J Coast Conserv (2016) 20:97–106
DOI 10.1007/s11852-016-0421-4

Population density and conservation status of the teiid lizard *Cnemidophorus littoralis*, an endangered species endemic to the sandy coastal plains (restinga habitats) of Rio de Janeiro state, Brazil

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Received: 16 September 2015 / Revised: 4 January 2016 / Accepted: 7 January 2016 / Published online: 24 February 2016
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Abstract The threatened lizard *Cnemidophorus littoralis* occurs in only four restinga habitats of Brazilian coast and its current conservation status is "endangered". Due to its restricted distribution, the effects of habitat degradation are especially harmful to them. To prevent a local or even total extinction, we analyzed changes in population density and in amount of disturbances of three restinga areas during a seven-year gap. This study took place in three restingas of Rio de Janeiro State, Brazil: Maricá, Jurubatiba and Grussaí. We compared *C. littoralis* current density with the one registered in 2005 by Menezes and Rocha (2013) with 2 ha transections in each restinga. We also made another group of transects to estimate population density along the entire extension of the restingas. Conservation index of each site was based on satellite images and field samplings. Data showed a decreasing trend of *Cnemidophorus littoralis* population density over the years. Grussaí had the lowest population density and the highest degradation index among the three sites, whereas Jurubatiba had the lowest degree of disturbance, the largest area and the highest lizard population density. Data showed an increase in the amount of disturbance in restingas over the years, which seemed to have a negative effect in *C. littoralis* population density. Improvement of surveillance and implementation of education programs in the protected areas and its surroundings, and periodic monitoring of *C. littoralis* populations to follow their density changes, are essential for the maintenance of the species.

Keywords Coastal habitat · Degradation · Management and conservation · Vegetation structure · Reptile

Introduction

Worldwide, the consequences of human alterations of the landscape, such as habitat fragmentation, urbanization, pollution, biological invasions, and climate change, are currently the major threats to the environment and its biodiversity (e.g. McKinney 2002; Galli et al. 2014). The presence of humans and their activities is usually more intense in coastal areas, where these impacts are responsible for the decline in populations of amphibians and reptiles at both local and global scales (Vinciprova and Verrastro 2001; Gibbons et al. 2000 Sinervo et al. 2010).

Restingas, a type of sandy coastal plain habitat associated with the Atlantic Rain Forest domain, are located along the littoral of eastern Brazil, coinciding with the area occupied by approximately 70 % of the country's population (Rocha et al. 2003). As a result, restingas are one of Brazil's most impacted environments, with high rates of habitat loss, and are probably the country's most endangered ecosystem (Rocha et al. 2003, 2007). Given this, many restinga species have declining populations and are currently threatened with extinction, even with some local extintions, as in the case of the endemic lizard *Liolaemus lutzae*, in Rio de Janeiro (Rocha 1985; Rocha et al. 2009; Almeida-Santos et al. 2015). Given the risks of the disappearance of this environment, there is an urgent need for a systematic understanding of habitat function and the potential for the conservation of its many species of animal

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and plants (Rocha et al. 2005; Menezes and Rocha 2013; Oliveira and Rocha 2015).

Four of the seven teiid lizard species found on the Brazilian Endangered Fauna Checklist are endemic to restinga habitats. Species of the genus *Cnemidophorus* (sensu Pyron et al. 2013) occur in restinga habitats all along the eastern coast of Brazil between its southern (Santa Catarina state) and northern (Rio Grande do Norte state) extremes (Menezes and Rocha 2013). However, three of the five coastal species of *Cnemidophorus* found in Brazil (*Cnemidophorus littoralis*, *Cnemidophorus nativo* and *Cnemidophorus abaetensis*) were categorized as "endangered" in the most recent Brazilian Endangered Fauna Checklist (2014), mainly due to habitat loss.

Cnemidophorus littoralis or the "green-tailed whiptail lizard" is a small (up to 82 mm SVL; Rocha et al. 2000) bisexual diurnal lizard restricted to four known localities on the coast of Rio de Janeiro, Brazil (Menezes and Rocha 2014, Fig. 1). This species usually initiates activity by around 8 h00 and retires by 15 h00, with a peak between 10 h00 and 12 h00 (Teixeira-Filho et al. 1995; Hatano et al. 2001). *Cnemidophorus littoralis* is endemic to restinga habitats, and has a mean body temperature of 38 °C when active (Menezes and Rocha 2011). It is predominantly insectivorous, feeding mainly on termites, beetles and insect larvae (Teixeira-Filho et al. 2003; Menezes et al. 2006). Considering the rapid rates of anthropic modification and loss of restinga habitats, monitoring lizard population densities over time will be crucial to the understanding of their population dynamics and response to environmental changes, and, ultimately, shifts in their conservation status. The comparative evaluation of the status of past and present populations is important for predicting changes in this status over time (Cerqueira et al. 2003), and providing guidelines for the implementation of effective conservation and management programs (Peloso et al. 2008).

In 2005, Menezes and Rocha (2013) conducted the first systematic survey of coastal cnemidophorines in Brazil, providing density estimates for the populations of a number of species found in restinga habitats along 4000 km of the Brazilian coast. These data provide an important baseline for the evaluation of changes in the status of the different populations, especially those of endangered species, over time. Here, we surveyed three populations of the endangered *Cnemidophorus littoralis* in order to evaluate long-term changes in the density and status of the populations between 2005 and 2013–14.

In the present study we aimed to: (i) estimate the current population density of *Cnemidophorus littoralis* in three restingas in Rio de Janeiro state; (ii) compare the current density and conservation status of each population with the data recorded in 2005; (iii) identify the most common elements of habitat degradation and disturbance in each restinga; (iv) identify the main causes of habitat loss; (v) identify the site with the greatest potential for the conservation of the species; and (vi) provide guidelines for the effective management and conservation of the *Cnemidophorus littoralis* populations.

Material and methods

Study areas

Fieldwork was carried out between December 2013 and March 2014 in three restinga habitats in the state of Rio de Janeiro, Brazil: (1) Grussaí, in the municipality of São João da Barra, (2) Jurubatiba, in the municipality of Macaé, and (3) Barra de Maricá, in the municipality of Maricá. The Grussaí/Iquipari lagoon complex, with a maximum extension of approximately 7.5 km (estimated using Google Earth), is located on the northern coast of Rio de Janeiro (21°44'S, 41°02'W). Mean annual temperature in the area is about 23 °C (Rocha et al. 2008) and total annual rainfall ranges from 800 mm to 1200 mm, with a distinct rainy season between November and March (Cesário and Gaglianone 2008). In October 2007, construction of the Porto do Açu shipping complex was initiated in the southern part of the Grussaí restinga, covering a total area of approximately 90 km^2.

The Jurubatiba restinga is also located in the northern part of the state (22°17'S, 41°41'W) and is one of the largest areas of restinga in Rio de Janeiro, extending along some 44 km of the coast (Rocha et al. 2007). The Jurubatiba Restinga National Park (PNRJ- Parque Nacional da Restinga de Jurubatiba) was created in 1998, and has an area of approximately 148.6 km^2 (Montezuma and Araujo 2007). Mean annual temperature in the area is 22.6 °C (Menezes et al. 2006; Montezuma and Araujo 2007) and mean annual rainfall is 1300 mm, concentrated in the months between October and April (Montezuma and Araujo 2007).

The Barra de Maricá restinga (22°57'S, 42°52'W), with a coastline of 6.2 km, is an environmental protected area (APA - Área de Proteção Ambiental), created by state decree n° 7230 of April 23, 1984 (Pereira et al. 2001). Mean annual temperature in the area ranges from 22 °C to 24 °C and mean annual rainfall from 1000 to 1350 mm (Nimer 1972; Franco et al. 1984), with about 70 % of precipitation occurring from November to April (Pereira et al. 2001).

Estimates of population density

To estimate the population density of *Cnemidophorus littoralis* in each studied restinga, we recorded the number of individuals sighted along two groups of transects between December 2013 and March 2014 (rainy season). All transects ran parallel to the beach line and were walked always in the same direction and in the same type of habitat (Open Non-Flooded shrubby vegetation - Decree RJ 41612 of December 23, 2008), to ensure the independence of the observations.

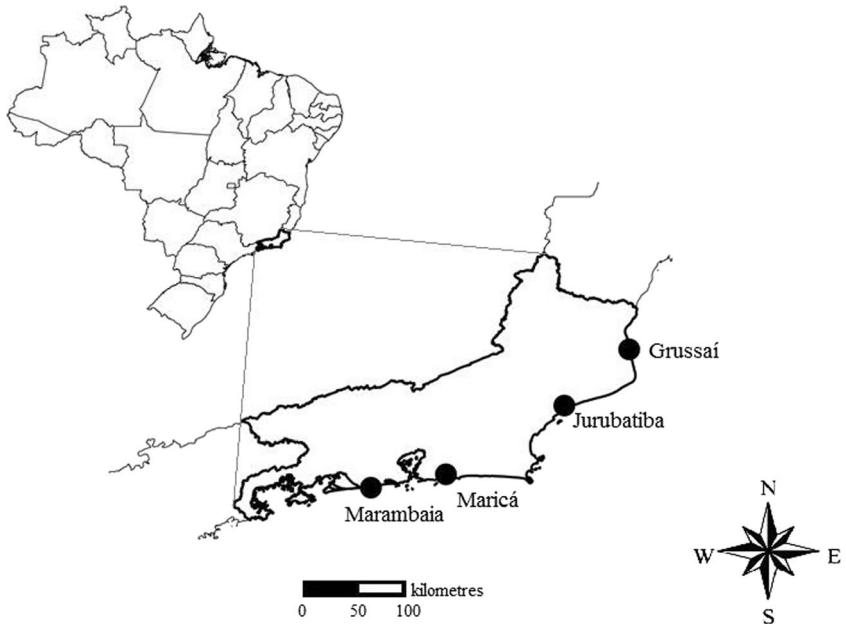

Fig. 1 Distribution of *Cnemidophorus littoralis* (black dots) in the four restinga areas where the species occurs, in the state of Rio de Janeiro. From top to bottom: Restinga of Grussaí, Restinga of Jurubatiba, Restinga of Maricá and Restinga of Marambaia

To ensure the reliability of the comparisons with the *C. littoralis* densities recorded in 2005, we adopted the same procedures followed by Menezes and Rocha (2013), referred to here as Density I. We established straight-line transects of 2 km in length, which were surveyed through a standardized 180 min walk. We counted every lizard sighted within a 10-m strip centered on the transect (5 m to each side) recording the perpendicular distance of each sighting in relation to the transect. A total area of 2 ha (2000 m length × 10 m width) was thus sampled in each restinga. All the samples were taken on sunny days, and during the peak period of *C. littoralis* activity (09 h00 to 13 h00), as in the previous study (Menezes and Rocha 2013). Two indices of population density were estimated for the data set: (1) transect density ($DI_{Transect}$) – total number of lizards recorded at each site divided by the total area sampled, expressed as the number of individuals per hectare (ind/ha); (2) population density ($DI_{Distance}$) – mean density estimated by detection error functions in the DISTANCE 6.0 program (Buckland et al. 1993) multiplied by the area of the open non-flooded shrubby vegetation found in each restinga. A number of different models were tested in DISTANCE 6.0, and the model with the lowest Akaike's Information Criterion (AIC) was selected.

We conducted a second set of transects to estimate the population density of *C. littoralis* within the entire area of open non-flooded shrubby vegetation in each study restinga (hereafter Density II). We divided each restinga into five equal portions and conducted a transect in each portion. All five transects in a given restinga were of the same size, and were spaced equally, being arranged in such a way as to best cover the full linear extension of the restinga, including its extremes. The sum of the extension of the five transects in each restinga was equivalent to 7 % of its total linear extension. This percentage was chosen to standardize the sampling effort among sites, while guaranteeing the viability of data collection, and represents a total of 3080 m of transect at Jurubatiba (the sum of five transects of 616 m), 435 m in Maricá (five transects of 87 m) and 510 m in Grussaí (five transects of 102 m). In each restinga, the minimum distance between transects was 100 m and the five transects were walked in a similar time. This density (DII) was calculated using the DISTANCE 6.0 software, based on the perpendicular distance from the transect line of each individual lizard sighted during the survey.

Estimates of the degree of habitat degradation

To calculate the remaining area of original vegetation in each restinga, we vectored polygons based on the interpretation of Google Earth satellite images (2014), identifying areas of sparse shrub growth (excluding the halophylous-psammophylous vegetation, restinga forest and areas covered by lagoons, plantations, roads or waste land). The total area (in hectares) of these polygons was calculated using the Quantum Gis Lisboa program.

In the field, we recorded evidence of anthropogenic degradation, which was classified according to the following categories, based on Rocha et al. (2007, 2009): 1) vegetation cleared for the construction of highways or streets; 2) trampling of the vegetation for beach access; 3) vegetation cleared for beach access; 4) vegetation cleared for house-building; 5) off-road vehicle tracks; 6) garbage disposal; 7) fire damage to the vegetation; 8) commercial quarrying of sand; 9) farmland; 10) car parking on the vegetation or sand; 11) hunting; 12) pasture; 13) domestic animals; 14) evidence of religious practices.

As the disturbance of each restinga had already been classified by Menezes and Rocha (2013) in 2005, we used the same approach to classify disturbance and compare the habitat degradation between years. We compared categories 1 to 12 above, attributing the following values: 0, when no disturbance was recorded; 1, when the disturbance was rare; 2, when the disturbance was frequent; and 3, when the disturbance was common. We then compared the degree of each type of disturbance and the total disturbance (the sum of each source of degradation) between years (2005 and 2013–14) in each restinga. We considered habitat degradation as "low" in areas where the sum of the scores was less than 10, "intermediate" where this degree was between 11 and 20, and "high", where it was above 20.

We also estimated the area and coordinates of all detectable disturbances in the satellite images (Google Earth Pro) within a buffer zone centered on each Density II transect. Each buffer zone extended twice the length of the transect in all directions, resulting in zones of 3080 m × 2464 m at Jurubatiba, 510 m × 408 m at Grussaí, and 435 m × 348 m at Maricá. The total area of disturbance within the buffer zone of each transect was quantified and summed to determine the proportion of disturbed area, which was extrapolated to the area of the restinga as a whole as a (percentage) index of degradation. The influence of these disturbances on the distribution of individuals was tested by a simple regression of the number of individuals sighted with the percentage of degraded area. It was not possible to analyze this relationship at Grussaí due to the small size of the sample from this site. We used the "R" software to test the data for normality, and the homogeneity and independence of variances.

According to the degradation index estimated for each restinga, we determined which area has the best potential conditions for the survival of the species, and which populations were most at risk.

Results

Population densities

In the Density I samples, a mean of 1.8 ± 0.5 individuals per transect (range: 0 to 4; N = 11) was recorded at Maricá, 4.4 ± 0.9 ind./transect (range: 1 to 6; N = 5) at Jurubatiba and 0.6 ± 0.3 ind./transect (range: 0 to 3; N = 13) at Grussaí (Table 1). Densities estimated for these same populations obtained in 2005 by Menezes and Rocha (2013), using both transect ($DI_{Transect}$) and DISTANCE ($DI_{Distance}$) approaches, are shown for comparison in Table 1. Current densities of the *C. littoralis* populations were consistently lower than those recorded in 2005 at Maricá and Jurubatiba, although they were higher at Grussaí. The best $DI_{Distance}$ model for the data from Maricá (AIC = 53.09) was the negative exponential model, whereas the uniform model was selected for Jurubatiba (AIC = 85.62) and Grussaí (AIC = 5.44).

Table 1 Population densities (ind/ha) of *Cnemidophorus littoralis* in three restinga areas in the state of Rio de Janeiro, Brazil, in 2005 (data from Menezes and Rocha 2013) and 2013–14 (present study). Density I-$DI_{Transect}$ (length of the transect per 10 m width); $DI_{Distance}$ (program Distance); Density II (program Distance) and total area of the Open Non-Flooded shrubby phytophisiognomy in each restinga

Restinga	Jurubatiba		Maricá		Grussaí	
Year	2005	2013	2005	2013	2005	2014
$DI_{Transect}$	13.33	10.26	34.72	10.00	0.96	2.00
$DI_{Distance}$	17.75	10.29	64.00	19.51	1.37	3.30
DII	–	17.78	–	11.49	–	5.05
Total Area (ha)	24,501.83		155.41		375.45	

The number of individuals sighted in each Density II transect ranged from 0 to 15 at Jurubatiba (x = 5.4 ± 3.0 ind./transect; adults =5.0 ± 2.7, N = 25; juveniles: 0.4 ± 0.4, N = 2), 0–3 at Maricá (x = 1.6 ± 0.6 ind./transect; adults =1.4 ± 0.7, N = 7; juveniles =0.2 ± 0.2, N = 1), and 0–2 at Grussaí (x = 0.4 ± 0.4 ind./transect; adults =0.4 ± 0.4 N = 2; juveniles =0). The best models for the Density II estimates, were the negative exponential model for Jurubatiba (AIC = 136.88) and the uniform model for Maricá (AIC = 33.27) and Grussaí (AIC = 5.44).

Degree of habitat degradation and conservation index

After discounting the degraded habitat from the satellite images, the estimated cover of open non-flooded shrubby vegetation (*C. littoralis* habitat) was 11,204.79 ha in the Jurubatiba restinga, 126.90 ha at Maricá, and 290.08 ha at Grussaí. In each area, we recorded at least 10 of the 14 most common types of environmental disturbance (Table 2) known to occur in Brazilian restingas (Rocha et al. 2007, 2009). Of the three restingas studied here, Jurubatiba had the lowest diversity of disturbance, with 10 types (Table 2). At this site, disturbance was related mainly to the clearing of vegetation for the construction of roads (paved and unpaved) within and around the restinga, as well as infrastructure, such as villages and farms. At Maricá, building was observed mostly in the area surrounding the remnant, and the principal disturbances were traffic, trampling, and the presence of domestic animals (Table 2). At Grussaí, the primary source of disturbance was the construction of the Porto do Açu shipping complex and associated urbanization (Table 2).

Comparing the twelve types of disturbance analyzed systematically in both 2005 and 2013/14, there was an increase in the degree of disturbance at all three sites, with indices increasing from 4 to 12 at Jurubatiba, 10 to 21 at Maricá, and from 16 to 20 at Grussaí. In general, the impact of each type of disturbance increased. Grussaí suffered the least change, with

Table 2 Geographic coordinates, total area of the remnants (in ha) and types of disturbance found in each restinga area in 2013/14 (Grussaí, Jurubatiba and Maricá, in Rio de Janeiro State, southern Brazil)

	Grussaí	Jurubatiba	Maricá
Coordinates (UTM)	291,506.92 m E; 7,588,772.28 m S/290,050.29 m E; 7,595,837.98 m S	221,075.50 m E; 7,532,376.79 m S/263,086.22 m E; 7,547,490.71 m S	715,033.03 m E; 7,458,609.03 m S/721,296.64 m E; 7,459,114.87 m S
Remnants (ha)	290.08	11,204.79	126.90
Types of Disturbance	Vegetation cleared for the construction of highways or streets; Trampling of the vegetation for beach access; Vegetation cleared for beach access; Vegetation cleared for house-building; Off-road vehicle tracks; Garbage disposal on vegetation; Commercial quarrying of sand; Farmland; Car parking on the vegetation or sand; Hunting; Domestic animals	Vegetation cleared for the construction of highways or streets; Trampling of the vegetation for beach access Vegetation cleared for beach access; Vegetation cleared for house-building; Off-road vehicle tracks; Garbage disposal on vegetation Farmland; Car parking on the vegetation or sand; Pasture; Domestic animals	Vegetation cleared for the construction of highways or streets; Trampling of the vegetation for beach access; Vegetation cleared for beach access; Vegetation cleared for house-building; Off-road vehicle tracks; Garbage disposal on vegetation Fire damage to the vegetation; Car parking on the vegetation or sand; Pasture; Domestic animals; Evidence of religious practice

four of the twelve types of degradation (vegetation cleared for building and beach access, off-road traffic and garbage disposal) remaining at the same level. Even so, house-building was already at its maximum level (3) in 2005 (Fig. 2). At Jurubatiba, off-road traffic and beach access remained stable (Fig. 2), whereas at Maricá, only the clearing of vegetation for beach access remained stable. Hunting, recorded in 2005, was not recorded at Maricá in the present study, and pasture and fire damage were absent from Grussaí (Fig. 2).

The distance of each transect to the sources of habitat disturbance measured from the satellite images ranged from 0 to 8.6 km ($x = 1.9 \pm 2.4$ km, N = 17) within the buffer zones in the Jurubatiba restinga, from 0.05 to 3.81 km ($x = 0.5 \pm 1.0$ km, N = 13) in the Maricá restinga, and from 0.02 to 8.16 km ($x = 2.0 \pm 2.9$ km, N = 7) at Grussaí. The clearing of vegetation for the construction of dirt roads was the most frequent source of degradation observed in the study, being found in at least one transect in each restinga (Table 3). Jurubatiba had the lowest number of sources of disturbance overall (Table 2), but also had the greatest variety of degradation sources within the buffer zones (Table 3).

In the transects at Maricá, there was a significant negative relationship between the extent of the degraded area and the number of individual lizards sighted ($F = 13.44$; $R^2 = -0.8$; $p = 0.03$; DF = 3, Fig. 3). Despite the negative trend recorded at Jurubatiba, the regression between the size of degraded area around transects and the number of lizards was not significant ($F = 0.76$; $p = 0.44$; DF = 3).

Discussion

While the two methods used to estimate Density I of *Cnemidophorus littoralis* populations provided different absolute values, similar patterns of variation were observed between 2005 and 2013–14. At Maricá, the population density ($DI_{Distance}$) of *C. littoralis* in 2013 was 30.5 % less in 2013 than that estimated in 2005, and the transect density ($DI_{Transect}$) was 28.8 % lower, indicating a decline of 69.5 % and 71.2 % between periods, respectively. At Jurubatiba, the same trend of decreasing density was detected between years, with a reduction of 23.0 % in the population density, and 41.9 % in the transect density. At Grussaí, by contrast, density increased, with the transect density changing by 122 %, and the population density by 153 %. The levels of habitat degradation detected in the present study probably account for the decline in the densities of *C. littoralis* recorded in the Maricá and Jurubatiba restingas. Some sources of degradation, principally those that impact the original substrate, may provoke a decline in the densities of restinga lizards, such as the liolaemid *Liolaemus lutzae* (Rocha et al. 2009).

A possible explanation for the increase in the density of the *C. littoralis* population at Grussaí is the establishment of a

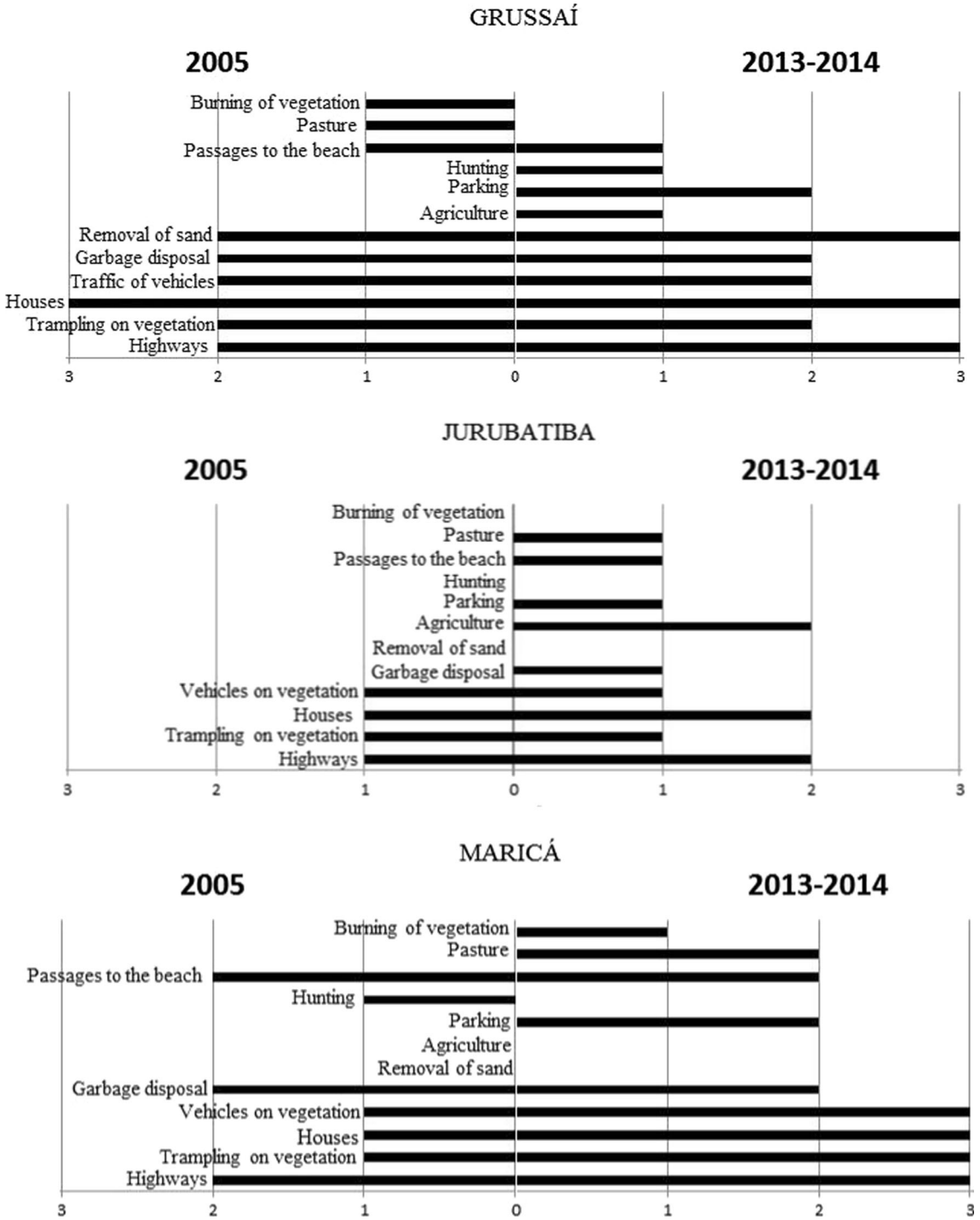

Fig. 2 Estimated degradation degree of each type of source of disturbance recorded in the restingas of Grussaí, Jurubatiba and Maricá in 2005 and 2013/2014. The values in the horizontal bar means that the type of disturbance was: 0- not found; 1- rare; 2- frequent; 3- very common

Private Natural Heritage Reserve (RPPN- Reserva Particular do Patrimônio Natural) in 2011, which may have contributed to a reduction in human activities and habitat degradation. Alternatively, this increase in density might be a consequence of the agglomeration of individuals within a small remnant of restinga isolated by the destruction of the habitat for house-building. The Grussaí restinga is distributed in two tracts, separated by the Iquipari lagoon, of which, one is much larger, representing approximately 80 % of the total habitat. As most of the lizards were recorded in the smaller tract (50 % in Density I and 100 % in Density II), the progressive reduction in the area of available habitat over the years may have resulted in the isolation of the local lizard population in this small area (bordered to the south by the Iquipari Lagoon and to the

Table 3 Total area of each restinga studied (ha), type and extension (ha) of the disturbances in the buffer area around the transects, number of disturbance and index of degradation estimated (total area of disturbance/total area of the restinga × 100) for each restinga studied in Rio de Janeiro State, southern Brazil

	Grussaí	Jurubatiba								Maricá
Total area of the restinga (ha)	375.45	24,501.83								155.41
Type of disturbance	Dirt road	Harbour	Urban area	Bicycle path	Constructions	Coconut trees	Dirt road	Railway	Houses	Dirt road
Disturbed area (ha)	0.41	8.37	154.09	1.68	130.08	158.28	4.87	5.44	0.02	3.14
Total area of disturbance	8.78	454.48								3.14
Number of disturbance sources	11	10								11
Index of degradation	2.34	1.85								1.99
Density of lizards (DII) (ind/ha)	5.05	17.78								11.49

north by urbanization). This agglomeration of individuals within a small area has likely contributed to an increase in competition for space, shelter and food, which may eventually lead to a decline in the population.

Both methods used to estimate Density I indicated a decline in lizard density in the Jurubatiba and Maricá restingas, but an increase at Grussaí. As the results of the different methods may vary with differences in habitat and detectability, a number of factors should be taken into account in studies of population density (Bennett and Gorman 1979). Visual censusing is considered to be an efficient and minimally invasive method for teiids, due to the difficulties of capturing these lizards (Radder et al. 2005). However, this method may underestimate population density due to the assumption that all individuals are encountered and observed along the transect, which may not always hold (Bennett and Gorman 1979). The estimates provided by the DISTANCE program nevertheless adjust estimates for detection error (Buckland et al. 1993). It is important to consider that the number, size and arrangement of the transects may also affect results, especially in comparative studies (Milstead 1965).

Comparing the DISTANCE estimates of the I and II surveys, Density II was 72.8 % higher than Density I at Jurubatiba, 53 % higher at Grussaí, and 38.8 % lower at Maricá. This may reflect the more representative distribution of the surveys in Density II, which would have allowed the software algorithm to better detect the influence of the variation in vegetation and disturbance on the lizard populations.

The population density of *C. littoralis* was highest in the Jurubatiba restinga, which is the largest of the three sites, and the least disturbed, while the lowest density was recorded at Grussaí, which had the highest degradation index. The evidence indicates clearly that Jurubatiba, which has the best conservation status and the protection of a national park, now has the safest population. However, considering the very limited occurrence of this lizard species, which is known from only four localities, the protection of the other two sites should also represent an important contribution to the conservation of *C. littoralis*.

The area of the Grussaí restinga was reduced considerably by the construction of Porto do Açu shipping complex, further accentuated by local urbanization. This resulted in the removal of much of the original vegetation, making this area potentially vulnerable to the local extinction of *C. littoralis* in the near future. It will thus be crucial to monitor the *C. littoralis* population at Grussaí systematically, in order to identify shifts in numbers and the need to adopt measures to prevent local extinction. The conservation status of the Maricá restinga is intermediate between these two sites, as observed in 2005 (Menezes and Rocha 2013), although population density had decreased over time. As Maricá has the smallest area of restinga, further habitat loss may cause irreversible damage

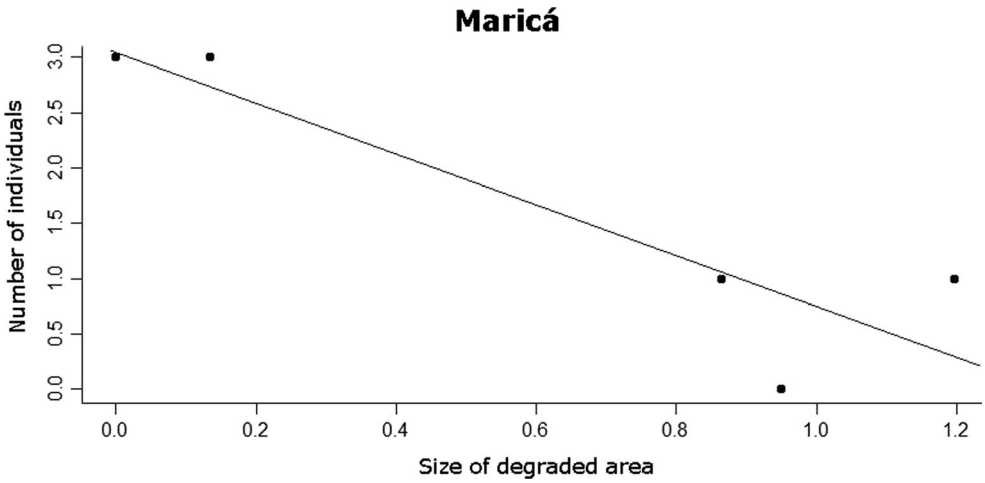

Fig. 3 Relationship between the number of lizards and the size of degraded area (ha) around the transects in restinga of Maricá (negative relationship)

to the local *C. littoralis* population, representing an additional source of risk.

The types of habitat degradation recorded in the present study have already been documented on the Brazilian coast (e.g. Rocha et al. 2005, 2009; Menezes and Rocha 2013). However, the quantitative effects of these impacts on the population dynamics of lizards are still unknown (Warner 2000). Our study indicated a progressive reduction in the density of two *C. littoralis* populations (Jurubatiba and Barra de Maricá), which represent half of the known localities of the species in Rio de Janeiro. We found a negative relationship between the total area of degraded habitat and the density of individuals sighted in the transects. Nevertheless, additional studies measuring the effects of the different types of disturbance on lizard population dynamics will be needed in order to apply efficient management plans for the conservation of this endangered species.

Our data indicate that road-building (paved and unpaved) was the most frequent disturbance in the restingas where *C. littoralis* occurs. This type of degradation may have negative effects, even in the vicinity of protected areas, due to the clearance of vegetation and landscape changes, such as habitat fragmentation and edge effects, as well as direct risks to the fauna from roadkill and the formation of potential barriers to dispersal (Fahrig et al. 1995; Prado et al. 2006).

The principal sources of disturbance documented in 2005 were still present in all three restingas. Six types recorded at Grussaí in 2014 were already documented in 2005 by Rocha et al. (2007), and new impacts included commercial sand quarrying, parking, hunting and the presence of domestic animals, which were not observed in the previous study. The overall degree of degradation estimated for the Grussaí restinga increased between 2005 and 2014, with impact increasing in eight of the 12 degradation categories. At Jurubatiba, all types of disturbance, except the clearing of vegetation for beach access, were recorded in 2005 by Rocha et al. (2007). Three new types of impact were identified in the present study – parking, grazing animals and pets. Even though it was considered the area with the best conservation status in the present study, overall degradation increased the most in the Jurubatiba restinga. At Maricá, we recorded four types of degradation (fire damage, parking, grazing animals and pets) that were not recorded by Rocha et al. (2007), and one type of impact – religious practices – not observed at all in 2005. While Maricá remained in an intermediate position relative to the other areas, it was the restinga with the largest number of types of degradation, all but one of which increased in their level of impact. One notable impact is the expansion of urbanization. In the 1980s, the Barra de Maricá region was considered to be the only unsettled area between Niterói and Ponta Negra (Silva and Somner 1984), but this restinga is now located within an urban area, and is surrounded by a large number of homes. The increasing degradation over the years in all restinga areas studied here is worrisome, and strengthens the need for urgent protection measures.

While not all kinds of environmental degradation have negative impacts on lizard species (e.g. Lettink et al. 2010), habitat loss and fragmentation are fundamental problems for the long-term survival of most species (Hokit et al. 1999). To guarantee the conservation of the endangered *Cnemidophorus littoralis*, we recommend the following actions: (1) the establishment of programs to eliminate sources of disturbance and reconstruct restinga habitats; (2) periodic standardized sampling to monitor fluctuations in the density of the *C. littoralis* population in the four restingas where the species occurs; (3) the systematic long-term collection of quantitative data on degradation rates to support analyses and conservation planning; (4) the establishment of species- and habitat-focused environmental education programs in the municipalities where *C. littoralis* occurs; and (5) the redefinition of Barra de Maricá Environmental Protection Area as a more effective category of protected area, such as a Biological Reserve, given the current lack of effective protection for its important population of *C. littoralis*. Ultimately, we conclude that all types of

disturbance increased progressively over the years, with negative consequences for the density of local *C. littoralis* populations, which have decreased in numbers at two of the three study sites.

Acknowledgments This study was supported by the Conselho Nacional do Desenvolvimento Científico e Tecnológico-CNPq (Process: 472,287/2012–5). We thank Vitor Borges, Catia Militão and Patrícia Santos for field assistance and Davor Vrcibradic and David F. Freitas for reviewing the manuscript. We thank the personnel of the the Reserva Particular do Patrimônio Natural Fazenda Caruara and Parque Nacional da Restinga de Jurubatiba for allowing acess to those areas. We also thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior –CAPES, for funding part of the project.

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