

Density and population size of mammals introduced on a land-bridge island in southeastern Brazil

Ricardo Siqueira Bovendorp · Mauro Galetti

Received: 16 March 2006 / Accepted: 2 June 2006
© Springer Science+Business Media B.V. 2006

Abstract The introduction of alien species is one of the main threats to the conservation of native species, especially in island ecosystems. Here, we report on the population growth of 15 species of mammals introduced in 1983 on the island of Anchieta, an 828 ha land-bridge island in southeastern Brazil. We estimated the density of mammals through 296 km of line transect census. Five species introduced became extinct (coypu, brocket deer, six-banded armadillo, nine-banded armadillo, maned three-toed sloth); six became overabundant (marmoset, coati, agouti, seven-banded armadillo, and capybara); one has a stable population (capuchin monkey). Anchieta Island has the highest density of mammals in the entire Atlantic forest (486.77 ind/km²), especially nest predators (232.83 ind/km²) and herbivores (253.58 ind/km²). Agoutis (*Dasyprocta* spp.) and marmosets (*Callithrix penicillata*) were, by far, the species with the highest population growth. The high density of mammals in this island may have strong consequences for plant recruitment and bird diversity.

Keywords Distance sampling · Exotic species · Herbivores · Line transect · Nest predation

Introduction

The introduction of species on ocean islands has frequently been cited as one of the great threats to the local biota and maintenance of these ecosystems (Emmel 1976; O'Dowd et al. 2003). Many species introduced on islands experience explosive population growth due to the lack of predators, parasites, and competitors (Emmel 1976). For instance, in 1957, wild goats were introduced into the island of Pinta, in the Galapagos Islands, Ecuador, and 15 years later, the National Park Service slaughtered 30,000 goats, when the population was estimated to be 100,000 animals (Emmel 1976). The impact of these herbivores in the Galapagos has been disastrous for various native plant species (Edington et al. 1979).

In Brazil, the impact of the introduction of exotic species has been studied little. In Fernando de Noronha archipelago, tegu lizards and rats have been cited as the greatest threat to local biodiversity (Péres Jr. 2003). On the island of Anchieta, off the northern coast of the state of São Paulo, the São Paulo Zoo introduced 15 species of mammals, and two of reptiles, in 1983. Since then, no information exists regarding the population status of these introduced species and their impact on local biodiversity. This study seeks to evaluate the population size and density of the mammal species introduced, as well as

R. S. Bovendorp · M. Galetti (✉)
Departamento de Ecologia, Laboratório de Biologia da Conservação, Universidade Estadual Paulista (UNESP), CP 199, 13506-900 Rio Claro, SP, Brazil
e-mail: mgaletti@rc.unesp.br

native species, on the island of Anchieta after 22 years.

Study area

On the coast of the state of São Paulo, there are 106 islands, 23 islets, and 20 rocky formations with almost no vegetation (Furlan 1998). At least one third are legally protected in Integral Protection Units. Nevertheless, various species of flora and fauna have decreased in number as a result of human actions.

The island of Anchieta ($23^{\circ}27'S$; $45^{\circ}02'W$), in Ubatuba, north coast of São Paulo state, Brazil, measures 828 ha, making it the second largest island on the northern coast of the state (Fig. 1). The island has a long history of human occupation and held a prison in the 1950s. In 1977, the island was transformed into a State Park, and today its entire area belongs to the Anchieta Island State Park. The island is one of the largest tourist attractions in the state, second only to the mountains of Campos de Jordão State Park. The vegetation on the island is composed of coastal Atlantic rainforest, with coastal plains where notable features include a stretch of restinga, and large areas of disturbed vegetation now occupied by ferns (*Gleichenia*). Because it is situated on a relief of cliffs, it could be said to have an extremely



Fig. 1 Location of Anchieta Island, Ubatuba, São Paulo, southeastern Brazil

fragile equilibrium, where natural avalanches and landslides are common (Cruz 1974).

In March of 1983, the São Paulo Zoo Foundation introduced various animals with the intent of “re-composing” the fauna on the Island of Anchieta (Guillaumon et al. 1989). Little is known about mammal fauna on the island prior to human occupation. However, it is probable that it was similar to that present on the continent, given its proximity (540 m), except for the presence of large predators (like the jaguar and the cougar).

Materials and methods

Mammal census

The method employed to calculate the population density of the mammals on Anchieta Island was the line transect census (Buckland et al. 1993). Census using line transects is probably the most common method used to estimate the density of medium and large mammals in tropical regions (Peres 1990; Bodmer et al. 1997). To apply this method, 296 km were walked on four established trails (Sul, Leste, Pedra do Navio, and Saco Grande), varying from 1.5 to 3.5 km long. We walked 123 km in the dry season (winter) and 173 km in the wet season (summer). The trails were walked slowly (approximately 1 km/h) between 6:30 and 11:30, 17:30 and 18:00, and at night from 21:00 to midnight. The densities and encounter rates were analyzed using the software DISTANCE (4.1) (<http://www.ruwpa.st-and.ac.uk/distance/>) (Buckland et al. 2001).

The population density of each species was estimated by multiplying the area of the island (not including the rocky coasts, beaches, and urban areas) by the estimated density. Only the forest-dwelling species were based on the forest cover of the island, which today measures 75%, or 615 ha of dense, broad-leaved hardwood forest (M. Fleury, unpublished data); whereas, for the species that use open fields and *Gleichenia* patches, we considered the whole island as potential habitat.

Results

One hundred and ninety-three samples were collected, totaling 296 km perambulated on the

four trails on Anchieta Island. Two hundred and thirteen kilometers were walked during the day and 83 km at night. In March of 1983, 100 mammals were introduced onto the island, and our census showed 32 times more animals on the island nowadays ($N = 3223$ animals sighted).

Of the 15 species introduced in 1983, five species were not recorded and are probably extinct. Examples of extinct species include the six-banded armadillo (*Cabassous tatouay*), brocket deer (*Mazama gouazoubira*), coypu (*Myocastor coypus*), nine-banded armadillo (*Euphractus sexcinctus*), and maned three-toed sloth (*Bradypus variegatus*). The only species that remained on the island until approximately the year 2000 was the coypu (M. Fontes, personal communication); however, no individuals were recorded in our census. The sloth that was introduced died before its release on the island.

Two species of agoutis were introduced (*Dasyprocta azarae* and *leporina*). In the present study, the individuals recorded in the sample were identified only at the level of genus due to difficulty in distinguishing between the specimens *Dasyprocta azarae*, *leporina* and possible hybrids.

Nine species were sighted, eight of which had been introduced on the island in 1983 (Table 1). There were a total of 497 sightings, with 946 individuals sighted. The mammal density on the Island of Anchieta is estimated in 486.77 ind/km². The density of nest predators (coati, capuchin monkey, and opossum) was 232.83 ind/km², and of herbivores (cabybara, agouti, and paca), 253.58 ind/km².

The species with the highest population densities and largest populations were the agouti and the marmoset (Table 1). The population of agouti increased by 161 and marmoset by 144 times the number introduced, followed by capybara (38 times), and the coati (12 times). The only species whose population remained stable was the Capuchin monkey, of which 33 individuals were introduced; today there are about 35 animals on the island (Table 1).

Only for the paca and porcupine it were not possible to estimate the population size and density, as there was only one sighting for each species. Although only one lesser anteater was introduced, we recorded at least three individuals;

Table 1 Introduced species and current population size and density of mammals on the island of Anchieta, São Paulo, Brazil

Order	Species	Body size (kg)	No of animals introduced	Mean Densities (Min–Max) (ind/km ²)	Mean Biomass (Min–Max) (kg)	Population size (Min–Max)
Marsupialia	<i>Didelphis aurita</i>	1,04	Present on the island	68.80 (41.65–113.62)	71.62 (44.35–117.52)	450,15 (272–743)
Xenarthra	<i>Dasyopus novemcinctus</i>	3,54	1 (possibly present)	45.23 (29.44–69.49)	160.11 (104.21–245.99)	295,93 (192–454)
Xenarthra	<i>Bradypus variegatus</i>	3,90	1	Extinct	Extinct	Extinct
Xenarthra	<i>Cabassous tatouay</i>	5,35	2	Probably extinct	Probably extinct	Probably extinct
Xenarthra	<i>Euphractus sexcinctus</i>	5,40	2	Probably extinct	Probably extinct	Probably extinct
Xenarthra	<i>Tamandua tetradactyla</i>	4,56	1	0.36 (0.12–0.60)	1.64 (0.54–2.73)	3
Carnivora	<i>Nasua nasua</i>	3,880	13	25.06 (14.72–42.67)	97.23 (57.11–165.55)	163,96 (96–279)
Primates	<i>Callithrix penicillata</i>	0,25	5	110.29 (83.34–145.94)	28.56 (21.58–37.78)	721,62 (545–954)
Primates	<i>Cebus nigritus</i>	3,44	33	4.2 (3.43–5.26)	14.46 (11.81–18.09)	27,48 (22–34)
Rodentia	<i>Dasyprocta azarae</i> and <i>leporina</i>	2,16	8	197.53 (156.81–243.82)	428.00 (339.8–528.35)	1292,43 (1026–1595)
Rodentia	<i>Hydrochaeris hydrochaeris</i>	31,5	7	35.30 (19.56–63.75)	1112.00 (616.14–2008.00)	272,51 (151–492)
Rodentia	<i>Agouti paca</i>	8,35	6	rarely seen	?	?
Rodentia	<i>Sphiggurus villosus</i>	1,3	7	Not seen	?	?
Rodentia	<i>Myocastor coypus</i>	4,2	11	Probably extinct	Probably extinct	Probably extinct
Artiodactyla	<i>Mazama gouazoubira</i>	16,00	3	Extinct	Extinct	Extinct

two of these were found dead, and had probably come from the continent, or were bred from a possibly pregnant female introduced.

Only one native species, the opossum (*Didelphis aurita*), was sampled during the census, but it is likely that the seven-banded armadillo also occurred in the island when a new individual was introduced in 1983. No other species were recorded that could occur on the island and that occur on the continent, such as sloths, howler monkeys, and other medium-sized marsupials (e.g. *Caluromys*, *Philander*, *Metachirus*).

Discussion

The mammal fauna on the island of Anchieta is quite impoverished due to its isolated location, as well as past human impact. The island was a penal colony for many years and was home to 200 families in 1881 (Guillaumon et al. 1989). Only one species of mammal was found in the census that was not introduced in 1983, showing that the current mastofauna is composed predominantly of introduced species. Forest fragments of similar size can shelter at least 21 mammal species of medium-to-large size (Chiarello 1999; Cullen et al. 2001). Given its proximity to the continent and its size (828 ha), the island could shelter some species that were not sampled in this study, such as sloths (*Bradypus variegatus*), deer (*Mazama* spp.), and even small cats (such as the margay, *Leopardus wiedii*).

Although five of the 15 species introduced did not establish themselves on Anchieta Island, the density of mammals is the highest found to date in the Atlantic Forest (Table 2). Chiarello (2000) found a density of mammals almost 10 times lower in the Linhares Reserve, in the state of Espirito Santo (Table 2).

The high density of introduced species found is probably due to the absence of large top predators that could control their populations Terborgh et al. (2001). On the island of Barro Colorado (BCI), in Panama, high densities of mammals have been found following its isolation (Glanz 1982; Wright et al. 1994). Wright et al. (1994) reported a density of mammals almost 1,42 times lower at BCI than on the island of Anchieta

Table 2 Total density of non-flying mammals of medium and large size in different localities

Study area	Density (ind/km ²)	Reference
Linhares, ES, Brazil	120.32	Chiarello (2000)
Sooretama, ES, Brazil	88.9	Chiarello (2000)
Caetetus, SP, Brazil	74.36	Cullen et al. (2001)
Morro do Diabo, SP, Brazil	74.60	Cullen et al. (2001)
Anchieta Island, SP, Brazil	486.77	this study
BCI, Panama	341.1	Wright et al. (1994)

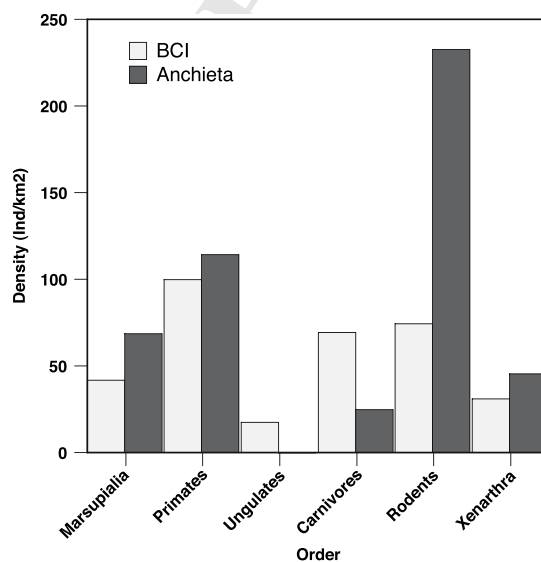


Fig. 2 Comparison of density of mammals on Anchieta Island, Ubatuba, SP, Brazil, and the island of Barro Colorado (BCI), Panama

(Fig. 2). The density of almost introduced orders are higher at Anchieta island than in BCI, only the biomass of ungulates and carnivores are higher at BCI (Fig. 2).

Exotic species can alter the physiognomy and structure of the system and produce drastic alterations in other trophic levels (Glanz 1982; Terborgh et al. 2001; Courchamp et al. 2003; O'Dowd et al. 2003). The introduction of large herbivores and carnivores has caused the extinction of native species or complete alteration of insular ecosystems (see references in Quammen 1996).

On the island of Anchieta, the high density of herbivores and nest predators is directly affecting the recruitment of plants (Fadini 2005), as well as

the survival of various species of birds, due to the predation of nests (Galetti et al. submitted). The inconsequent introduction of species on this island caused a disproportional increase in the population of some species. There is an urgent need to eradicate some species (capybaras and marmosets) and control the abundance of others (agoutis, coatis, and armadillos) (Courchamp et al. 2003). Currently, the legislation, environmental agencies, and public opinion continue to be mistaken with respect to exotic or invasive species, which hampers the management of charismatic animals such as mammals in diverse areas.

Acknowledgments We would like to thank FAPESP (Project Biota 2001/14463-5), the International Foundation for Science (IFS), conservação Internacional (Brasil) and idea Wild for the financial support. We are also grateful to the Instituto Florestal for the permission to work on Anchieta Island. R. Bueno, M. Soares and R. M. Marques for invaluable help in the field work. MG is a CNPq research fellow and RSB received a research grant from PIBIC-CNPq.

References

- Bodmer RE, Heisenberg JF, Redford KH (1997) Hunting and the likelihood of extinction of Amazonian mammals. *Conserv Biol* 11:460–466
- Buckland ST, Anderson DR, Burnham KP, Laake JL (1993) Distance sampling: estimating abundance of biological populations. Chapman and Hall, New York
- Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L (2001) Introduction to distance sampling. Oxford University Press, Oxford, p 432
- Chiarello AG (1999) Effects of fragmentation of the Atlantic forest on mammal communities in south-eastern Brazil. *Biol Conserv* 89:71–82
- Chiarello AG (2000) Density and population size of mammals in remnants of Brazilian Atlantic forest. *Conserv Biol* 14: 1649–1657
- Courchamp F, Chapuis JL, Pascal M (2003) Mammal invaders on islands: impact, control and control impact. *Biol Rev* 78:347–383
- Cruz O (1974) A serra do mar e o litoral na área de Caraguatatuba, SP – Contribuição à geomorfologia litorânea e tropical. Série Teses e Monografias – IGEOG 11:1–181
- Cullen L Jr, Bodmer RE, Valladares-Padua C (2001) Ecological consequences of hunting in Atlantic forest patches, São Paulo, Brazil. *Oryx* 35:137–144
- Edington JE, Edington MA (1979) Ecology and environmental planning. Chapman and Hall, London, p 246
- Emmel CT (1976) Population biology. Chapman and Hall Ltd, London, p 371
- Fadini RF (2005) Limitações bióticas afetando o recrutamento da palmeira *Euterpe edulis* em uma ilha continental da mata Atlântica Dissertação de mestrado em Ciências Biológicas em Botânica
- Furlan JD (1998) Modelagem de objetos através da UML – the Unified Modeling Language. Makron Books, São Paulo
- Glanz WE (1982) The terrestrial mammal fauna of Barro Colorado Island: censuses and long-term changes. In: Leigh EG Jr, Rand AS, Windson DM (eds) The ecology of a tropical forest: seasonal rhythms and long-term changes. Smithsonian Institution Press, Washington, D.C, pp 455 – 468
- Guillaumon JR et al (1989) Plano de Manejo do Parque Estadual da Ilha Anchieta. IF – Série Registros, São Paulo, p 103
- O’Dowd DJ, Green PT, Lake PS (2003) Invasional ‘meltdown’ on an oceanic island. *Ecol Lett* 6:812–817
- Peres CA (1990) Effects of hunting on western Amazonian primate communities. *Biol Conserv* 53:47–59
- Péres AK Jr (2003) Sistemática e Conservação de Lagartos do Gênero *Tupinambis* (Squamata, Teiidae). Tese de Doutorado, Departamento de Zoologia, Universidade de Brasília, p 193
- Quammen D (1996) The song of the Dodo. Island biogeography in an age of extinctions. Pimlico, Londres
- Terborgh J, Lopez L, Nunez P, Rao M, Shahabuddin G, Oriuela G, Riveros M, Ascanio R, Adler GH, Lambert TD, Balbas L (2001). Ecological meltdown in predator-free forest fragments. *Science* 294:1923–1926
- Wright SJ, Gomper ME, Deleon B (1994). Are large predators keystone species in Neotropical forests? The evidence from Barro Colorado island. *Oikos* 71:279–294