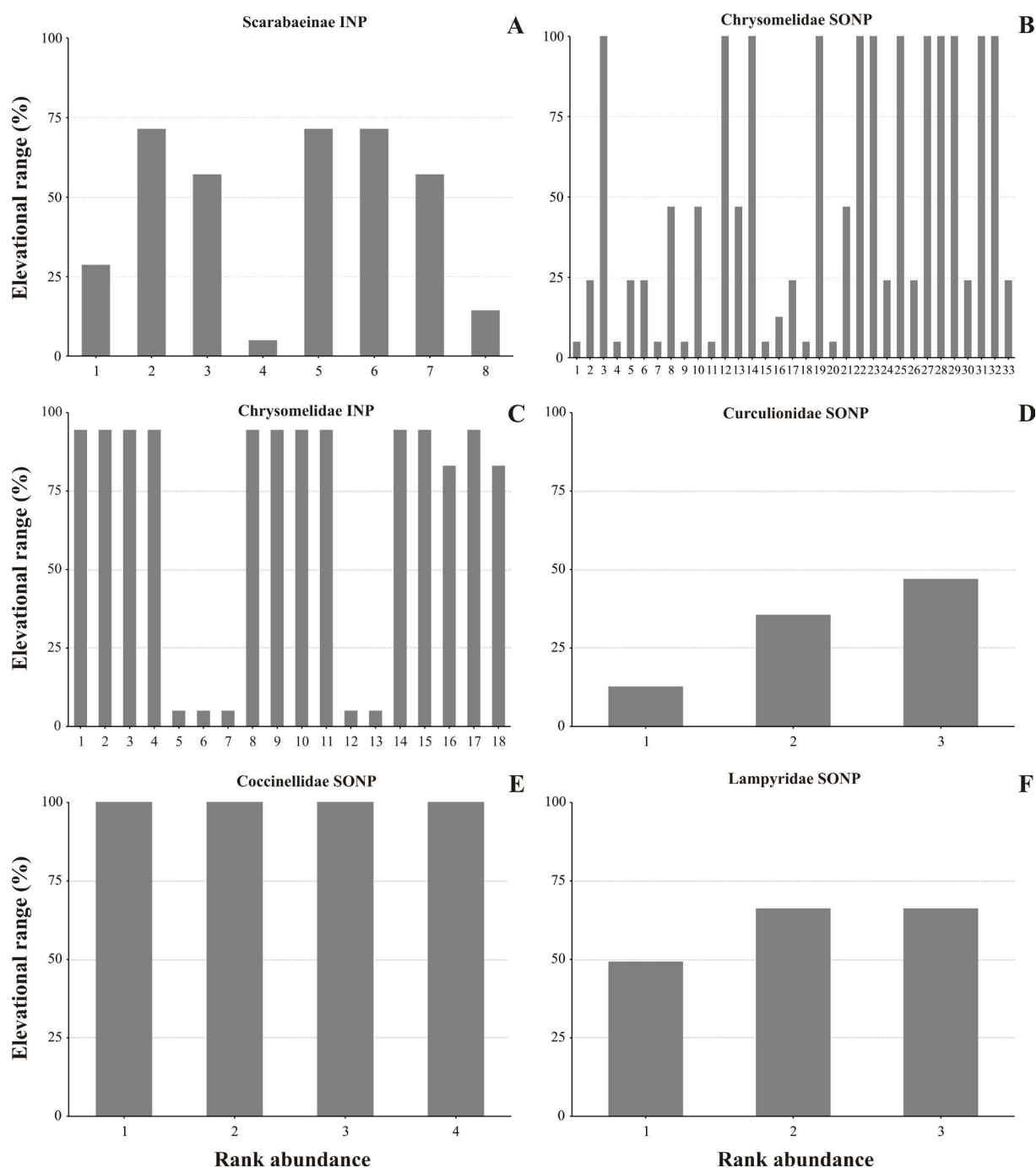The herbivores had more non-rare species occurring in the CA ($x^2 = 8.40$; $p < 0.05$), and

Figure 2. Elevational range of non-rare species of: Scarabaeinae at INP (A), Chrysomelidae at SONP (B), Chrysomelidae at INP (C), Curculionidae at SONP (D), Coccinellidae at SONP (E) and Lampyridae at SONP (F). Species are arranged from the most (left) to the less (right) abundant one in the CA. Bars of 5% indicate species present only in the CA. Maximum elevational range possible: 1750 m (in A, B, D, E), 1650 m (in C) and 1180 m (in F). INP = Itatiaia National Park; SONP = Serra dos Órgãos National Park; CA = Campos de Altitude.

restricted to 1600 m / 1800 m or higher elevations ($\chi^2 = 19.54$; p < 0.0001) and restricted to the CA. Predators and detritivores had very similar percentages of non-rare species occurring in the CA but predators had no species with elevational ranges restricted to above 1600 m / 1800 m, and 1900 m / 2100 m, or occurring exclusively in the CA (Figure 5).
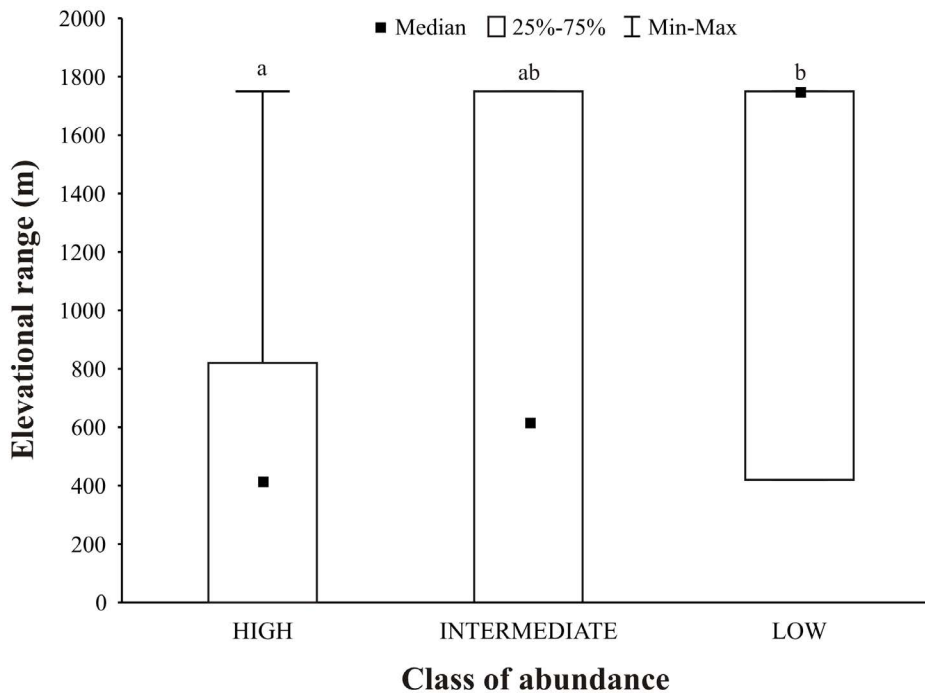
Figure 3. Median, 1st and 3rd quartiles, and minimum and maximum elevational ranges for Chrysomelidae with high (11 to 115 individuals, n = 11), intermediate (5 to 10 individuals, n = 10) and low (1 to 4 individuals, n = 12) abundances in the CA at SONP. K-W p < 0.05. Different letters above bars mean significantly different medians (p < 0.05 by K-W test). SONP = Serra dos Órgãos National Park; CA = Campos de Altitude.
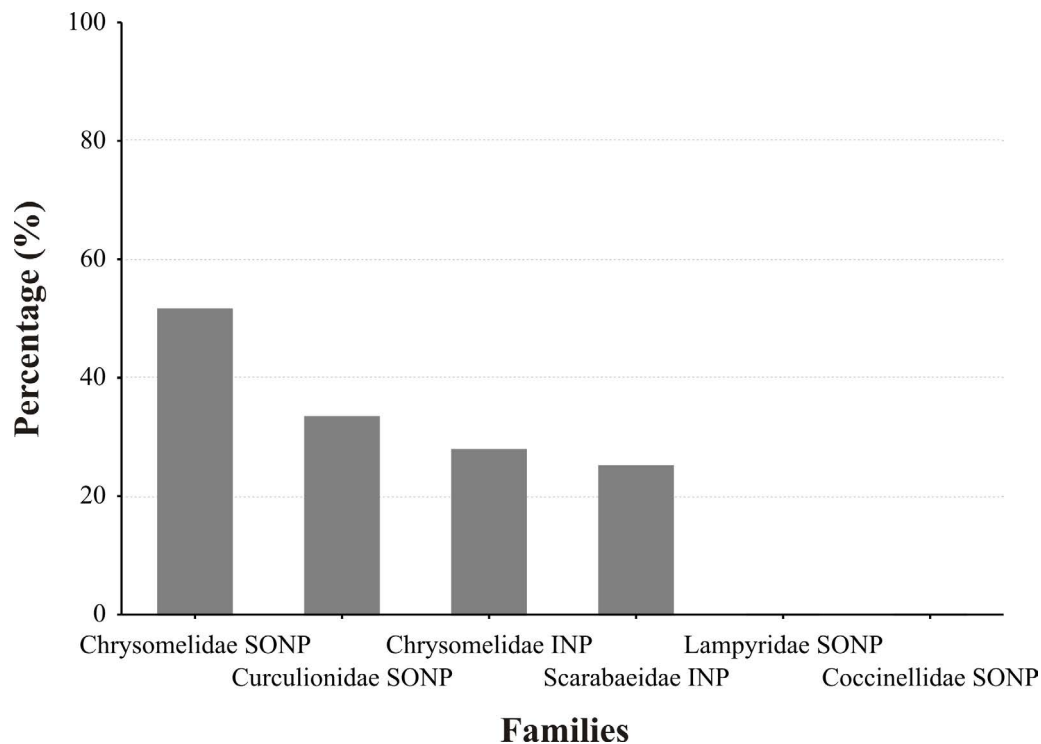

Figure 4. Percentage of species occurring in less than a quarter of the total elevational range sampled. INP = Itatiaia National Park; SONP = Serra dos Órgãos National Park.

Table 2. Total number of species, absolute and relative number of species in the CA, total abundance, and absolute and relative abundance in the Campos de Altitude (CA) for the three trophic groups studied: detritivores (Scarabaeinae), herbivores (Chrysomelidae and Curculionidae) and predators (Coccinellidae and Lampyridae). Only the Chrysomelidae species from Serra dos Órgãos National Park were considered.

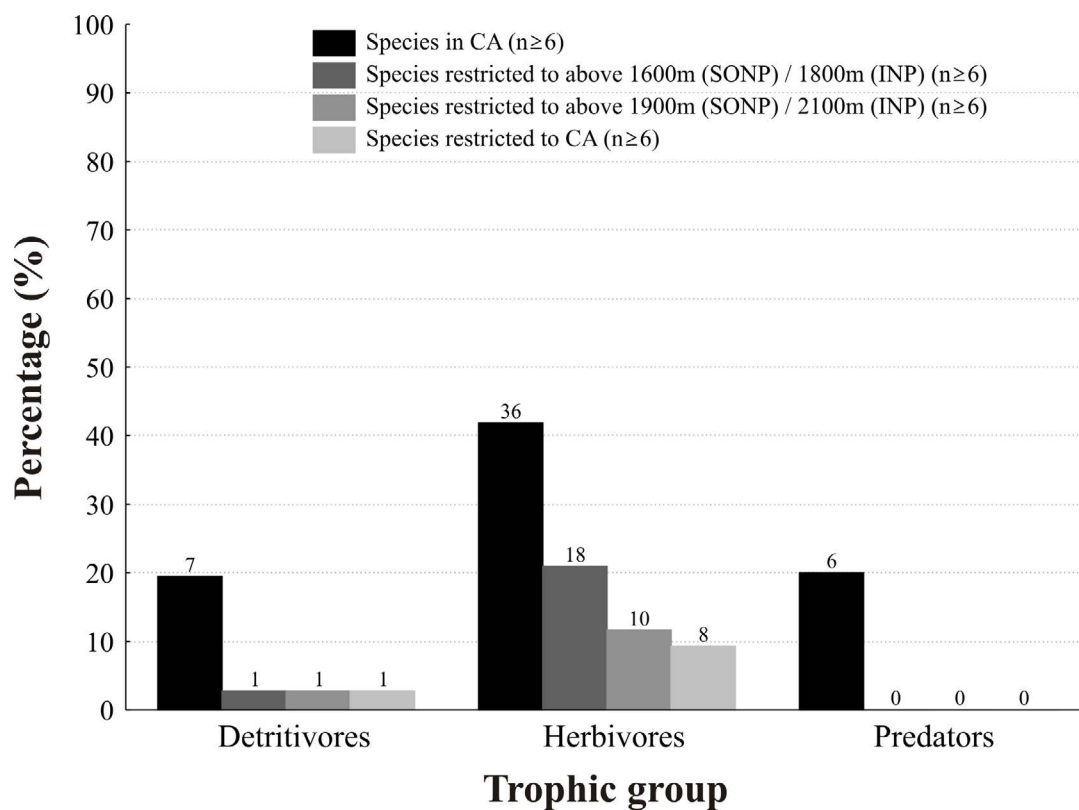| Trophic groups	Total species	Species in CA	% Species in CA	Total abundance	Abundance in CA	% Abundance in CA
Detritivores	51	8	15.7	2,548	306	12.0
Herbivores	494	92	18.6	3,768	618	16.4
Predators	58	7	12.1	1,943	85	4.3

Figure 5. Percentage of non-rare species in each trophic group occurring in the CA, restricted to elevations higher than 1600 m (SONP) / 1800 m (INP), restricted to elevations higher than 1900 m (SONP) / 2100 m (INP), and restricted to the CA. Trophic groups were: detritivores (Scarabaeinae), herbivores (Chrysomelidae and Curculionidae) and predators (Coccinellidae and Lampyridae). Only the Chrysomelidae species from SONP were considered in this figure. Number of species above the bars. INP = Itatiaia National Park; SONP = Serra dos Órgãos National Park; CA = Campos de Altitude.

DISCUSSION

In this study we describe the patterns of elevational range of Coleoptera species occurring in the CA for the first time. We found different elevational ranges among the studied taxa and among species within each taxon. However, herbivores tended to have narrower ranges than detritivores, and predators were the trophic group with species with broader ranges. Many species were found to be restricted to the CA, mainly among the herbivores. The results

are discussed under predicted scenarios of climate warming.

The percentage of species occurring in the CA from the total collected species was different among taxa. Although there is considerable evidence that each species responds individually to climate (e.g. Parmesan *et al*. 1999, Thomas *et al*. 2001) and our results about the diversity of elevational ranges point in the same direction, the taxa studied in the CA tended to have broader ranges in the following order: Chrysomelidae – Curculionidae – Scarabaeidae – Coccinellidae and Lampyridae (Figure 4). This suggests that this is also the order of decreasing risk of local extinction under climate warming if environmental tolerance or thresholds are the factor most limiting species' elevational ranges as already described (Moir & Leng 2013).

Studies have suggested that vulnerability to extinction increases with trophic level, making predators, the least abundant group, more sensitive to changing temperature (Voigt *et al*. 2003). Thus climate change might have an especially strong effect on top-consumer extinctions and range shifts (Zarnetske *et al*. 2012). However, just considering the elevational ranges, this does not seem true for the Coleoptera trophic groups studied here. Considering the narrower elevational range of the herbivores we would expect predators to be less vulnerable to extinction due to climate warming than the herbivores if we consider the whole mountain and, so, the higher possibility of predators shifting their distribution upwards and / or southwards.

Although our data cannot directly test Rapoport´s elevational rule (Stevens 1992), the difference in elevational range among trophic groups of species occurring in the CA suggests that there may be a difference in the way each group varies species' range along the elevational gradient. Thus, we suggest that studies on Rapoport´s elevational rule should also consider trophic groups since, for example, herbivores could follow an inverse Rapoport´s elevational rule, with species tending to have narrower ranges with elevation.

Under the unrealistic scenario that climate niche is the only trait restricting elevational distribution (see Colwell *et al*. 2012 and Zarnetske *et al*. 2012 for discussion) and that under a warming climate species would shift their ranges

upwards by 600 m or 300 m in the rest of the century (considering the high and low-intermediate scenarios of temperature increase of 4.0ºC or 2.0ºC and the *ca*. 0.65ºC temperature rise each 100 m increase in elevation), we would expect that *ca*. 29% and 15% of the Chrysomelidae species for the two scenarios, respectively, and *ca*. 4% of the Curculionidae species in both scenarios would go extinct in the CA of SONP. In the CA of INP we would expect that *ca*. 3% of the Scarabaeidae and *ca*. 22% of the Chrysomelidae species in both temperature-increase scenarios would be faced with extinction by the beginning of the next century. So even considering the low-intermediate temperature increase scenario of 2ºC, many species are expected to be lost as the number of endemic species in the CA is very high. No Coccinellidae or Lampyridae species would go extinct under these scenarios according to our data. As pointed out this is a simple and unrealistic scenario as species interact with each other in ways that deeply affect their viability (Zarnetske *et al*. 2012), which means that extinction could be even higher. For example, Scarabaeinae species are very sensitive to environmental variations like temperature, vegetation cover and soil (Halffter & Matthews 1966, Philips 2011). Their sensitivity to temperature comes from their tropical Gondwana evolutionary origin (Escobar *et al*. 2006). On temperate mountains, the Scarabaeinae fauna is completely replaced by species of the Aphodiini tribe at higher altitudes (Escobar *et al*. 2005). This might explain the low number of species in the cold higher elevations. With climate warming, Scarabaeinae species will tend to expand their upper distribution limits or shift their entire range up-slope (Menéndez *et al*. 2014). Both scenarios can lead species to extinction. The first would cause an increase in competition at the lower limits of species living at higher altitudes because of immigration of species from lower altitudes. Secondly, Brazilian mountains are not very high, leading to a lack of space for species moving upslope according to their climate niche (Wiens & Graham 2005). Without considering the probable scenario changes resulting from species' adaptations, such species will be lost. We cannot forget other factors like resource availability and vegetation cover, also important to the group

(Halffter & Matthews 1966, Philips 2011) and which may be affected differently by expected climate change.

Furthermore, under these simplest scenarios we can expect to lose species that we do not even know. Considering that only about 30% of the 2.5 - 3.7 million insect species have been named (Hamilton *et al*. 2010), that many endemic species are expected in the CA (Lara & Fernandes 1996) and that insects have been poorly studied in these habitats, we should be very concerned about losing many yet-unknown species. This is reinforced by the findings for the lampyrids: among the three species recorded in the CA, one belongs to a new genus and the other two are probably new *Lucidota* species. A new genus and three new species were recently described for the study area, one of them endemic of the CA (Silveira & Mermudes 2014). Due to this dramatic scenario we urgently need to study insects in elevational gradients including the CA so that we can appropriately evaluate which factors limit species' distributions in an effort to predict the impacts of climate change and to be able to plan conservation strategies to minimize damage to this unique biota.

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