Research Article

Short-term success in the reintroduction of the red-humped agouti *Dasyprocta leporina*, an important seed disperser, in a Brazilian Atlantic Forest reserve

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Abstract

Reintroduction is an increasingly important tool to restore local extinctions and ecological interactions. Evaluating the success of reintroduction projects allows conservationists to learn from previous experience. Here we report on the reintroduction of agoutis, *Dasyprocta leporina,* to a Brazilian Atlantic Forest reserve in order to (1) determine the short-term status of the reintroduction; (2) describe and evaluate the management procedures that contributed to reintroduction success; and (3) identify the fruits and seeds consumed and buried by the agoutis, as an indication of their role in restoring ecological processes. We captured and tagged 21 adult individuals from a semi-captive population and reintroduced four males and seven females. One male died and almost all individuals lost weight (range=0-620 g; n=11) during quarantine (median=133 days; range=67-243 days; n=20). Six males and three females died, but the others gained weight during acclimatization (range=150-260 g; n=5). Individuals abandoned the food supplement up to 87 days after release, establishing home-ranges at least three times larger than in natural populations of agoutis. The estimated annual survival rate was 0.83, and 10 nature-born cubs were observed. The reintroduction was considered successful in the short-term. Among the main recommendations for future reintroductions, we suggest the reduction of quarantine and the maintenance of acclimatization periods, with structural improvements for both. Agoutis were seen eating fruits and seeds of 10 species and burying seeds of three of them. The buried seeds are from zoochoric large-seeded trees, thus enhancing recruitment in a disperser-impoverished forest.

Keywords: *Dasyprocta leporina*, frugivory, radiotracking, reintroduction, spatial patterns.

Resumo

A reintrodução é uma ferramenta cada vez mais importante para restaurar extinções locais e interações ecológicas. Avaliar o sucesso de projetos de reintrodução permite que conservacionistas aprendam com experiências prévias. Aqui nós reportamos a reintrodução de cutias *Dasyprocta leporina* em uma reserva da Mata Atlântica brasileira, objetivando (1) determinar o status da reintrodução em curto prazo, (2) descrever e avaliar os procedimentos de manejo que contribuíram para o processo de reintrodução e (3) identificar os frutos e sementes consumidos e enterrados pelas cutias, como um indicativo do seu papel na restauração de processos ecológicos. Nós capturamos e marcamos 21 indivíduos adultos originários de uma população semi-cativa e reintroduzimos quatro machos e sete fêmeas. Um macho morreu e quase todos perderam peso (variação=0-620 g, n=11) durante a quarentena (mediana=133 dias, variação=67-243 dias, n=20). Seis machos e três fêmeas morreram, mas os outros ganharam peso durante a aclimatação (variação=150-260 g; n=5). Os indivíduos abandonaram a suplementação alimentar em até 87 dias depois da soltura, estabelecendo áreas de vida pelo menos três vezes maiores do que as encontradas para populações naturais de cutias. A taxa de sobrevivência anual estimada foi de 0,83 e 10 filhotes nascidos na natureza foram observados. A reintrodução foi considerada bem sucedida em curto prazo. Dentre as princpais recomendações para futuros projetos de reintrodução, nós sugerimos a redução do período de quarentena e a manutenção da aclimatação, com melhorias estruturais para ambos. As cutias foram vistas predando frutos e sementes de 10 espécies e enterrando três delas. As enterradas pertencem a espécies vegetais de sementes grandes, dispersadas por animais, assim aumentando o recrutamento em uma floresta carente de dispersores.

Palavras-chave: *Dasyprocta leporina*, frugivoria, monitoramento por radiotelemetria, reintrodução, padrões espaciais.

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Introduction

The primary goal of reintroduction in conservation is "to re-establish a viable population of the focal species within its indigenous range" [1]. There has also been a growing concern about recovering ecosystem processes through reintroduction [2, 3]. Most reintroduction attempts have failed [4]; unfortunately, many of the failures have not been published, thus published studies are biased towards the successful ones [5]. Therefore, it is important to describe the procedures used in reintroduction projects and to evaluate their success, in order to allow conservationists to learn from previous experience [2-4, 6].

The first stages of a reintroduction, when the population is still small, are critical and especially prone to failure [2, 7]. Some objective criteria that have been proposed to evaluate the short-term success of a reintroduction are: independence from food supplementation; post-release settlement (evaluated through the establishment of home ranges); high annual survival rates of reintroduced individuals; and occurrence of breeding in nature [8-13].

Among the procedures proposed to increase the reintroduction success of captive raised animals, is the use of a quarantine period in a zoo or a similar institution, where health examinations are performed [1]. This is important to ensure that animals are healthy and not likely to introduce pathogens to the release site [14]. Another key procedure is soft-release (sensu [15]), where animals are kept in a pen located in the reintroduction site for an acclimatization period before being released. Acclimatization is important to familiarize the animals with local conditions, to allow them to gain weight, and to perform skill training (e.g. [16-21]). It also allows monitoring of the individuals' adaptation to the tracking equipment (in this study, a modified TXE-311C collar with activity sensor; Telenax®, Playa del Carmen, Mexico; see [16]). After release, food supplementation is usually provided outside the pen, to help animals to survive their first days in nature when their foraging skills may be still inefficient, and to inhibit large displacements to adjacent unsuitable areas [1, 10, 15, 22, 23]. Finally, monitoring allows the researcher to follow the animals, to intervene if needed, and to assess the program's success indicators [24].

Here we report on the reintroduction of a population of red-humped agoutis *Dasyprocta leporina* to the Tijuca National Park (hence TNP), an Atlantic Forest reserve in Brazil. The species occurs in forested areas up to 2,000 m, usually near watercourses. It is mainly diurnal, with activity peaks in the early morning and late afternoon [25, 26]. Its diet is mainly composed of fruits and seeds with occasional consumption of insects, fiber and leaves [27]. Agoutis are among the most important large-seed dispersers [28-30]. These scatter-hoarding rodents hide seeds in widely spaced caches in the soil surface as food reserves to be retrieved and eaten later [31].

The reintroduction of *D. leporina* is therefore an important tool for restoring animal-plant interactions in Brazilian Atlantic Forest areas where these animals are absent.

Agoutis had not been seen in the area for at least two decades prior to the start of our project in 2010, leading to the assumption that they were locally extinct. The probable causes of extinction were hunting and intense habitat loss and fragmentation from the sixteenth to the nineteenth century due to replacement of forest by sugarcane, coffee plantations, and pastureland (for the history of fragmentation, see [32]). Nowadays, these causes of extinction have been extirpated, but some trophic webs are still impoverished [33] and there has been little recruitment of some large-seeded tree species in TNP [34], emphasizing the need to restore ecological processes in this important reserve.

The objectives of this study were: (1) to evaluate the short-term success of the reintroduction of agoutis; (2) to describe and evaluate the management procedures used to reintroduce the agoutis (quarantine, soft release and food supplementation); and (3) to identify the food items consumed and buried by the agoutis, as an indication of the potential of the reintroduction for restoring ecological processes.

Methods

Study area

TNP is located in the middle of Rio de Janeiro city (22°55'-23°00' S, 43°11'-43°19' W); it is considered the world's largest urban forest (3,953 ha) (Fig. 1). The vegetation of TNP is composed of typical Atlantic Rain Forest species plus some exotic trees, especially jackfruit *Artocarpus heterophyllus*, eucalyptus *Eucalyptus* spp. and corn-plant *Dracaena fragrans*. Mean monthly temperatures vary between 18°C and 26°C, and annual precipitation exceeds 1,200 mm, with no marked seasons and no water deficit [35].

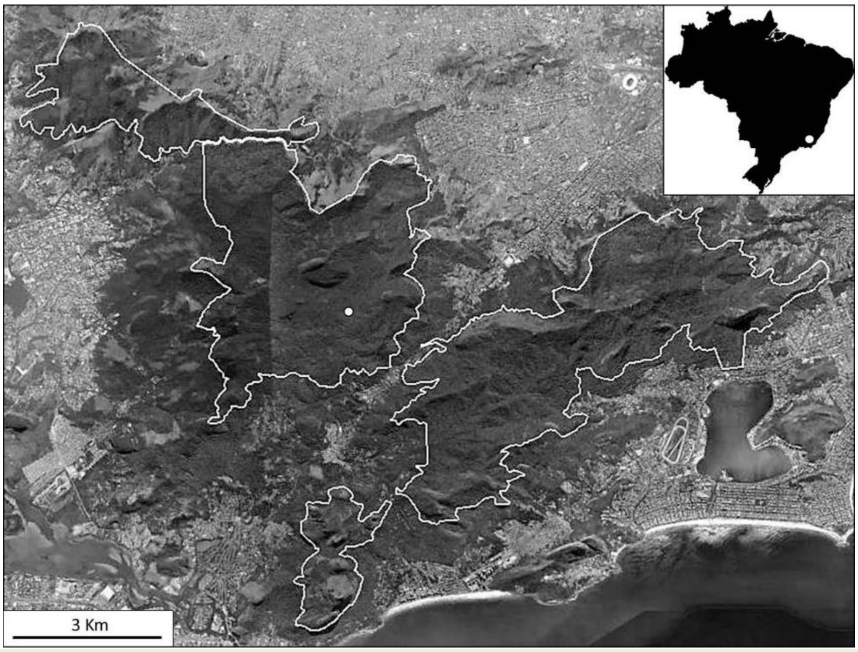

Fig. 1. Tijuca National Park (Rio de Janeiro, Brazil), where the population of agoutis (*Dasyprocta leporina*) was reintroduced. The white contours determine the Park's limits. The white dots represent the locations of the acclimatization pen (release site) within the study area and of the latter within Brazil (map in the upper-right corner).

Reintroduction procedures and monitoring

The animals used for reintroduction (21 adult agoutis; 11 males and 10 females) were provided by a semi-captive population. This population inhabits a municipal park in the centre of Rio de Janeiro city (locally known as Campo de Santana), where they were fed daily with a mixture of fruits and vegetables. We trapped the agoutis using Tomahawk® live traps (100x80x80 cm and 81x23x23 cm, Tomahawk Live Trap Co., Tomahawk, WI,U.S.A.), baited with bananas. After capture, we took the animals directly to Rio de Janeiro Zoo, where they were anesthetized (using 20 mg/Kg of ketamine and 2 mg/Kg of xylazine), weighed, sexed, and health screened through blood, faecal and clinical analyses during the quarantine. These analyses showed no pathogens or significant alterations to normal patterns, and all animals were considered healthy. While in the zoo, the agoutis were kept in an enclosure with a concrete floor and fed twice a day with a mixture of fruits and vegetables.

After quarantine, we weighed the agoutis again and equipped them with radiotracking collars. Total collar weight was 23 g (~1% of agouti body weight). We then transported the animals to a pre-release acclimatization pen in TNP, as part of the soft-release process. The pen was a 10x10 m wire mesh fenced cage with two subdivisions, a main part (8x10 m) and an annex (2x10 m) to allow eventual isolation of aggressive individuals. During the acclimatization period, we provided wood shelters and water *ad libitum* in addition to 500g/day of food per animal (a mixture of fruit and vegetables). We also provided the agoutis with fruits and seeds of plant species that were fruiting in TNP at the time.

On the release day, we weighed the agoutis, took them to the annex, and opened the door to the exterior; the animals then left the pen by themselves. We compared animal weight variations over the reintroduction stages using paired t-tests. It was not possible to weigh all individuals at all stages due to problems with the equipment; the number of weighed animals was provided in each case. After release, we monitored the animals using the "homing-in on the animal" observation technique [36], following the individuals two or three times a week until either the animal died or the batteries on their tracking devices failed. We performed the Moran's spatial autocorrelation index [37] and found that 45 minute intervals were enough to ensure temporal independence among fixes. Thus, consecutive fixes of the same individual were recorded within intervals of at least one hour.

We provided water and food (500 g/day.animal) near the pen every day for 30 days or until the released animals abandoned the food supplements. If an animal did not abandon the food supplement voluntarily, we reduced its amount gradually after the 30 days. We calculated the time each animal took to abandon the supplementary food by counting the days between its release and the last time it was seen feeding on it. This research and the reintroduction procedures adopted have been approved by ICMBio, the appropriate Brazilian environmental agency.

Home-range establishment

The settlement of individuals was evaluated through the establishment of home-ranges. To estimate home-range size we excluded the first fixes of each individual in order to discard the initial exploratory movements. To know from which fix to start the home range estimation, we plotted the cumulative fixed-kernel 95% [38] areas chronologically (hereafter kernel 95%), with ad hoc estimation of the h_{ref} value. We considered the first large displacement between two asymptotes as the beginning of the estimation, as it represents the departure from the vicinity of the acclimatization pen and from food supplementation, thus indicating the establishment of an independent home-range. To identify the first large displacement, we fitted a linear model to the cumulative kernel 95% estimation spanning eight fix intervals, and started the home-range estimation from the last fix of the first interval whose slope was significantly different from zero. We estimated home-range sizes using kernel 95% and the mean h_{ref} as smoothing factor (h=63.1). From these contours, we estimated the individual home-range overlaps, pairwise for all possible pairs of individuals who had, at least, 30 fixes each for the same time interval. In order to allow comparisons with other studies on agoutis, we also estimated the home-range sizes using the minimum convex polygon 100% (hereafter MCP 100%).

Population establishment
Population establishment was evaluated using the occurrence of reproduction and individual survival rates. The occurrence of reproduction was detected by the sighting of cubs with the reintroduced females. We estimated the annual survival rate based on the individuals' capture histories, using the known fates models of program MARK [39]. As only two released animals died before the end of the study (a male and a female), we used the simplest model for estimating the survival rate, where survival is equal among all sampling occasions (months) intervals and its estimation is not dependent on any covariates. We used R v.3.0.1 for all other analyses (packages used: adehabitatHR, maptools, rgdal and rgeos) [40].

Food item consumption
From September 2010 to August 2011, we carried out independent focal-days (one individual followed per day) to identify the food items consumed by the agoutis. On those days we used the radio transmitter signal to find an agouti and followed it for four or five hours, using binoculars to identify the items consumed. We recorded results when the individual was seen feeding on an item. A new record was considered if the animal fed on a different item or if the individual was absent for 30 minutes or more and returned to the same food patch. Additionally, we made occasional records of food items eaten or buried by agoutis during the regular monitoring.

Results
Individuals lost weight during quarantine; their mean weight was 2,586.8 g (sd=426.9) on the capture day and 2,302.3 g (sd=404.1) by the end of this period (t_{10}=4.74, p<0.001, n=11; Fig. 2). Additionally, a male agouti died as a consequence of fighting with other agoutis during that period. Because of logistical problems, the quarantine period was variable, with a median of 133 days (range=67-243; n=20; Table 1).

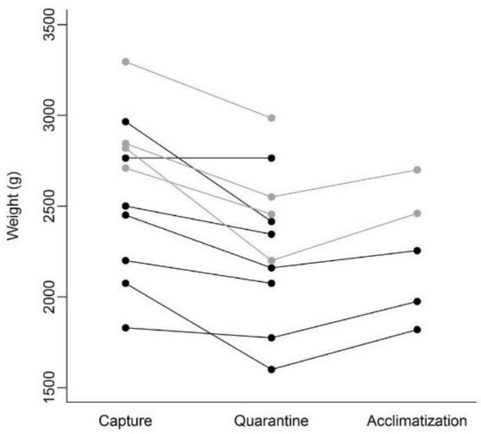

Fig. 2. Weight change of agoutis (*Dasyprocta leporina*) in different reintroduction stages (capture, quarantine and acclimatization). The lines connecting dots represent the measurements taken from the same individual on different occasions; males are in black and females in grey.

During the acclimatization period nine animals died (Table 1). The identified causes of death were fighting among males (3), fighting among individuals whose sex could not be determined (2), problems with the original model of radiotracking collars (1) [16], hypothermia (1) and death by the attack of two domestic dogs that broke into the acclimatization pen (1), pushing through the lower edge of the wire mesh fence (Table 1).

For the 11 animals that remained in the pen until release, the median acclimatization period was 21 days (range=14-76; Table 1). Animals gained weight in this period (t_4=7.46, p=0.002, n=5; Fig. 2). The mean weight at release for these five animals was 2,242 g (sd=355.9). The animals remained near the pen for a median of 17 days after release and always fed on the supplementary food (range=3-87; n=11).

Table 1. Length of each stage of the reintroduction process and status of individual agoutis (*Dasyprocta leporina*) captured to be reintroduced in Tijuca National Park (Rio de Janeiro, Brazil). M = males and F = females. Status = individual's status by the end of the study (September 2011).

Sex	Status	Quarantine length (days)	Acclimatization length (days)	Release date	Stage when death was recorded	Cause of death
M1	Alive	96	15	01 Feb 10	-	
M2	Alive	100	21	08 Feb 10	-	
M3	Alive	156	35	26 Apr 10	-	
M4	Dead	-	-	-	Quarantine	Aggressive interactions
M5	Dead	180	-	-	Acclimatization	Hypothermia
M6	Dead	96	-	-	Acclimatization	Aggressiveness between males
M7	Dead	150	-	-	Acclimatization	Aggressiveness between males
M8	Dead	150	-	-	Acclimatization	Aggressiveness between males
M9	Dead	96	-	-	Acclimatization	Unknown
M10	Dead	243	-	-	Acclimatization	Unknown
M11	Dead	163	35	26 Apr 10	After release	Unknown
F1	Alive	100	21	08 Feb 10	-	
F2	Alive	100	21	08 Feb 10	-	
F3	Alive	180	77	07 Jun 10	-	
F4	Alive	96	33	15 Mar 11	-	
F5	Alive	96	33	15 Mar 11	-	
F6	Alive	243	21	28 Jul 11	-	
F7	Dead	67	-	-	Acclimatization	Collar injuries
F8	Dead	192	-	-	Acclimatization	Domestic dog attack
F9	Dead	243	-	-	Acclimatization	Unknown
F10	Dead	116	15	01 Feb 10	After release	Aggressive interactions

After release, we monitored four males and seven females for 192 non-consecutive days (February 2010 – September 2011). One male and one female agouti died before the end of the study (324 and 160 days after release, respectively). One female removed its collar after 118 days, but we continued to monitor the animal whenever it was seen and its identity could be ascertained unequivocally. We lost track of another female 11 days after release and could not estimate her home-range size.

A total of 1,012 fixes (range=34-128; n=11) were recorded for all agoutis. Following our criterion for establishment, we selected 772 fixes (range=45-108, n=10) for home-range analysis. Using this criterion, we excluded 207 fixes (range=13-38, n=10). Time from release date to the date of the first fix used to estimate the home-ranges ranged from two to 67 days (n=10; Table 2). The distances from release site to the centroid of the fixes used to estimate home-ranges sizes for each individual ranged from 171.5 to 561.3 m (Fig. 3). Minimum and maximum distances from release site ranged from 4.4 to 230.4 m and from 378.7 to 844.1 m, respectively (n=10, Table 2). Home-range sizes estimated for all individuals by kernel 95% ranged from 15 to 38.8 ha (n=10; Fig. 3; Table 2) and mean home-range overlap was 0.46 (sd=0.24; n=55 pairs of individuals). The estimates obtained by MCP 100% ranged from 3.9 to 26.9 ha (n=10; Table 2). Male and female home-ranges sizes did not differ significantly using either the kernel 95% (Wilcoxon=5, p=0.171) or the MCP 100% (Wilconxon=4, p=0.114).

Table 2. Spatial patterns of released agoutis (*Dasyprocta leporina*) in Tijuca National Park (Rio de Janeiro, Brazil) (February 2010 to September 2011). M = males and F = females. Total fixes = number of fixes obtained for each individual from release to the end of the batteries or death. Number (N) excluded fixes / days = number of fixes excluded following our criterion for home-range establishment, and time (in days) from release date to the date of the first fix used to estimate the home-ranges. Home-range fixes = number of fixes used to estimate the home-ranges of each reintroduced agoutis. Distances from release site (m) = distance from release site to the centroid of the fixes used to estimate the home-ranges sizes (in parenthesis, minimum and maximum distances from release site).

Sex	Days of monitoring	Total fixes	N excluded fixes / days	Home-range fixes	Distances from release site (m)	Home-range Kernel 95% (ha)	Home-range MCP 100% (ha)
M1	548	128	29 / 22	99	359.6 (52.8, 592.5)	24.5	18.4
M2	357	81	19 / 9	63	561.2 (143.2, 844.1)	29.3	20.7
M3	420	97	16 / 3	81	287.2 (5.1, 680.9)	38.8	26.9
M11	265	93	20 / 14	73	171.5 (4.4, 650.1)	24.9	14.4
F1	371	127	38 / 67	89	387.6 (217, 493.3)	16.6	7.2
F2	264	70	16 / 9	54	413 (17, 625.9)	26.5	15.7
F3	401	111	13 / 3	98	180.3 (7.8, 583.8)	32.9	24.4
F4	127	121	13 / 2	108	281.3 (39.6, 441.3)	16.9	9.7
F5	150	76	14 / 2	62	199.3 (15, 378.7)	17.4	6.3
F6	11	34	16 / 5	19	-	-	-
F10	160	74	29 / 22	45	335.6 (230.4, 434.7)	15	3.9

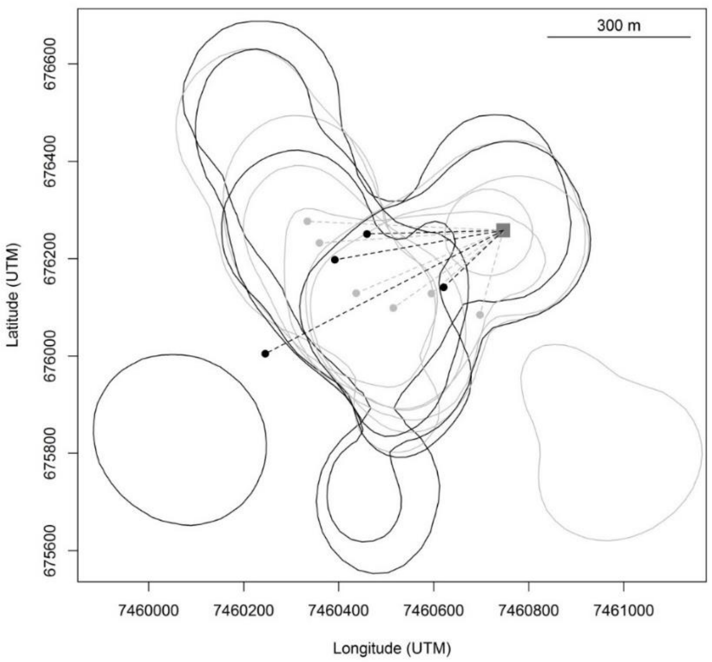

Fig. 3. Home-range contours (using kernel 95%; h=63.1) of agoutis (*Dasyprocta leporina*) reintroduced in Tijuca National Park, Rio de Janeiro, Brazil. The dark grey square represents the location of the acclimatization pen (release site). The dots indicate the centroid of the fixes used to estimate the home-ranges sizes for each individual. The dashed lines show the distance from the release site to the centroids. Males are in black and females in grey.

We obtained 63 records of food item consumption by five different agouti individuals during 25 focal-days. A total of 22 fruit and seed morphotypes were consumed by agoutis, and 10 of them could be identified (Table 3). The species consumed most often were the jussara palm *Euterpe edulis* and cutieira *Joannesia princeps*, with 15 and 13 records respectively. The agoutis were seen burying *J. princeps*, Panama tree *Sterculia chicha* and *A. heterophylus* seeds (Table 3).

The estimated annual survival rate was 0.83, and the female F1 was the first one to be observed with a litter (two cubs), 241 days after the first release and 234 days after her own release. Altogether, 10 cubs were observed with four reintroduced female agoutis (F1, F3, F4 and F5) in five reproductive events during the study period (median litter size=2 cubs/litter, range=1-3), providing evidence of successful reproduction in the reintroduced population.

Table 3. Fruits and seeds used by reintroduced agoutis (*Dasyprocta leporina*) in Tijuca National Park (Rio de Janeiro, Brazil) (September 2010 to August 2011).

Family	Species	Records	Fate
Arecaceae	*Euterpe edulis*	15	Consumed
Euphorbiaceae	*Joannesia princeps*	13	Consumed, buried
Myrtaceae	*Myrciaria* sp.	6	Consumed
Fabaceae	*Piptadenia gonocantha*	3	Consumed
Sterculiaceae	*Sterculia chicha*	3	Consumed, buried
Moraceae	*Artocarpus heterophyllus*	2	Consumed, buried
Annonaceae	*Xylopia brasiliensis*	1	Consumed
Fabaceae	*Cassia ferruginea*	1	Consumed
Lythraceae	*Lafoensia glyptocarpa*	1	Consumed
Myrtaceae	*Myrcia spectabilis*	1	Consumed

Discussion

According to the criteria adopted, the reintroduction of the agoutis in Tijuca National Park can be considered successful in the short-term (Fig. 4). All released agoutis reached food independence, abandoning the food supplements and feeding on items found in nature. All tracked animals established home-ranges in a defined area after release, and there was a high individual annual survival rate with evidence of breeding in the population. We believe that in most aspects that the procedures adopted before and after release were suitable and could be used by others.

The shortest quarantine to which our animals were submitted was longer than the 35 days recommended for rodents by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA). With a short quarantine period, there is an increased risk of diseases emerging after release [41]. On the other hand, with a long quarantine, the animals are more prone to contamination, stress, and injuries caused by fighting [42, 43]. The death of an agouti and the weight loss of all individuals during quarantine show that it was a stressful period for them. For future agouti reintroduction programs, we recommend a shorter quarantine than the period we used. Also, the agoutis should be separated into smaller groups of no more than five individuals (ideally with a single male per group) in each enclosure. With these precautions, the stress and fighting can be minimized during the quarantine, reducing the mortality in this stage.

The deaths which occurred in the pen show that the acclimatization period can also be critical, especially due to fighting among males. Furthermore, the dog attack upon the agoutis shows that the pen can function as a trap. The odour produced by the concentration of animals can attract predators, and if they break into the pen, the enclosed animals become easy prey [44].

On the other hand, the acclimatization was important to monitor the adaptation of the agoutis to radio collars [16]. The weight gain during the acclimatization was also important because released animals, especially the ones coming from captivity, may find it difficult to get food right after release and die of malnutrition (e.g. [44, 45]). The weight at release is thus an important predictor of post-release survival [14, 46]. We therefore do not recommend shortening the acclimatization period.

Regarding the acclimatization pen, it is important to keep in mind that fences must be strong enough not only to keep the individuals of the reintroduced species inside, but also to prevent any local predator entering the pen. In this stage it is also important to keep males separated from each other. The number of agoutis inside a 100 m² pen at any given time must not exceed five. With these precautions, we can expect weight gain and minimize the probabilities of fighting and of attracting predators, thus reducing the mortality in this stage.

The acclimatization period and the supplementary food probably induced the agoutis to stay near the pen in the first days after release. This proximity facilitates the process of finding and monitoring the animals, allowing interventions if needed. It also favours population cohesion and reproduction. The lack of population cohesion was probably the cause of the failure of the first agouti release in TNP, which occurred without acclimatization, food supplementation, or monitoring [47-49]. The importance of food supplementation is corroborated by the occasions when the animals did not abandon it voluntarily. In these cases, we had to reduce the amount of food gradually, until the animal could survive eating only items found in nature. We recommend the maintenance of the food supplementation for at least 30 days in each release, then gradually reducing supplements in cases where animals are still feeding on them, as adopted in this study.

It should be noted that the agouti home-range sizes estimated here were larger than values found in the literature. Home-range sizes estimated in this study were three times larger than those reported by Silvius and Fragoso [50] (W=44, p=0.019) and by Jorge and Peres [26] (W=36, p=0.023) for *D. leporina.* The comparison with *D. punctata* home-range sizes revealed that the ranges estimated in this study were six times larger than those reported by Aliaga-Rossel *et al.* [51], both for males (W=20, p=0.019) and for females (W=18, p=0.024). However, we were conservative when choosing the fixes that were used to estimate the home-range sizes by excluding data from the first days after release, when the animals are exploring the new habitat and using the food supplements. We think the large areas used do not reflect exploratory behaviour but actual home-ranges. An explanation for a larger home-range is that the TNP is an impoverished forest, where tree recruitment is low [32, 34]. This can lead to lower food resource abundance compared for example to a nut stand (*Bertholletia excelsa*) in Amazonia, as studied by Jorge and Peres [26]. Resource scarcity could therefore explain the large home-range sizes found in the present study.

The estimated annual survival rate was actually higher than described for natural populations of agoutis [52, 53]. These high adult survival rates are probably due to the absence of the main agouti predators in TNP [53-56], although domestic dogs have been seen chasing adult agoutis and can be a real threat to them. Capture sessions performed in 2013 showed that some of the first agoutis were still alive three years after release. The survival rates of the cubs could not be estimated, but they would probably be lower than the overall survival rates, because young agouti mortality is high in nature [53, 56]. However, the demographic patterns we found are indicative of a thriving, breeding population.

The food items that were most consumed were two tree species (*E. edulis* and *J. princeps*) that are considered under threat in the Brazilian Atlantic Forest [57, 58]. Two of the three species buried by the reintroduced agoutis (*J. princeps* and *S. chicha*) are large-seeded trees which need animals as dispersers. Zucaratto [59] observed that seeds of the large-seeded palm *Astrocaryum aculeatissimum* were buried and germinate only in areas where agoutis were reintroduced. For these tree species, the agoutis' scatter-hoarding behaviour can help to disseminate the seeds and enhance recruitment in a forest that lacks animal dispersers. The agoutis were also seen burying *A. heterophyllus* seeds, an exotic, invasive tree species. Nevertheless, the agoutis do not seem to be contributing to invasion by this species. Patches with more than 100 *A. heterophyllus* seedlings/m² were found in the TNP, a defaunated forest, before the agouti reintroduction started [60], showing that this tree does not need the agoutis for its recruitment. Moreover, although we offered *A. heterophyllus* seeds to agoutis during acclimatization, we found no seedlings inside the acclimatization pen, indicating that the agoutis are eating rather than hoarding seeds of this species. During the study period, agoutis acted as predators of seven of the 10 species consumed. All of them have small seeds (> 1.5cm in diameter) which are generally not buried by agoutis [61]. Most of these species, however, including *E. edulis* (the most consumed one), are dispersed primarily by birds [62, 63], and do not depend on agoutis for seedling regeneration.

Fig. 4. Agoutis (*Dasyprocta leporina*) in Tijuca National Park, Rio de Janeiro, Brazil. Upper photo left: female F1 with the first cub born in the wild; photo credit: Marco Terranova. Upper right photo: first cub born in the wild; photo credit: Marco Terranova. Bottom-left photo: female F3 eating a seed; photo credit: Rui Salaverry

Implications for conservation

We faced some problems in the beginning of this reintroduction programme. The main one was the high agouti mortality during the pre-release stages when about half of the captured individuals died, mostly because of aggressiveness among individuals due to stress. With a more limited source population, researchers should be careful about the number of individuals they can remove from it to guarantee a minimum for the reintroduction while not jeopardizing the source population. The procedures adopted in this study and the modifications proposed can minimize stress and mortality during the pre-release stages and make agouti reintroductions more prone to success.

Contrary to what was thought, it was shown that the agoutis can and do disperse large seeds to great distances (>100 m) [31]. Moreover, these rodents carry seeds towards locations with lower conspecific tree densities [30]. These characteristics combined make the seed dispersal by agoutis highly effective, enhancing the chances of a given seed to become a seedling [64, 65]. The short-term success of the reintroduction and the interactions of the agoutis with the large-seeded trees show that this conservation tool has much potential to restore seed dispersal in Neotropical forests such as the Brazilian Atlantic Forest. This biome has been reduced to 11.4–16% of its original cover, with 80% of the remaining fragments smaller than 50 ha [66]. Many of these patches are empty forests where seed dispersal interactions have been disrupted or imbalanced by the loss of the dispersers [67-69]. To replicate the reintroduction of agoutis elsewhere can be an important tool to restore seed dispersal throughout many of the Neotropical Forests.

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