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Hyper abundant mesopredators and bird extinction in an Atlantic forest island

Mauro Galetti [1]; Ricardo S. Bovendorp [1]; Rodrigo F. Fadini [1, 2]; Carlos O. A. Gussoni [1]; Marcos Rodrigues [3]; Ariane D. Alvarez [1]; Paulo R. Guimarães Jr [4] & Kaiser Alves [1]

[1] Laboratório de Biologia da Conservação, Departamento de Ecologia, Universidade Estadual Paulista. Caixa Postal 199, Rio Claro 13506-900, São Paulo, Brasil. Email: mgaletti@rc.unesp.br

[2] Coordenação de Pesquisas em Ecologia, Instituto Nacional de Pesquisas da Amazônia. 69011-970 Manaus, Amazonas, Brasil.

[3] Departamento de Zoologia, Universidade Federal de Minas Gerais. Caixa Postal 486, 31270-901 Belo Horizonte, Minas Gerais, Brasil.

[4] Department of Ecology and Evolutionary Biology, University of California. Santa Cruz, 95060, CA, USA.

ABSTRACT. Islands can serve as model systems for understanding how biological invasions affect native species. Here we examine the negative effects of mesopredator mammals on bird richness at Anchieta Island, an 826 ha offshore island in the coast of Brazil. Anchieta Island has the highest density of mammals of the entire Atlantic forest, especially nest predators such as marmosets and coatis, introduced more than 20 years ago. This indiscriminate introduction of mammals may have affected directly the bird community, nowadays represented by 100 species comprised mainly by water-crossing birds, being 73 forest-dwelling species. A small component of these remnant bird species nests in tree holes and on the forest floor, null model analysis suggest that birds within these two nest types are under-represented on Anchieta Island. All guilds were affected negatively, but "opportunist insectivorous/omnivorous". Experiments using artificial nests showed a predation of 73% of nests on the floor while only 26% on the mainland. Camera traps recorded predation by coatis, agoutis, and opossums. The restoration of the bird community on this island is highly constrained by the high density of hyper abundant nest predators.

KEY WORDS. *Callithrix*; exotic species; line transect; mesopredator release; null models.

The introduction of vertebrate alien species is one of the main threats to the conservation of native species, especially in island ecosystems (e.g. Bibby 1995, Clout 2002). Mammal populations when introduced on islands usually became hyper abundant due to the absence of their predators, competitors and parasites (Emmel 1976, Vitousek *et al.* 1995, Terborgh *et al.* 2001), and they represent one of the most important taxa concerning biological invasions on such habitats. In fact, a small number of mammal species is responsible for most of the damage to invaded insular ecosystems, such as rats, cats, goats, rabbits, pigs and a few others (Courchamp *et al.* 2003, Cuthbert & Hilton 2004). Islands with more exotic mammal predator species have lost a greater proportion of their avifauna since European colonization (Blackburn *et al.* 2004). Cats and rats have a strong impact on nest and bird predation (Robinet *et al.* 1998, Thibault *et al.* 2002, Nogales *et al.* 2004).

The Atlantic Forest has one of the highest rate of bird endemism on the planet (Wege & Long 1995) comprising an avifauna of 682 species, including 199 endemics and 144 threatened species, most due to habitat loss (Stotz *et al.* 1996). Islands are the most disturbed components of the entire Atlantic forest ecosystem because they have long history of human occupation and because they are more susceptible to human impact (Olmos 1996, Naka *et al.* 2002). One of these islands is Anchieta Island, in southeast Brazil. In 1983, the São Paulo Zoo introduced in this island 100 mammals from 15 species which originally occurred in the mainland of the Atlantic forest or in Brazilian savannas (Cerrado) such as agoutis, coatis, and marmosets (Bovendorp & Galetti 2007). After 24 years, some mammal species increase 140 times, many of which are nest predators (Bovendorp & Galetti 2007, Alvarez *et al.* 2008, Bovendorp *et al.* 2008). Today, Anchieta Island represents an excellent opportunity to study the impact of introduced mammals on avian extinction at the Atlantic forest.

In this paper we examine the bird diversity at Anchieta Island and test if the absence of some species is due to high predation risk on certain nesting types. We hypothesized that in an island characterized by a hyper abundance of mesopredators some bird nesting types would be more sensitive to predation and the loss of bird species does not follow a random process.

MATERIAL AND METHODS

The Anchieta Island has 826 ha and is located in the north of São Paulo state, 400 m offshore from Ubatuba, São Paulo state, south-east Brazil (45°02'W, 23°27'S, Fig. 1). On the mainland,

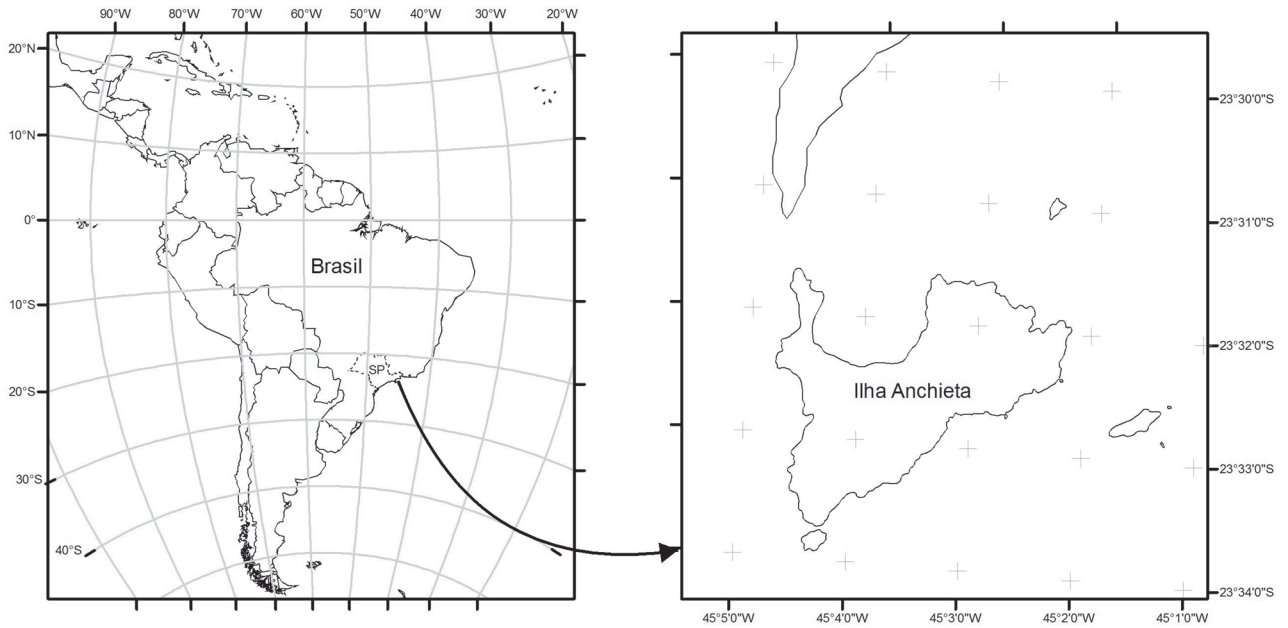

Figure 1. Location of Anchieta Island in the coast of Brazil (based in M. Fleury, unpubl. data).

the Atlantic coastal forest holds one of the highest levels of terrestrial biodiversity on Earth (Myers *et al.* 2000). The Serra do Mar, to which Anchieta Island is geologically related, is one of the key centers of species endemism (Silva *et al.* 2004). The island is composed of two hills of up to 330 m above sea level. Pigs, dogs, cats, and the domestic fowl were brought to the island in order to sustain its human community in the beginning of the last century, especially during the years when a prison was active (1904-1955) (Guillaumon *et al.* 1989). The island was transformed in a state park in 1977 and nowadays about 90,000 tourists visit the island per year, especially in the summer, imposing a considerable impact on the island's biodiversity (M. Robim, Instituto Florestal, pers. com).

Bird survey

We sampled the bird community at Anchieta Island during 23 months (from July 2003 to June 2004 and from December 2005 to January 2007, excluding March and May 2006), totalizing more than 678 hours of observations along the trails, including point counts censuses (Fadini *et al.* 2009) and 380 hours of mist netting. All birds observed on the island were grouped into categories according to (1) habitat (forest, forest edge or open areas); (2) occurrence status (resident or non-resident); (3) relative abundance (common, rare or vagrant); (4) gap crossing ability (water-crossing and no water crossing) and (5) nesting characteristics. Each bird species was assigned a nest category as follows: aerial-opened, aerial-closed, cavity, ground-opened, ground-closed; nest parasite (see Sieving 1992). Nest characteristics were obtained from literature (Sick 1997) and our previous experience. We divided the bird community into twelve feeding guilds, based on Aleixo & Vielliard (1995), and Anjos & Boçon (1999).

Statistical Analysis

We investigated if guild and nest category affect the extinction of birds at Anchieta Island using a null model approach (Gotelli & Graves 1996). The idea underlying our null model is that bird assemblage of Anchieta Island is essentially a random sample of bird species from the mainland (Caraguatatuba). Indeed, more than 89% of bird species of Anchieta Island also occur on the mainland and the seven species that occur solely at Anchieta were discarded from null model analyses. Sea birds were not included in our comparisons. If extinction is not related to biological attributes such as nesting habitats and guilds, we expected that the loss of species due to smaller size of the island and/or effects of introduced species would be essentially a random process, that is, all species have the same extinction risk. We simulated random extinctions on the mainland assembly until the number of bird species reaches the same of Anchieta Island. Random extinctions are simulated as follows: we randomly sorted the number of species on Anchieta (n = 73) from the pool of Caraguatatuba species (n = 199). We repeat this process 1,000 times, recording the number of sorted species in each guild or nest category. Our statistic (p) is the probability that a random replicate has a number of species equal to or more extreme than the observed value (Manly 1997).

We estimated the number of forest-dwelling bird species that would occur on an inshore island, comparing a dataset of 17 bird lists from land-bridge islands in the Atlantic forest in southeast Brazil. All of these islands were connected to the

mainland in the Pleistocene and are close to the mainland. We plotted the log of island area *vs.* the number of forest-dwelling species. The functional form of the relationship followed a power-law and we fitted the distribution using a least-square log-log regression. We therefore predicted the number of forest-dwelling species at Anchieta Island. This regression curve is, however, an underestimation of the probably bird diversity because all islands had recently local extinctions due to human disturbance.

Nest predation experiments

To evaluate the impact of mesopredators on bird reproduction, we performed an experiment using artificial nests with quail eggs (see Alvarez & Galetti 2007). Thirty nests on the ground and on the understory vegetation (~1.3 m of height) were placed at Anchieta Island and in the mainland (Caraguatatuba). Each nest was composed of two quail eggs (*Coturnix coturnix*, Linnaeus, 1758, Phasianidae, 2.5-3 cm of length). Quail eggs underestimate the overall nest predation, because some mesopredators are not able to break them (Alvarez & Galetti 2007). However, due to logistic limitations we decide to use quail eggs instead of canary or plasticine eggs.

The nests on the ground were made using the available botanical matter (Maier & DeGraaf 2000), while the understory nests (10 cm of diameter, 3.5 cm of height) were camouflaged with litter. Nests were placed at intervals of 25 m along trails. After seven days, the number of eggs preyed upon was recorded. We assumed that either broken or missing eggs were preyed on by vertebrates. Rubber boots and gloves were used during the experiment to minimize human scent and, consequently, reduce experimental bias (Burke *et al.* 2004). In order to identify the potential nest predators we used two camera traps during 311 hours in nests on the ground and 288 at 1.3 m height at Anchieta Island. At the mainland we left the cameras for less time (60 hours for ground nests) and 36 hours (for aerial nests).

RESULTS

Bird species richness and guild losses

We recorded 100 bird species at Anchieta Island, and 73 forest-dwelling species (Appendix I). We compiled information of 15 land-bridge islands in the coast of Brazil (Tab. I) and plotted a species-area curve to determine the number of species predicted by the size of Anchieta (Fig. 2). We found a strong correlation between island size and number of forest-dwelling bird species ($r^2 = 0.75$, $p < 0.0001$) (Fig. 2). Therefore, the number of species found in Anchieta Island is predicted by the species-area relationship (Fig. 2).

Foraging guilds were severely impoverished at Anchieta Island. Nevertheless, the current bird composition at Anchieta Island is almost entirely reproduced by our null model that assumes random extinctions (Tab. II). The proportion of birds in the guild "opportunist omnivorous/insectivorous" was the only one that differed in relation to the mainland, increasing

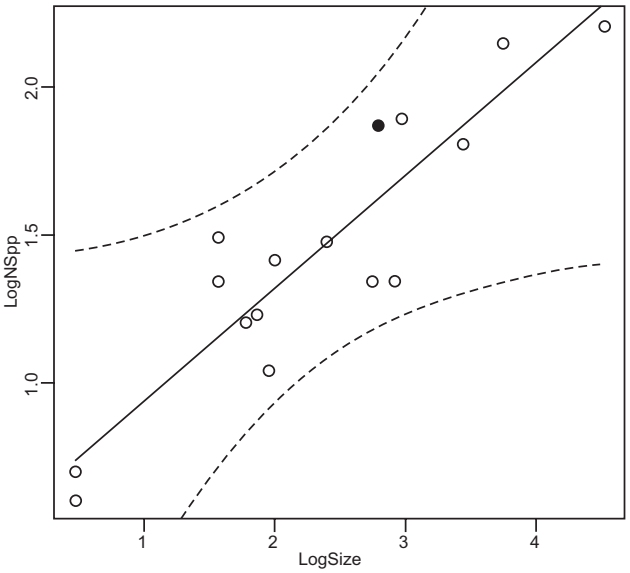

Figure 2. Regression curve of the species-area relationship (Log-transformed) of the bird richness and island size in offshore islands in the coast of Brazil. Dot lines are confidence intervals and the black dot is the Anchieta Island.

Table I. Bird species richness and island size on the inshore islands in the Atlantic rain forest, Brazil.

Site	Size (ha)	Number forest dwelling species	Reference
Costa, RJ	3	4	1
Pombas, RJ	3	5	1
Pombeba, RJ	3	5	1
Galhetas, PR	37	31	2
Palmas, PR	37	22	2
Convivência, RJ	60	16	1
Currais, PR	73	17	2
Jorge, RJ	90	11	1
Santana, RJ	100	26	1
Jaguanum, RJ	250	30	1
Cabo Frio, RJ	560	22	1
Anchieta, SP	826	73	This study
Itacuruça, RJ	830	22	1
Cotinga, PR	937	78	2
Mel, PR	2,762	64	2
Grande, RJ	5,600	140	1
Ilhabela, SP	33,356	160	3

1) Coelho *et al.* (1991), 2) Moraes (Unicamp, unpub. data), 3) Olmos (1996).

in Anchieta Island (Tab. II). Therefore, bird species in Anchieta Island is a random subset of Caraguatatuba for most guilds (Tab. II), but there was a large non-random increase of the opportunist omnivore/insectivores guild.

Extinctions were not completely random across different nesting habitats (Tab. III). There was an over-representation of bird species that nest in aerial closed sites in Anchieta Island, while there were no resident bird species that nest on the ground-opened, and only nine species (six residents and three vagrants) that nests into trunk cavities on Anchieta (Tab. III). Differently, three nesting strategies: aerial opened, ground closed, and nest parasites are small, random subsets of birds in the mainland (Tab. III).

Table III. Bird species grouped by their nest habitats on the mainland of Serra do Mar (Caraguatatuba) and Anchieta Island. The actual number of species in Anchieta is the sum of two numbers, respectively, the number of species that also occurs in Caraguatatuba (N = 60) and the number of species that only occur in Anchieta (N = 7). The expected number of species is the mean predicted by our null model (see text for further details). * $p < 0.05$.

Nest type	Site		Expected number of species for Anchieta Island
	Mainland	Anchieta	
Aerial-open	115	42+6	34.71
Aerial-closed	23	10	6.95*
Cavity	45	8+1	13.52*
Nest parasites	2	0	0.55
Ground-opened	10	2	3.04*
Ground-closed	4	0	1.17

The frequency of resident and non-resident species differed significantly between Anchieta Island and the mainland (χ^2 = 5,48, df 1, p = 0,019). About 27% of all bird species at Anchieta were non-resident, i.e. they do not breed on the island, and include a few migrants (13 species). Twenty-six species were vagrant, which means that they were observed only once at the island, while another 23 (22,77%) were rare, or with very few individuals in Anchieta (Appendix I).

Nest predation

The frequency of nest predation on the ground was higher than in the understory (73.33 vs 27%; $\chi^2 = 14.076$, df = 1, $p < 0.001$) at Anchieta, but not on the mainland (33% and 27%; $\chi^2 = 0.317$, df = 1, p = 0.573). Nest predation on the ground differed between the island and the mainland ($\chi^2 = 0.9.64$, df = 1, p = 0.0019), but not in the understory.

Camera traps recorded three species of nest predators for ground and aerial nests. Opossums (*Didelphis aurita*, Wied, 1826) were the most common nest predators on the island (10 photos), followed by agoutis (*Dasyprocta leoprina*, Linnaeus, 1758, 17 photos), coatis (*Nasua nasua*, Linnaeus, 1766, 10 photos), and tegu lizard (*Tupinambis merianae*, Linnaeus, 1758, one photo). At the mainland we recorded only the opossum (10 photos). In addition, a group of marmosets was seen preying on a juvenile of the Sayaca tanager (*Thraupis sayaca*, Linnaeus, 1766, Emberezidae) at Anchieta Island, showing that not only eggs or nestlings are vulnerable to predation.

DISCUSSION

This study shows that although the number of bird species found on Anchieta is within the predicted species richness based on a species-area relationship, some nest guilds such as ground-closed and nest parasites are absent on this island. Poaching, deforestation and the recent introduction of mesopredators are probably the major drivers of the modification to the bird community. Mesopredators may be influencing the bird composition by preying on select species and by inhibiting colonization from the mainland. Anchieta Island has twice the primate density, five times more mesopredators and four times more agoutis than several large well protected Atlantic forests on the mainland (Bovendorp & Galetti 2007).

In the past 100 years, half of the island was cleared for the prison construction, while the elevated herbivory caused by domestic pigs, goats, capybaras and agoutis, left the vegetation highly disturbed (Alvarez *et al*. 2008). This intense land use transformed the island vegetation into a secondary forest mixed with exotic and invasive species with poor fruit productivity (Genini *et al*. 2009). Only 550 ha (c. 66%) of the island is covered by secondary forest and 44% by the fern *Gleichenium* sp. and exposed soils (M. Fleury, Universidade de São Paulo, unpublished data). Therefore, forest specialists, such as the toucanets (*Selenidera maculirostris*, Lichteinstein, 1823, and *Pteroglosus bailloni*, Vieillot, 1819), the Blue-bellied parrot (*Triclaria malachitacea*, Spix, 1824), the Ferrugineous Antbird (*Drymophilla ferruginea*, Temminck, 1822) and the Rufous-breasted Leafscraper (*Sclerurus scansor*, Ménétriès, 1835), still common in the mainland, are lacking at Anchieta Island.

The bird fauna of Anchieta Island appears severely reduced when compared to adjacent mainland and forest fragments (Goerck 1997, Ribon *et al*. 2003, Faria *et al*. 2006), but it is in accordance to what has been found for other land-bridge islands in the Atlantic forest. The species abundances patterns may be quite different from the mainland because the community is dominated by a few hyperabundant species (Røv 1975,Wiens 1989). For instance, the density of *Turdus albicollis* (Seebohm, 1887) (Turdidae) is 12 times higher and *Turdus flavipes* (Vieillot, 1818) four times higher on Anchieta than on the mainland Serra do Mar (Fadini *et al*. 2009).

The relationship between island size and number of forest-dependent bird species in the land-bridge islands along the coast of the Atlantic rain forest is extremely hard to predict by the well-known models of island biogeography (MacArthur & Willson 1967), because (1) there are few surveys of birds on

most of the islands (see Coelho *et al*. 1991, Naka *et al*. 2002, Marsden *et al*. 2003), (2) many bird species were probably extinct before ornithologists became aware (see Naka *et al*. 2002). Therefore, our estimate on bird species richness from Anchieta Island is probably an underestimation of the diversity that was present before European colonization.

Many well know bird species that are expected to be found at Anchieta are lacking. For instance, the lack of game species is most evident and is probably due to heavy hunting regime in the past. Guans, as well as large other large-bodied species, are present in smaller and isolated forest fragments on the mainland. Additionally, tinamids and guans are known to crossing large open water gaps and they could cross the 400 m of sea gap between the mainland and the island. Both groups of species, represented by at least five species, are present in the mainland (R. S. Bovendorp, Universidade de São Paulo, pers. comm.).

Large frugivores that require large areas to survive (Willis 1979, Goerck 1997) such as toucans, and large psittacids, also do not occur on the island. We recorded just two species of large cotingas on Anchieta (*Procnias nudicollis* (Vieillot, 1817) and *Pyroderus scutatus* (Shaw, 1792), but they are infrequent visitors (Fadini *et al*. 2009). Forest eagles as well as falcons and birds or prey are extremely rare. Bamboo specialists, such as antbirds and ovenbirds (Rodrigues *et al*. 1994), large terrestrial ant-thrushes and even gnat-eaters are all absent at Anchieta. One of the most notable absences if the Speckle-breasted Antpitta (*Hylopezus nattereri*, Pinto, 1937), a large forest floor bird which occurred on the island just before mammal introduction (Guillaumon *et al*. 1989), but it was not recorded in our census. In this turn, we believe that most of these absences are a result of high rates of nest predation on Anchieta.

The patterns of nest predation observed in our study was similar to those recorded by Loiselle & Hoppes (1983) in Barro Colorado Island (BCI), Panama: an elevated nest predation on the floor (88%) and a lower predation of understory nests (11%). It is important to notice that these authors did not record the same pattern in the mainland (Loiselle & Hoppes 1983). Terborgh *et al*. (1997) found that islands with high densities of capuchin monkeys had overwhelmingly high levels of nest predation in the Lago Guri, Venezuela.

Our empirical and simulation results support the notion that the extinction of some bird species, especially those that nest on the floor, may be related to nest predation by the elevated abundance of mesopredators (Wilcove 1985, Gibbs 1991). In fact, the few natural nests that we found (e.g. *Amazilia* spp.) were preyed upon in a few days. Opossums and marmosets were spotted preying upon nestlings at Anchieta Island and our data with camera traps also recorded a high predation risk by coatis and opossums. Additionally, tegu lizards are also expected to predate most of the ground nests.

Nowadays, there are only two species of birds that could nest on the forest floor at Anchieta (nightjars), and there is strong evidence that ground-nesting birds have being wiped out from the island due intense nest predation. Ground-nesting birds occur even in highly disturbed small forest fragments, such as small tinamous (*Crypturellus*), quails, nightjars and several passerine birds (Aleixo & Vielliard 1995, Willis 1979). The same pattern was found for cavity-nesting birds. Only nine species nest on cavities at Anchieta, including the Sharp-tailed Streamcreeper, a bank-nesting species. The remaining four species, including two piculets and two foliage-gleaners ovenbirds, nest in tree holes. Cavity-nesting birds, such as parrots and woodpeckers are common species in the nearest mainland. At least 16 (7%) bird species in the mainland of Serra do Mar nests on the forest floor and another 37 (18%) in tree holes.

The surviving bird community at Anchieta Island

One of the main distinctions of the avifauna of Anchieta Island is between water crossing and non-water crossing species (Diamond 1984). From the 73 forest dwelling bird species recorded at Anchieta Island, 90% are known to cross open areas between fragments or sea gaps (Olmos 1996, Bierregaard & Stouffer 1997, Sick 1997). Hence, no-water crossing species that once occurred at Anchieta and became locally extinct may have serious problems in re-colonizing the island.

Most bird guilds were affected negatively at Anchieta Island, but the opportunist omnivore/insectivore edge insectivore guild was positively affected. Some guilds were severely affected. For instance, only one ant-bird species thrives at Anchieta Island (*Dysithamnus mentalis*, Themminck, 1823) and according to the "limited dispersal hypothesis" (see Sekercioglu *et al*. 2002), understory insectivores face local extinction in isolated fragmented forests, because of their relatively sedentary habits and possible behavioral avoidance of clearings (Willis 1979, Bierregaard & Stouffer 1997, Sekercioglu *et al*. 2002). The sea gap between the mainland and Anchieta Island might be a great barrier for this guild. However, it is notable that even isolated small forest fragments have more species of understory insectivores than Anchieta Island (Aleixo & Vielliard 1995).

Another missing family at Anchieta Island is the Psittacidae. Parakeets and parrots are extremely common in the mainland, even in small forest fragments (Aleixo & Vielliard 1995). Psitacids are good flyers and they can easily cross the sea gap that divides Anchieta Island from the mainland. Surprisingly, the only species recorded at Anchieta was a group of vagrant Parrotlet *Forpus xanthopterigius* (Spix, 1824), which was recorded only once. At least for parrots, the distance to the mainland is not a barrier for colonization of Anchieta.

The pattern of bird extinction found at Anchieta may also occur in many islands in the coast of the Neotropics. Most islands suffer from species introduction and forest reduction, both of which can have a significant impact on bird communities. The bird community at Anchieta Island cannot be restored if the current high densities of nest predators and herbivores are maintained. The most effective response to restore the bird community is to control the mammalian population, either by regularly reducing their numbers, or better still, by

eradicating the population of some species as a whole from the island. As a first step, we suggest the complete eradication of marmosets because it is the only "truly" exotic species, since *Callithrix penicillata* (É. Geoffroy, 1812) does not occur in the coastal Atlantic forest.

In addition, we must increase the carrying capacity of the vegetation, especially through the restoration of young secondary forest or open areas. Nowadays, Anchieta Island has one of the smallest fruit productivity in the Atlantic forest (Genini *et al.* 2009) and the tree community is dominated by few species (V.B. Zipparro, Universidade Estadual Paulista, unpublished data). Some important families for fruit-eating birds are lacking or have being severely reduced, such as Lauraceae, Myrtaceae, and Myristicaceae (V.B. Zipparro, Universidade Estadual Paulista, unpublished data). Due to the high density of mammalian seed predators or herbivores, such as agoutis and capybaras, the restoration of vegetation will only succeed if we control their populations in the island (Alvarez *et al.* 2008, Fadini *et al.* 2009).

All islands in the Atlantic coastal forest of Brazil have suffered from intense human pressure, where native vegetation has been highly disturbed and exotic species have been introduced (e.g. Olmos 1996, 2005, Naka *et al.* 2002). These "ecological paradises", highly publicized by the media are, in fact, product of chronic biological impoverishment caused by humans and the species introduced by them. Nevertheless, land-bridge islands, such as Anchieta Island, may have an important role in bird conservation in the future, since some of them are more easily protected (especially from poaching) than areas in the mainland. Once these mesopredators are controlled or become eradicated, and the forest restored to its primitive levels, some bird species will have to be reintroduced in the island because of their poor ability to cross open areas.

At the moment, Anchieta Island is probably operating as a sink area from water-crossing bird species due to the high density of nest predators incorrectly introduced by humans.

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Appendix I. Bird list of Anchieta Island, Ubatuba, São Paulo, Brazil.

Family/species	Habitat	Guild	Status	Relative abundance
Sulidae				
Sula leucogaster (Boddaert, 1783)	s	c	Non-resident	v
Phalacrocoracidae				
Phalacrocorax brasilianus (Gmelin, 1789)	s	c	Non-resident	v
Fregatidae				
Fregata magnificens (Mathews, 1914)	s	c	Resident	c
Ardeidae				
Nyctanassa violacea (Linnaeus, 1758)	r	c	Resident	r
Egretta thula (Molina, 1782)	r	c	Resident	c
Cathartidae				
Cathartes aura (Linnaeus, 1758)	f, o	c	Resident	c
Coragyps atratus (Bechstein, 1793)	f, o	c	Resident	c
Accipitridae				
Accipiter striatus (Vieillot, 1818)	f	c	Resident	r
Rupornis magnirostris (Gmenlin, 1788)	f, o	c	Resident	c
Buteo brachyurus (Vieillot, 1816)	f	c	Non-resident	v
Falconidae				
Caracara plancus (Miller, 1777)	e, o	c	Resident	c
Milvago chimachima (Vieillot, 1816)	e, o	c	Resident	c
Falco femoralis (Temminck, 1822))	e, o	c	Non-resident	v
Rallidae				
Aramides cajanea (Statius Muller, 1776)	f	ooi	Resident	c
Pardirallus nigricans (Vieillot, 1819)	r	ooi	Resident	r
Charadriidae				
Pluvialis squatarola (Linnaeus, 1758)	s	ooi	Non-resident	v
Laridae				
Larus dominicanus (Lichtenstein, 1823)	s	c	Resident	c
Sternidae				
Sterna hirundinacea (Lesson, 1831)	s	c	Non-resident	v
Columbidae				
Patagioenas cayennensis (Bonnaterre, 1792)	e, o	af		
Patagioenas plumbea (Vieillot, 1818)	f	af	Non-resident	v
Leptotila verreauxi (Bonaparte, 1855)	e, f	tg	Resident	c
Leptotila rufaxilla (Richard & Bernard, 1792)	e, f	tg	Resident	c
Geotrygon montana (Linnaeus, 1758)	f	tg	Non-resident	v
Psittacidae				
Forpus xanthopterygius (Spix, 1824)	e, f	af	Non-resident	v
Cuculidae				
Piaya cayana (Linnaeus, 1766)	e, f	ci	Resident	r

Continue

Appendix I. Continued.

Family/species	Habitat	Guild	Status	Relative abundance
Caprimulgidae				
Nyctidromus albicollis (Gmelin, 1789)	o, f	ti, ooi	Non-resident	v
Hydropsalis torquata (Gmelin, 1789)	o, f	ti, ooi	Resident	r
Apodidae				
Streptoprocne zonaris (Shaw, 1796)	f, o	ai	Non-resident	v
Chaetura meridionalis (Hellmayr, 1907)	f, o	ai	Resident	r
Trochilidae				
Glaucis hirsutus (Gmelin, 1788)	f	ni	Non-resident	v
Phaethornis ruber (Linnaeus, 1758)	f	ni	Resident	r
Florisuga fusca (Vieillot, 1817)	f	ni	Non-resident	v
Thalurania glaucopis (Gmelin, 1788)	f	ni	Resident	c
Amazilia fimbriata (Gmelin, 1788)	f, o	ni	Resident	c
Alcedinidae			Resident	
Megaceryle torquata (Linnaeus, 1766)	o, r	c	Resident	c
Chloroceryle americana (Gmelin, 1788)	o, r	c	Resident	c
Picidae				
Picumnus cirratus (Temminck, 1825)	f	tti	Resident	c
Picumnus temminckii (Lafresnaye, 1845)	f	tti	Resident	r
Dryocopus lineatus (Linnaeus, 1766)	f	tti	Non-resident	v
Thamnophilidae				
Dysithamnus mentalis (Temminck, 1823)	f	ui	Resident	c
Dendrocolaptidae				
Lepidocolaptes angustirostris (Vieillot, 1818)	o	tti	Non-resident	v
Furnariidae				
Synallaxis ruficapilla (Vieillot, 1819)	f	bi	Resident	r
Synallaxis spixi (Sclater, 1856)	e, f	ui	Resident	c
Philydor atricapillus (Wied, 1821)	f	ui	Resident	c
Automolus leucophthalmus (Wied, 1821)	f	ui	Resident	c
Lochmias nematura (Lichtenstein, 1823)	f, r	ti	Resident	r
Tyrannidae				
Leptopogon amaurocephalus (Tschudi, 1846)	f	ui	Resident	c
Elaenia flavogaster (Thunberg, 1822)	f, o	ooi	Resident	c
Camptostoma obsoletum (Temminck, 1824)	e, f, o	ui	Resident	c
Tolmomyias sulphurescens (Spix, 1825)	f	ci	Resident	c
Platyrinchus mystaceus (Vieillot, 1818)	f	ui	Resident	r
Hirundinea ferruginea (Gmelin, 1788)	o	ai	Non-resident	v
Lathrotriccus euleri (Cabanis, 1868)	f	ui	Resident	r
Fluvicola nengeta (Linnaeus, 1766)	o	ti	Resident	c
Myiozetetes similis (Spix, 1825)	e, f, o	ooi	Resident	c

Continue

Appendix I. Continued.

Family/Species	Habitat	Guild	Status	Relative abundance
Tyrannidae (continued)				
Pitangus sulphuratus (Linnaeus, 1766)	e, f, o	ooi	Resident	c
Myiodynastes maculates (Statius Muller, 1776)	f	ooi	Non-resident	v
Megarhynchus pitangua (Linnaeus, 1766)	e, f	ooi	Resident	c
Empidonomus varius (Vieillot, 1818)	e, f	ooi	Resident	r
Myiarchus swainsoni (Cabanis & Heine, 1859)	o, e	ooi	Non-resident	v
Myiarchus ferox (Gmelin, 1789)	e	ooi	Resident	c
Attila rufus (Vieillot, 1819)	f	ooi	Resident	c
Pipridae				
Chiroxiphia caudata (Shaw & Nodder, 1793)	f	ufi	Resident	c
Manacus manacus (Linnaeus, 1766)	e, f	ooi	Resident	r
Tityridae				
Pachyramphus polychopterus (Vieillot, 1818)	f	ooi	Resident	c
Vireonidae			Resident	
Cyclarhis gujanensis (Gmelin, 1789)	f	cfi	Resident	c
Vireo olivaceus (Linnaeus, 1766)	f	ooi	Non-resident	v
Cotingidae				
Procnias nudicollis (Vieillot, 1817)	f	af	Non-resident	v
Pyroderus scutatus (Shaw, 1792)	f	af	Non-resident	v
Hirundinidae				
Progne tapera (Vieillot, 1817)	o	ai	Non-resident	v
Pygochelidon cyanoleuca (Vieillot, 1817)	f, o	ai	Resident	c
Stelgidopteryx ruficollis (Vieillot, 1817)	e, o	ai	Resident	r
Troglodytidae				
Troglodytes musculus (Naumann, 1823)	o	ooi	Resident	c
Turdidae				
Turdus flavipes (Vieillot, 1818)	f	af	Resident	r
Turdus rufiventris (Vieillot, 1818)	e, f, o	ooi	Resident	c
Turdus leucomelas (Vieillot, 1818)	e, f	ooi	Resident	c
Turdus amaurochalinus (Cabanis, 1850)	e, f, o	ooi	Resident	r
Turdus albicollis (Vieillot, 1818)	f	ufi	Resident	c
Emberezidae			Resident	
Parula pitiayumi (Vieillot, 1817)	e, f, o	ci	Resident	c
Geothlypis aequinoctialis (Gmelin, 1789)	f, o	ooi	Resident	c
Basileuterus culicivorus (Deppe, 1830)	f	ui	Resident	c
Coerebidae				
Coereba flaveola (Linnaeus, 1758)	e, f, o	ni	Resident	c

Continue

Appendix I. Continued.

Family/Species	Habitat	Guild	Status	Relative abundance
Thraupidae				
Trichothraupis melanops (Vieillot, 1818)	f	ufi	Resident	c
Habia rubica (Vieillot, 1817)	f	ufi	Resident	c
Tachyphonus coronatus (Vieillot, 1822)	e, f	ooi	Resident	c
Ramphocelus bresilius (Linnaeus, 1766)	e, f	ooi	Resident	c
Thraupis sayaca (Linnaeus, 1766)	e, f, o	ooi	Resident	c
Thraupis palmarum (Wied, 1823)	e, o	ooi	Resident	c
Tangara cyanocephala (Statius Muller, 1776)	f	cfi	Resident	c
Tangara cayana (Linnaeus, 1766)	e, f, o	ooi	Resident	r
Dacnis cayana (Linnaeus, 1766)	e, f	ni	Resident	r
Hemithraupis ruficapilla (Vieillot, 1818)	f	cfi	Resident	r
Emberezidae				
Zonotrichia capensis (Statius Muller, 1776)	o	ooi	Resident	c
Haplospiza unicolor (Cabanis, 1851)	f	bi	Non-resident	v
Volatinia jacarina (Linnaeus, 1766)	o	ooi	Resident	r
Sporophila caerulescens (Vieillot, 1823)	o	ooi	Resident	r
Tiaris fuliginosus (Wied, 1830)	f	bi	Non-resident	v
Cardinalidae				
Saltator similis (d'Orbigny & Lafresnaye, 1837)	e, f	ooi	Resident	c
Fringillidae				
Euphonia chlorotica (Linnaeus, 1766)	e, f, o	cfi	Resident	c
Euphonia pectoralis (Latham, 1801)	f	ufi	Non-resident	r

Habitat: (e) edge, (f) forest, (o) open area, (r) river, (s) sea. Guild: abbreviations as in table II, (ai) aerial insectivore. Relative abundance: (c) common, (r) rare, (v) vagrant.

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