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PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA

AN ANALYSIS OF THE RELEVANCE OF SOCIAL SYSTEMS ON REINTRODUCTION BIOLOGY AND THE RELEASE OF THE FIRST GROUP OF BROWN HOWLER MONKEY (*Alouatta guariba*) AT TIJUCA NATIONAL PARK, RIO DE JANEIRO

BRUNO DE SOUSA MORAES

Dissertação apresentada ao Programa de Pós-Graduação em Ecologia da Universidade Federal do Rio de Janeiro, como parte dos requisitos necessários à obtenção do grau de Mestre em Ciências Biológicas (Ecologia).

Orientador: Fernando Antonio dos Santos Fernandez

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“Ciência é uma maneira de falar sobre o Universo em palavras que o conectam a uma realidade comum. Magia é um método de falar com o Universo em palavras que ele não é capaz de ignorar. As duas coisas são raramente compatíveis.”

— Neil Gaiman

Dedico o presente trabalho a todos os bugios do mundo, e a seus entusiastas.

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Mas a verdade é que a parte mais difícil de escrever dessa dissertação foi a dissertação em si.

Não é uma constatação muito bonita, eu sei. Mas é uma constatação verdadeira. E, além de eu realmente acreditar que vale a pena recompensar com essa sinceridade as pessoas que me ajudaram a chegar até aqui, creio que reconhecer nessa sessão o quão difícil foi a trajetória de meus dois anos e quatro meses de mestrado torna ainda mais valiosa a minha gratidão por quem esteve do meu lado durante especiais momentos desta grande massa de coincidências, incidentes, vitórias, derrotas e moléculas de adrenalina que foi meu mestrado. Cada pessoa importou absurdamente, até mesmo aquelas que não aparecerem nominalmente no texto abaixo. Como disse acima, a memória com a qual eu guardo os nomes é menor do que o coração com o qual eu amo cada um de vocês.

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RESUMO – A Biologia da Reintrodução é uma ciência relativamente nova, focada no conhecimento que se pode ganhar ao delinear projetos de translocação de espécies de forma a testar hipóteses científicas. É importante que publicações na área da Biologia da Reintrodução sejam analisadas em busca de eventuais padrões que possam informar futuros projetos de translocação. A presente dissertação é estruturada em dois capítulos. O primeiro capítulo é uma revisão de livros de estudos de caso publicados pelo Grupo de Especialistas em Reintrodução da União Internacional para Conservação da Natureza (RSG/IUCN), conduzida de forma a identificar padrões no que diz respeito à translocação de animais sociais. A partir de 52 casos incluindo peixes (n = 1), aves (n = 28), mamíferos (n = 22) e répteis (n = 1), analisei a influência de seis fatores na probabilidade de sucesso de projetos de translocação. Dentre os fatores analisados, apenas a implementação de protocolos que levam em conta as características da socialidade da espécie translocada teve um efeito significativo, resultando em maiores taxas de sucesso do que as de projetos que não implementavam "tratamentos sociais". O segundo capítulo descreve os protocolos adotados pelo nosso grupo durante a condução do projeto de reintrodução de uma espécie social, o bugio ruivo (*Alouatta guariba*) no Parque Nacional da Tijuca, Rio de Janeiro - RJ, além de avaliar os primeiros resultados do projeto. O capítulo apresenta estimativas das áreas de vida ocupadas pelos quatro indivíduos soltos em setembro de 2015, além de discutir os principais problemas enfrentados até o momento na realização do projeto. Por fim, o capítulo traça diretrizes com base no ganho de informação que tivemos após a primeira soltura. As áreas de vida foram estimadas de três maneiras distintas: a partir do método do mínimo polígono convexo utilizando 95% dos dados, mínimo polígono convexo utilizando 100% dos dados, e o método do kernel fixo utilizando 95% dos dados. O número de localizações espaciais utilizadas no capítulo não foi suficiente para permitir estimativas confiáveis de área de vida, sugerindo que um período de quatro meses não é longo o bastante para o final da fase de exploração do hábitat e o estabelecimento de área de vida para o bugio ruivo.

PALAVRAS-CHAVE: Reintrodução, bugio, *Alouatta guariba*, sociobiologia, socioecologia, Mata Atlântica.

ABSTRACT – Reintroduction Biology is a relatively new field of science focused on the knowledge that can be gained by conducting hypothesis-oriented translocation projects. It is important that publication in the field of Reintroduction Biology are analyzed in search of eventual patterns that can inform future translocation projects. The present dissertation is structured in two chapters. The first chapter is a review based on case-study books published by the Reintroduction Specialist Group of the International Union for Conservation of Nature (RSG/IUCN), conducted in order to identify patterns concerning the translocation of social animals. From 52 cases involving fish (n = 1), birds (n = 28), mammals (n = 22) and reptiles (n = 1), I analyzed, by performing G-tests, the influence of six factors on the probability of success of translocation projects. Of all the analyzed factors, only the implementation of protocols which take into account characteristics of the species' sociality had a significant effect (G = 7,106, df = 1, p = 0,007), resulting in higher success rates than the ones obtained by projects which did not implement "social treatments". The second chapter describes the protocols our group adopted while conducting the reintroduction project of a social species, the brown howler monkey (*Alouatta guariba*) at Tijuca National Park, Rio de Janeiro – RJ, besides evaluating the first results of the project. The chapter presents estimates of the home-range areas occupied by the four individuals released at the park on September, 2015, in addition to discussing the main problems faced so far. Finally, the chapter suggest guidelines based in the information gained after the first release. Home-range areas were estimated in 3 different ways: by using the minimum convex polygon method with 95% of the data, the minimum convex polygon method with 100% of the data and the fixed kernel methos, with 95% of the data. The number of spatial location utilized in the chapter was not sufficient to allow reliable home-range area estimates, suggesting that a

period of 4 months is not enough for the initial habitat exploration phase of the brown howler monkey to end, and for the establishment of a home-range by this species

KEYWORDS: Reintroduction, howler monkey, *Alouatta guariba*, sociobiology, socioecology, Atlantic Rainforest.

GENERAL INTRODUCTION

Reintroduction Biology is a new and expanding field, concerned with the practice of translocating organisms for diverse conservation purposes (Armstrong & Seddon, 2007; Seddon *et al.*, 2007; Ewen *et al.*, 2012; IUCN/SSC, 2013). The scientific approach of Reintroduction Biology is directed at answering questions about management practices, effects of translocating individuals (either on population genetics and viability or on ecosystem processes) and factors influencing the outcome of reintroductions (Armstrong & Seddon, 2007; Ewen *et al.*, 2012).

Translocation is a complex and expensive practice, under the influence of behavioral (in the case of animals), physiological and immunological factors of translocated individuals, as well as management decisions and characteristics of the target site (Ewen *et al.*, 2012), which calls for rigorous planning and organization on part of researchers. The translocation of social animals presents reintroduction biologists with a new array of challenges related to the development and maintenance of social behavior and natural social systems in face of the inherent stress translocated animals face upon being released in the wild (Gusset *et al.*, 2006).

The present dissertation is structured in two chapters which relate to the reintroduction of social animals. The first chapter analyzes two case-study compilations organized by the Reintroduction Specialist Group of the International Union for Conservation of Nature (RSG/IUCN) in search of general patterns concerning translocation attempts of social animals and their management practices. The second chapter describes the methods adopted for the release of four individuals of brown howler monkey, *Alouatta guariba* (Humboldt, 1812) at Tijuca National Park, the first step of a reintroduction project aiming at re-establishing this species in the park and restoring its ecological role.

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CHAPTER 1

AN ANALYSIS OF THE RELEVANCE OF SOCIAL SYSTEMS ON REINTRODUCTION BIOLOGY

INTRODUCTION

The history of anthropogenic translocation of other species reaches far into the past. From the origins of agriculture and farming to the present time, humans have been moving animals, plants and microorganisms both within and outside their native ranges (Wilson *et al.*, 2009).

With the global extinction crisis, characterized by the decline and extirpation of biological populations through the whole world, the stability and functioning of communities and ecosystems have become increasingly threatened (Hooper *et al.*, 2012). Translocation-based conservation strategies directed towards the mitigation of these problems gave rise to Reintroduction Biology (Armstrong & Seddon, 2007; Ewen *et al.*, 2012, IUCN/SSC, 2013). The main concern of this new science is the gain of knowledge about reintroductions and other conservation translocations (for definitions and nomenclature of Reintroduction Biology, see IUCN/SSC, 2013), by approaching translocation projects in a hypothetico-deductive and experimental manner (Seddon *et al.*, 2007). Knowledge thus obtained can guide future translocation efforts. Additionally, the compromise to science-driven rather than anecdotal or descriptive works is vital for the growth of Reintroduction Biology as a discipline.

One of the most important factors for the success of translocation programs is the previous knowledge about the biology, ecology and, for animals, behavior of the species in question (IUCN/SSC, 2013). Regardless of using captive-bred or wild animals to form release groups, there must be management decisions directed to guarantee the retention or return to natural behavior, compatible with wild-living animals (Kleiman, 1989). Studies about learning, sociality and behavior may thus function as to augment the likelihood of success of the reintroduction (e.g.: survival and population increase / establishment), as well as to prevent the release of animals presenting aberrant behavior associated with living in captivity. The latter concern is even greater when dealing with animals that display social learning (Custance *et al.*, 2002), because stereotypical behaviors can spread to other animals in the population, both in captivity (Custance *et al.*, 1999) and in the wild (Riesch *et al.*, 2006), eventually with drastic influence in the social behavior itself, like the case of a population of bottlenose-dolphins (*Tursiops truncatus*) which learned to co-operate with human fishermen (Daura-Jorge *et al.*, 2012).

The social context is an important determinant of individual fitness and behavioral patterns in species with some degree of sociality (reviewed by Krause & Ruxton, 2002). Therefore, there is great value in translocation experiments designed to understand the role played by group forming in captivity, social interactions and social learning on the outcome of translocations (Custance *et al.*, 2002; Gusset *et al.*, 2006; Jones & Merton, 2012; Le Gouar *et al.*, 2012). When dealing with individuals held in captivity, artificially established social relationships may greatly influence post-release cohesion, movements and survival (Gusset *et al.*, 2006). Thus, especially in this case, these experiments have the potential to generate theoretical predictions and recommendations for conservation and management practice.

The knowledge gathered to date in socioecology may help us to understand how pair- and group-living species organize themselves in nature. This discipline delves into insights about the trade-offs likely driving the evolution of social behavior (*e.g.*: the loss of exclusive access to resources on a territory, weighted against the advantages like a lower risk of predation or a higher foraging efficiency), and also provides description of behaviors associated with social ranks and mate selection. The theoretical framework of socioecology, thus, should be of great value to the translocation of social animals.

Important works on Reintroduction Biology point to the importance of taking sociality into account in translocation projects, including the Guidelines produced by the Reintroduction Specialist Group (RSG) of the International Union for Conservation of Nature (IUCN/SSC, 2013), reviews claiming for a scientific approach to the field (Armstrong & Seddon, 2007; Seddon *et al.*, 2007) and field studies on reintroductions (Gusset *et al.*, 2006; Homberger *et al.*, 2014).

The IUCN Guidelines make explicit recommendations to researchers conducting translocation of social animals, advising them to monitor the social behavior in captivity and in the wild, and some studies have focused specifically on the importance of socioecological characteristics of the species being translocated (*e.g.*: Gusset *et al.*, 2006). However, reviews summarizing the importance of the social system for translocation success are not yet available. Additionally, a recent review of the reintroduction literature, compiling factors involved in the outcome of reintroduction programs did not find any relevant effect of social systems on the reintroduction success, in part due to data scarcity (Estrada, 2014). Even though Reintroduction Biology is a new science, with formal appeals in the literature for scientific approaches emerging only during the 1990s (Seddon *et al.*, 2007), it is possible that the articles published to date have generated enough data to allow for generalizations concerning the role of sociality in translocations.

The present chapter is based on data from two books on reintroductions and translocations published by the RSG of the IUCN, analyzing the current understanding of the mechanisms by which sociality influences the outcome of these conservation programs. The aim of this review is to detect trends on the reports, as well as to discuss management actions in light of their effectiveness, in order to highlight the advances Reintroduction Biology made this far, regarding the topic of sociality. My main question was if accounting for the social system of a translocated species would result on a higher probability of attaining success. Additionally, I investigated the influence of other factors, such as the social structure of the species in nature, taxonomic classification and release strategy, in order to be able to discriminate other possible explanations about the success probability.

My expectation was that projects which used pre-release methods designed to address the specificities of the species' sociality ("social treatment") would be successful more frequently than those which didn't take sociality into account.

METHODS

I collected data about translocations from the first two books of the "Global Reintroduction Perspectives" series, published by the RSG (Soorae, 2008, 2010). These publications consist of reports written by the staff of translocation projects worldwide, with the project overview, methodological description and criteria utilized for success evaluation. The books were published in 2008 and 2010, and present 62 and 72 case-studies of translocations, respectively. I excluded data from translocations of plants, invertebrates and solitary vertebrates. Besides, I also excluded some reports of translocations of social vertebrates, either because they did not report a success evaluation (e.g.: *Crax blumenbachii*; Soorae, 2008) or based the success evaluation on other criteria than the outcome of the release (e.g.: community acceptance, animal welfare). For every species for which no socioecological information was available, I surveyed the literature for confirmation of the social system.

As some of the projects reported data on more than one translocation, I collected data for each individual case on a particular study. I considered each case as one single species translocated to a single release site. The data collected for each case were: "Translocation Type" (if the project was a Reintroduction or a Population Reinforcement), taxonomical information ("Class", "Order" and "Species"), "Origin of Translocated Animals" (if the individuals were Captive-Bred, Wild-Born or if the release groups were composed of both Captive and Wild-Born individuals), "Social System" (Pairs, Mixed-sex Groups and Same-sex groups), "Social Treatment" (present if social interactions were considered before release, e.g.: translocation of family-groups or group forming in captivity; absent whenever else), "Soft Release" (e.g.: the construction of an enclosure at the release site, to acclimatize the animals, which may be given supplemental feeding; either present or absent), "Success" (yes or no) and "Reasons for Success" (only those concerning the translocated population).

In the IUCN books, translocation attempts are classified in one of four success categories (Failure, Partially Successful, Successful or Highly Successful), followed by a list of reasons on which the authors based their classification. To reduce uncertainty in the analyses, I used only two categories (Success or Failure). For this step, I counted translocations which presented at least one biological criterion for being considered either as a success (i.e.: breeding in the wild, home range settlement, population increase or stability, etc) or as a failure (i.e.: population decline, high mortality or dispersal rates, extirpation, etc). I also classified translocations for which criteria for success or failure were not listed in the respective session, but were present elsewhere in the report.

In addition to testing whether accounting for sociality had a significant effect on success rates, I tested the effect of soft vs. hard-release, the influence of the origin of the individuals, the influence of the social system and of the translocation type. Additionally, I compared translocations of mammals and birds, in order to detect a possible taxonomic component in the variation of success rates. I performed G-tests to compare different frequencies of translocation success for each of these factors.

RESULTS

Data collection

I analyzed 52 translocations, involving 34 species. Data for all 52 translocations, including the type of translocation, taxonomical information, origin and social system of translocated animals and information about pre-release protocols and translocation success are presented in Table 1. Among those, 37 (71.2%) were successful translocations according to this chapter’s criteria. Twenty two (42%) cases reported mammal translocations; twenty eight (54%) reported bird translocations; there was only one case each (2%) for fish and reptiles. The vast majority of cases (48, or 92.3%) were reintroductions, with 3 population reinforcements (5.7%) and 1 conservation introduction (2%). Twenty one (61.8%) of the translocated species live in mixed groups; twelve (35.3%) species live in pairs; in the remaining species (*Atrichornis clamosus*; 2.9%) only males form associations, meeting with the solitary females at the breeding season. Twenty seven (51.9%) translocation programs relied solely on wild-born individuals; 20 others (38.5%) translocated groups of captive individuals; the remaining 5 (9.6%) projects translocated mixed groups, comprising both wild and captive individuals. In only 21 (40.4%) cases sociality was taken into account before release, and 17 (32.7%) of the 52 cases involved the construction of soft-release pens.

Table 1: Data collected from 52 translocations. Each case study is presented with publication date, information about the translocation itself (type, the occurrence of social treatment and soft release), the released animals (taxonomical information, origin and social system according to the literature) and the success or failure of the translocation.

Publication Year	Translocation Type	Class	Order	Species	Origin	Social System	Social Treatment	Soft Release	Success
	Reintroduction	Aves	Struthioniformes	*Struthio camelus camelus*	Captive	Mixed Groups[a]	No	Yes	Yes
	Reintroduction	Aves	Anseriformes	*Branta sandvicensis*	Captive	Pairs[a]	Yes	No	Yes
	Reintroduction	Aves	Apterygiformes	*Apteryx haastii*	Wild	Pairs[a]	Yes	No	Yes
	Reintroduction	Aves	Passeriformes	*Petroica longipes*	Wild	Pairs[a]	Yes	No	Yes
	Reintroduction	Aves	Passeriformes	*Zosterops modestus*	Wild	Mixed Groups[c]	No	No	Yes
	Reintroduction	Aves	Anseriformes	*Oxyura leucocephala*	Captive	Mixed Groups[d]	No	No	No
	Reintroduction	Aves	Galliformes	*Catreus wallichi*	Captive	Mixed Groups[a]	No	Yes	No
	Reintroduction	Aves	Accipitriformes	*Gypaetus barbatus*	Captive	Pairs[a]	Yes	Yes	Yes
	Reintroduction	Aves	Falconiformes	*Falco femoralis septentrionalis*	Captive	Pairs[a]	No	No	Yes
2008	Reintroduction	Aves	Accipitriformes	*Milvus milvus*	Mixed	Pairs[e]	Yes	No	Yes
	Reintroduction	Mammalia	Carnivora	*Canis lupus*	Wild	Mixed Groups[a]	Yes	Yes	Yes
	Reintroduction	Mammalia	Artiodactyla	*Gazella subgutturosa marica*	Captive	Mixed Groups[a]	Yes	Yes	Yes
	Reintroduction	Mammalia	Artiodactyla	*Oryx leucoryx*	Captive	Mixed Groups[a]	Yes	Yes	Yes
	Reintroduction	Mammalia	Artiodactyla	*Oryx leucoryx*	Captive	Mixed Groups[a]	No	Yes	No
	Reintroduction	Mammalia	Artiodactyla	*Oryx leucoryx*	Captive	Mixed Groups[a]	No	Yes	No
	Reintroduction	Mammalia	Artiodactyla	*Oryx leucoryx*	Captive	Mixed Groups[a]	No	Yes	Yes
	Reintroduction	Mammalia	Artiodactyla	*Oryx leucoryx*	Captive	Mixed Groups[a]	Yes	No	Yes
	Population Reinforcement	Mammalia	Primates	*Varecia variegata*	Captive	Mixed Groups[a]	Yes	No	Yes
	Reintroduction	Mammalia	Primates	*Gorilla gorilla gorilla*	Captive	Mixed Groups[a]	Yes	Yes	Yes

Table 1 (cont.):

	Reintroduction	Actinopterygii	Salmoniformes	*Salmo salar*	Wild	Mixed Groups[f]	No	No	Yes
	Reintroduction	Reptilia	Squamata	*Hoplodactylus duvaucelii*	Wild	Mixed Groups[g]	No	No	Yes
	Reintroduction	Aves	Ciconiiformes	*Ciconia nigra*	Captive	Pairs[b]	Yes	Yes	No
	Reintroduction	Aves	Psittaciformes	*Cyanoramphus malherbi*	Captive	Pairs[b]	Yes	No	Yes
	Reintroduction	Aves	Psittaciformes	*Cyanoramphus novaezelandiae*	Wild	Pairs[b]	No	No	Yes
	Reintroduction	Aves	Psittaciformes	*Cyanoramphus auriceps*	Wild	Pairs[b]	No	No	Yes
	Reintroduction	Aves	Psittaciformes	*Cyanoramphus auriceps*	Wild	Pairs[b]	No	No	Yes
	Reintroduction	Aves	Psittaciformes	*Cyanoramphus auriceps*	Wild	Pairs[b]	No	No	Yes
	Reintroduction	Aves	Passeriformes	*Dasyornis longirostris*	Wild	Pairs[h]	Yes	No	No
	Reintroduction	Aves	Passeriformes	*Stipiturus malachurus intermedius*	Wild	Pairs[b]	Yes	Yes	Yes
	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	Yes
	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	No
	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	No
	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	Yes
	Conservation Introduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	Yes
	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	Yes
2010	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	No
	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	No
	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	No
	Reintroduction	Aves	Passeriformes	*Atrichornis clamosus*	Wild	Male Groups[i]	No	No	No
	Reintroduction	Mammalia	Hyracoidea	*Procavia capensis*	Mixed	Mixed Groups[b]	No	No	No
	Reintroduction	Mammalia	Macropodidae	*Petrogale xanthopus xanthopus*	Captive	Mixed Groups[b]	Yes	Yes	Yes
	Reintroduction	Mammalia	Carnivora	*Lycaon pictus*	Mixed	Mixed Groups[b]	Yes	Yes	Yes
	Reintroduction	Mammalia	Primates	*Leontopithecus rosalia*	Mixed	Mixed Groups[b]	Yes	Yes	Yes
	Population Reinforcement	Mammalia	Primates	*Pan troglodytes troglodytes*	Wild	Mixed Groups[b]	Yes	Yes	Yes
	Population Reinforcement	Mammalia	Artiodactyla	*Beatragus hunteri*	Wild	Mixed Groups[b]	No	No	No
	Reintroduction	Mammalia	Artiodactyla	*Oryx leucoryx*	Captive	Mixed Groups[a]	No	No	Yes
	Reintroduction	Mammalia	Artiodactyla	*Oryx leucoryx*	Captive	Mixed Groups[a]	No	No	Yes
	Reintroduction	Mammalia	Artiodactyla	*Naemorhedus caudatus*	Wild	Mixed Groups[j]	No	No	Yes
	Reintroduction	Mammalia	Artiodactyla	*Rupicapra pyrenaica ornata*	Mixed	Mixed Groups[k]	No	No	Yes
	Reintroduction	Mammalia	Proboscidae	*Loxodonta africana*	Wild	Mixed Groups[b]	No	No	No
	Reintroduction	Mammalia	Proboscidae	*Loxodonta africana*	Wild	Mixed Groups[b]	Yes	No	Yes
	Reintroduction	Mammalia	Artiodactyla	*Porcula salvania*	Captive	Mixed Groups[b]	Yes	Yes	Yes

References: a – Soorae, 2008; b – Soorae, 2010; c – Rocamora & Richardson, 2003; d – Matthews & Evans, 1974; e – Mougeot, 2000; f – Gotceitas & Godin; g – Barry, Shanas & Brunton, 2014; h – Smith, 1987; i – Smith, 1996; j – Baskin & Danell, 2003; k – Nowak & Paradiso, 1983.

Analyses

The success rates did not differ between reintroductions and population reinforcements (G = 0.02, df = 1, p = 0.88). Similarly, success rates did not differ between release regimes (soft vs. hard release; G = 0.35, df = 1, p = 0.55) or between different origins of translocated animals (wild, captive or mixed origins; G = 0.61, df = 2, p = 0.73). Besides, success rates also did not differ between taxonomic groups (birds vs. mammals; G = 1.01, df = 1, p = 0.32).

On the other hand, success rates were higher in reintroductions with social treatment, as compared to those which did not take this factor in account (G = 7.10, df = 1, p = 0.007). I also found differences in success rates for translocations of species with different social systems (male groups, mixed groups and pairs; G = 6.04, df = 2, p = 0.05). However, when excluding the cases of the single species forming male groups (*Atrichornis clamosus*; 10 cases), this effect disappears (G = 0.67, df = 1, p = 0.41).

The translocation success rates used for the G-tests are represented in Figure 1.

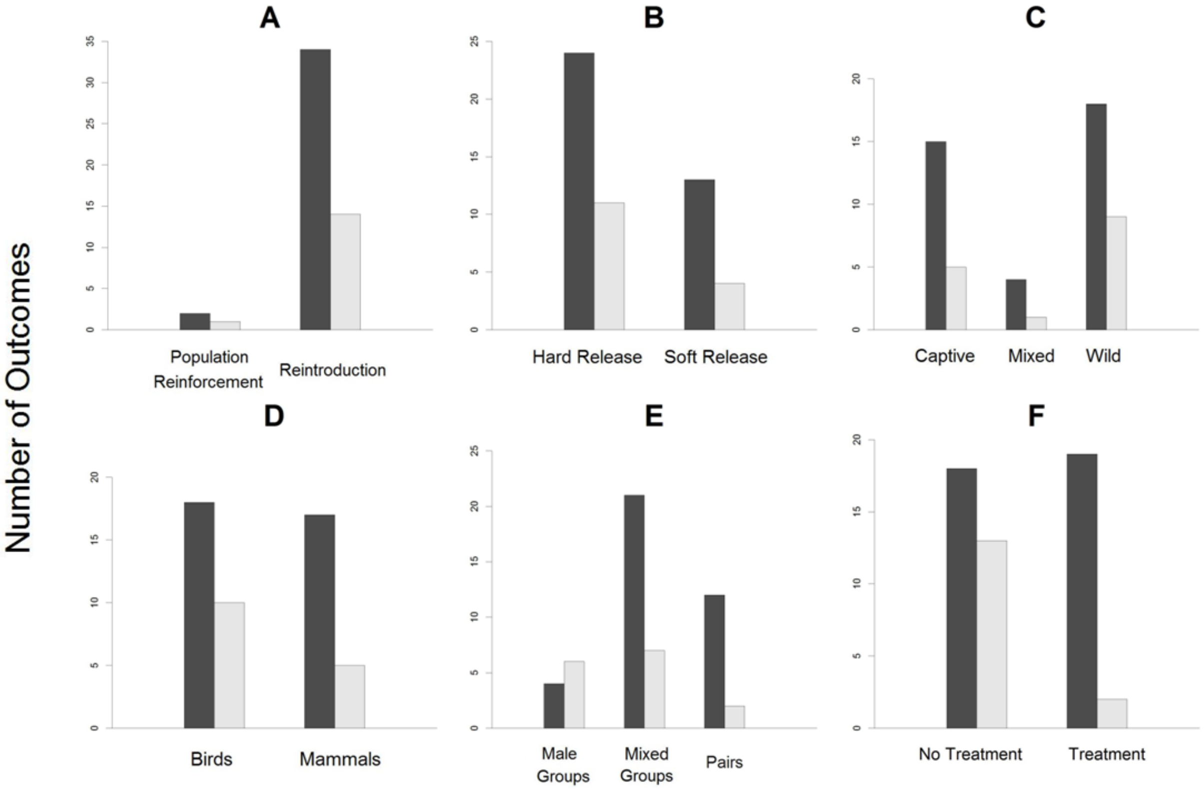

Figure 1. Success rates of translocation reports. Dark bars: successful cases; light bars: unsuccessful cases. N = 52 case studies, except when noted. A – Translocation type (N = 51); B – Release regime; C – Origin of translocated animals; D – Taxonomic affiliation (N = 50); E – Social system; F – Social treatment.

DISCUSSION

Reintroduction attempts consume a considerable amount of time and resources, and involve the risk of losing individuals, sometimes belonging to endangered species. For these reasons, knowledge about the species' life history and attendance to the needs of released individuals is crucial to reduce the risks of spending money, time and animals on reintroductions that are doomed to fail because of avoidable reasons (IUCN/SSC, 2013).

The sociality of the species is one of the life history characteristics that should be taken in account in translocation methods. Sociality is a complex concept, because social behavior is subject to intraspecific variation influenced by ecological pressures, such as resource availability and predation risk, and factors like physiology and behavior (for a review of intraspecific variation of vertebrate social systems, see Lott, 1984). At least for some species, there is evidence to support the hypothesis that characteristics like gregariousness, dominance and mating strategies are not always fixed; rather they are influenced by nutritional state, habitat quality and interspecific interactions (discussed by Mason, 1979). Even in face of this intraspecific variation, it is important to survey the literature on the reintroduced species' social systems, because knowledge on patterns of aggregation, dominance, mating behavior and parental care should be available for many species, and it could contribute to the design of pre- and post-release methods. Those informed decisions are expected to influence positively the outcome of social animal translocations (IUCN/SSC, 2013).

My results show that accounting for a species' social system while planning and executing a translocation has a positive influence on the outcome of the endeavor, translated on higher success rates than expected otherwise. However, the number of cases which incorporated social conditioning on pre- and/or post-release methodology was relatively low (40.4% of 52 cases). In fact, most reports analyzed did not even mention the social systems of the studied species, which indicates that this aspect has not attracted the attention it deserves. The IUCN Guidelines for Reintroductions explicitly recommends that social interactions are addressed on translocation projects, since they are good indicators of social cohesion and return to natural behavior, and can be accompanied by transmission of efficient predator-avoidance and foraging behaviors (IUCN/SSC, 2013). The findings of the present study reinforce the importance of such advice.

Among the other five factors included on this study, only the species' social system influenced the reintroduction success. This could be seen as an indicative that species with different social systems differ in terms of performance during translocations. The fact that the exclusion of *Atrichornis clamosus*, the only species analyzed that forms male groups, made this effect disappear suggests that the effect of the social system on translocation success was artificial, influenced by low translocation success of this species.

Another problem I found while reading and analyzing the case-study reports was that some of the authors relied only on non-biological criteria to evaluate their translocations. The report of the reintroduction of several species of gibbons (*Hylobates* sp.; Soorae, 2008), for instance, had no data on survival, birth rates or integration of social groups. Nevertheless, the researchers classified the project as a successful reintroduction, citing the act of learning with past mistakes as a reason for success. Other cases include inexact reports on mortality (one *Oryx leukoryx* reintroduction reported the death of "more than nine individuals"; Soorae, 2008), absent information on survival and, in one case (*Capreolus capreolus*; Soorae, 2010), the claim that the project was successful because it established a sustainable population, even though the authors did not provide data to support the claim of sustainability. Those reports had to be excluded from the analyses but, more importantly, they wasted the opportunity to provide accurate information which could help reintroduction biologists throughout the world. The collection of success indicators is difficult (Estrada, 2014), but they are necessary to report a translocation project as successful.

The translocation of social animals presents additional complexity to reintroduction biologists, and brings scientific questions which do not apply to the context of solitary animal reintroductions. Our data indicate that paying careful attention to such complexity and being sensitive to the socioecology of the working species may be useful not only for the scientific inquiry, but also to the reintroduction itself.

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CHAPTER 2

BEGINNING THE REINTRODUCTION OF THE BROWN HOWLER MONKEY, *Alouatta guariba* (HUMBOLDT, 1812), TO TIJUCA NATIONAL PARK, RIO DE JANEIRO, BRAZIL

INTRODUCTION

A biological reintroduction is the deliberate movement of living organisms to one or more sites within their species' native range, with the intention to bring the species back to areas from which it has been previously extirpated (IUCN/SSC, 2013). Reintroduction-based conservation actions can be focused on different objectives, ranging from expanding the distribution of a single species to restoring ecological processes lost in the target area after species loss (Spalton *et al.*, 1999; Gibbs *et al.*, 2008; IUCN/SSC, 2013). The concern of restoring ecological processes is key in face of the current state of degradation of Earth's biodiversity. In fact, the 2013 edition of the IUCN Guidelines for Reintroductions and Other Conservation Translocations states that "It is increasingly recognized that, while species conservation remains a priority for conserving biodiversity, reintroduction needs to be undertaken in the context of the conservation and restoration of habitats and ecosystem services." (IUCN/SSC, 2013).

Biomes like the Atlantic Rainforest, with a long history of human degradation, can benefit from the restoration of ecological processes as seed dispersal (Jaroszewicz et al., 2008) and soil fertilization (James & Elridge, 2007). With this in mind, the red-humped agouti, *Dasyprocta leporina*, was reintroduced to Tijuca National Park (hereafter TNP), a large and defaunated urban forest in Rio de Janeiro, in 2010 (Cid et al., 2014). This intended to be the first of a series of mammal reintroductions in order to carry out refaunation (sensu Oliveira-Santos and Fernandez, 2010, 2011) of TNP, re-establishing ecological interactions and generating knowledge about management practices. Within this framework, the second species reintroduced in TNP was the brown howler monkey (*Alouatta guariba*), a large group-living primate which can benefit habitat restoring, primarily through seed dispersal (Anzures-Dadda *et al.*, 2011) and soil fertilization (Neves *et al.*, 2010).

Since the 1990s, the reintroduction literature increasingly advises researchers to conduct systematic and well planned post-release monitoring (Seddon et al., 2007). Monitoring of released animals is important because: (a) it provides information about population establishment, growth and main factors associated with mortality, dispersal and natality; (b) it allows testing of hypotheses about best management actions for the translocated species which can sometimes be generalized to similar species; and (c) it permits to assess if the goals of the translocation (like the re-establishment of ecological interactions and other processes) are met, and to design new methods if they're not (Armstrong & Seddon, 2008; Seddon et al., 2007). Reintroduction Biology is a new and expanding field, and data derived from well-monitored release groups can benefit other translocation projects, advancing the field as a whole.

Publishing these data in clear reports and articles, alongside detailed information about pre- and post-release methodology, is vital to Reintroduction Biology. The publishing of reports about failed translocations is as valuable as those about successful ones, because other researchers may be able to avoid committing the same mistakes (Seddon et al., 2007). Knowledge gained from these reports is likely to inform future reintroductions of the studied species or related ones (i.e. congeners or ecological equivalents) (Fischer & Lindenmayer, 2000; Ewen *et al.*, 2012). The extension of such knowledge is limited, since translocations are complex endeavors subject to great variability regarding factors determinant to the outcome (reviewed by Batson *et al.*, 2015). For example, though there are cases in which the construction of acclimatization pens (a method also known as 'soft release') can be positive to the reintroduction success, by improving survival and reproduction (Bright & Morris, 1994; Hamilton *et* *al.*, 2010; Mitchell *et al.*, 2011), there's also evidence of possible detrimental effects of the prolonged stress posed by the delayed release (Richardson *et al.*, 2015).

The present chapter contains information about the procedures adopted during the twelve months comprising the initial phase of the reintroduction of the howler monkey. The chapter also presents spatial data derived from monitoring the released individuals in the first four months of post-release field work.

Study Site

The Tijuca National Park is a 3,953-ha nature reserve in Rio de Janeiro, Brazil (22°55'-23°00' S, 43°11'-43°19' W). Annual rainfall exceeds 1,200 mm, and mean monthly temperatures vary between 18ºC and 26ºC (ICMBio, 2008). Most of TNP occupies areas once deforested for the establishment of coffee plantations, one of the major historical reasons for Atlantic Forest loss in Southeastern Brazil. In the 19th century the place was reforested, with the intent of protecting the water supply to the city of Rio de Janeiro (Pádua, 2002). The vegetation is classified as montane and submontane ombrophilous forest, and contains both native and exotic species. Even though the presence of non-native species is a problem at the park, the forest houses 1625 native taxa like *Cecropia glaziovii*, *Cariniana legalis* and *Tabebuia chrysotricha.* A total of 433 of those are endangered species recognized by at least one Red List (ICMBio, 2008).

The deforestation process implicated the loss of many animal species that have not yet re-colonized the Park. Thus, there is evidence of the loss of ecological interactions on the area, with impoverished trophic webs (Oda, 2000) and a low recruitment of late successional plants (Montezuma *et al.* 2005). The diminished recruitment of those plants is likely to be due to the loss of seed dispersers, like birds, medium-sized rodents and primates, as Tabarelli & Peres (2002) suggested that seed dispersal by vertebrates is a key process in mature / regenerating Atlantic montane forest patches.

Other re-introduction attempts and opportunistic animal releases have been conducted at TNP on the past. The most notable faunal reintroduction attempts were conducted by Adelmar Coimbra-Filho and Antonio Aldrighi, who, from 1969 to 1973 released individuals of 25 bird species, 7 mammals species and 1 reptile species (Coimbra-Filho & Aldrighi, 1971; Coimbra-Filho & Aldrighi, 1972; Coimbra-Filho et al., 1973). Post-release monitoring was not conducted for any of the species reintroduced, and most of the species failed to establish a viable population. One notable exception was the successful establishment of the channel-billed toucan (*Ramphastos vitellinus ariel*), described in detail by Coimbra-Filho (2000).

Tijuca National Park is located at Rio de Janeiro, one of the largest cities in Brazil, and it is currently the most visited National Park in the country. This renders the reintroduction project a good opportunity to inform people about ecology and conservation, while also having the drawback of dealing with a considerable number of visitors and tourists who can cause problems by interacting with the animals, like feeding them inappropriate food, which may result in discomfort and / or disease. Additionally, an urban forest is exposed to more human-induced disturbance, for example in the form of trash, chemical pollution of the soil, air and water bodies and noise pollution (reviewed by McDonald *et al.*, 2009). Poaching and animal traffic is virtually absent at TNP, especially at the release area, so this was not a major concern in the project.

Study Species

Among the mammal species lost in TNP is the brown howler monkey, *Alouatta guariba* (Humboldt, 1812), an arboreal, group-living atelid primate. One of the most recent recordings of *Alouatta guariba* at TNP comes from Charles Darwin's diary "The Voyage of The Beagle" (Darwin, 1839). Howler monkeys (all species of the genus *Alouatta*) are characterized by their loud (up to 91 db at 5 m, *Alouatta palliata*; Whitehead, 1989) territorial vocalizations, predominantly performed by adult males, and large body size compared to other nonhuman Neotropical primates (male average weight: 6.73 kg; female average weight: 4.35 kg, *Alouatta guariba*; Smith & Jungers, 1997). Howler monkeys have a primarily folivorous diet, though with significant intake of fruits, flowers and buds when available (reviewed in Dias & Rangel-Negrín, 2014). The fact that *Alouatta* rely on a diet comprised mostly of leaves gives them the ability to persist in small fragments (<10 ha, *Alouatta palliata mexicana*; Arroyo-Rodríguez *et al.*, 2007), because of their low trophic level and high dietary flexibility (Bicca-Marques, 2003). Howler monkeys can adapt to anthropogenic impacts by raising the rates of leaf consumption and adding new and/or exotic species to their diet (Bicca-Marques & Calegaro-Marques, 1994; Bicca-Marques, 2003; Rivera & Calmé, 2006). Because of the frugivory and intense folivory, howler monkeys play roles on key processes like seed dispersal (Anzures-Dadda *et al.*, 2011) and soil fertilization (Neves *et al.*, 2010).

Howler monkeys tend to live in groups of three distinct compositions: pairs (one adult male and one adult female), single-male multi-female groups and multi-male multi-female groups. Frequently these groups have the presence of infants and juveniles (Neville *et al.*, 1988; Ostro *et al.*, 2001). Animals from both sexes commonly disperse from the group once they attain sexual maturity (Glander, 1992). As attempts of joining established groups are typically met with agonistic behavior, it is usual that young dispersing adults aggregate to form new groups of varying composition (Zucker & Clarke, 1998; Ostro *et al.*, 2001). Compared to other neotropical primates, like *Sapajus sp.* and *Lagothrix sp.*, species in this genus tend to display low levels of intra- and inter-group aggressiveness, with rare fatal injuries from physical conflicts (Cristóbal-Azkarate *et al.*, 2004).

The group released in TNP belongs to the subspecies *Alouatta guariba clamitans*, which occurs in Atlantic Forest fragments of south and southeastern Brazil, and in the region of Misiones, Argentina. This subspecies is classified as "Least Concern" by the IUCN (Mendes *et al.*, 2008a), and as "Vulnerable" by the Brazilian environmental agency ICMBio (Bicca-Marques *et al.*, 2015). The combined factors of a high consumption of leaves, high dietary flexibility, low intra-specific aggressiveness and favorable conservation status deemed the brown howler monkey as an ideal species for a reintroduction project. Besides the potential to contribute to the species conservation by expanding its current range, the reintroduction can benefit the ecosystem of TNP and also provide information that can be useful for future reintroductions, especially of other *Alouatta* taxa like the Critically Endangered *Alouatta guariba guariba* (Mendes et al., 2008b).

METHODS

Study Group and Pre-Release Conditioning

The released group consisted of four young adult individuals (two males and two females) which were previously living in captivity. We retrieved the dominant male (M1) and the older female (F1) from the Wild Animals Screening Center of Rio de Janeiro State (CETAS-RJ), where they lived with a juvenile male (JM). These 3 individuals were wild-born howler monkeys rescued from risky or conflict situations. Two other howlers — making a initial total of five, of which only four were actually released — were a couple of captive-born siblings (female F2 and male M2) held by the licensed breeding center Criadouro Passaredo, which provided both animals and supported the project with personnel and initial health care.

On February 24, 2015, we transported all 5 howlers to the Primatology Center of Rio de Janeiro (CPRJ), unsedated and in two separate crates, following CPRJ veterinarians' instructions. The transportation using two crates allowed the separation of the two groups and prevented potential aggressive behavior among unfamiliar individuals.

Once in the CPRJ, we lodged the animals in two large cages made of concrete and steel, separated by captive origin, and monitored their behavior. One to 3 people made continuous observations, monitoring each animal for 2h a day, focusing on the possible occurrence of agonistic behavior. On March 6, we put the two groups on a large cage with a barrier which allowed for visual and auditory contact, but prevented aggressive behavior and injuries. We observed the animals for at least 3 days per week during this period and, as no signs of agonistic behavior were detected, we scheduled a test removal of the barrier for April 15. During the first two days of experimental removal of the barrier, the animals were free to interact from morning to early evening, and then separated again during the night. As we observed no fighting, and even the unfamiliar individuals displayed positive social behaviors like food sharing and grooming, the division was suspended from April 16 onward (Figure 1).

Figure 1: Howler monkeys from two different captive origins sitting together inside of the cage at CPRJ. From left to right: F2, M2, M1 and F1.

During the first months in the new captivity, CPRJ staff provided the animals with their routine feeding for howler monkeys. Our group, following advice from CPRJ veterinarians, opted to delay the dietary reeducation protocol, so the animals would have time to recover from potential stress due to transport and adaptation to the new locality. Thus, they fed on whole-grain sliced bread and milk in the morning and a mix of commercial fruits (papaya, *Carica papaya*; banana, *Musa x paradisiaca*; orange, *Citrus* *x sinensis*; cucumber, *Cucumis sativus*; melon, *Cucumis melo*; watermelon, *Citrullus lanatus*; and pumpkin, *Cucurbita pepo*), leaves (lettuce, *Lactuca sativa*; chicory, *Cichorium endivia*; collard, *Brassica oleracea*; and spinach, *Spinacia oleracea*), roots (sweet potato, *Ipomoea batatas*; carrot, *Daucus carota*; and beet, *Beta vulgaris*) and raw corn ears (*Zea mays*) in the afternoon. We maintained this diet until May 13, when the dietary reeducation was implemented (see below).

We had to exclude JM from the release because of a conflict with the dominant male (M1) that occurred on July, 8. We assumed the conflict to be unrelated to the mixing of the two groups, since the two individuals were in the same group at CETAS-RJ. Though relatively rare, fighting occurs in howler monkey groups in the wild, and it is common that individuals reaching sexual maturity are expulsed by dominant individuals (Glander, 1992; *Alouatta palliata*). The animal had injuries on skin and muscle tissue of the right leg, but no broken bones or signs of internal damage. CPRJ provided him healthcare, separated from the group.

We transported the other four howler monkeys to the TNP in the morning of August 15, 2015. The transportation occurred similarly to the transport to CPRJ, without sedation and in two large crates. We transferred the animals to a soft release pen immediately after arrival (see the "Soft release" session below).

Dietary Reeducation

Pre-release conditioning is of great importance when dealing with captive animals for a reintroduction (Kleiman, 1989). Since all individuals were used to a diet composed by commercially viable items, we conducted a phase of dietary reeducation, so the animals would recognize Atlantic Forest leaves and fruits as proper food. For this phase, we changed the feeding procedure of the individuals. Both the morning and the afternoon meals consisted of the same items: the same mix of commercial fruits (papaya, banana, orange, cucumber, melon, watermelon and pumpkin) and roots (sweet potato, carrot and beet), with the addition of Atlantic Forest tree leaves (pitanga, *Eugenia uniflora*; arariba, *Centrolobium tormentosum*; guava, *Psidium guajava*; spiked spiralflag, *Costus spicatus*; jacaranda, *Jacaranda sp.*; inga, *Inga sp.*; e garapa *Apuleia leiocarpa*), and fruits/flowers when available. We collected the leaves daily from trees present in CPRJ. We kept feeding the howler monkeys with commercial fruits and roots to avoid problems related to malnutrition. We conducted the re-education protocol from May 13 until the transport of the animals to the TNP, on August 15, 2015.

Soft release

In order to reduce stress and get the animals used to the wild environment, we lodged the group inside of a 4 x 2 x 2 m soft release pen built on a clearing in the forest (Figure 2). During this time, we fed the animals twice a day, with a mix of 1,4 kg of commercially viable fruits which also occur in TNP (bananas; papayas; avocados, *Persea americana*; guavas; chayotes, *Sechium edule*; and mangoes, *Mangifera indica*), and 1 kg of leaves collected on site. After the first two weeks of supplementary feeding inside the enclosure, we started to reduce the amount of fruit provided, so the animals could be stimulated to use the natural environment for foraging. Thus, we monitored the presence of fruit leftovers from the previous day. Because the morning and the evening meals were provided on separate bowls, we were able to discriminate when food was left uneaten for more than 24h. Whenever this happened for 4 consecutive days, we reduced 400g of the fruits, to a minimum of 600g per meal. We also provided the animals with fresh water, which was replaced daily. The howlers stayed inside of the pen from August 15 to September 4, the day of release. The method of release was to open the door of the pen, so the animals could exit at will.

We kept providing 1 kg of fruits daily during the first two months after the release. For this, on September 27 we installed a platform in a tree located approximately 150m away from the release pen, consisting of a crate which could be lifted and lowered by a rope on a sheave (Figure 3).

Figure 2: Soft release pen (4 x 2 x 2 m) mounted on a forest clearing at TNP.

Figure 3: Howler monkey feeding at the hanging platform.

Post-release monitoring

Each individual received a custom-built telemetry device (TGB-315, Telenax®, Playa del Carmen, Mexico) with an embedded GPS and a unique radio signal (Figure 4). The embedded GPS recorded each animal's position 4 times every day, and these data could be downloaded biweekly via Bluetooth, with a customized tablet provided by the device's manufacturer. For the females, the device was inserted on a collar adjusted to the neck, while the males received anklets containing the devices. This allowed individual tracking of the howler monkeys, for observation and collection of additional spatial data with a handheld GPS (Garmin eTrex 20®, Schaffhausen, Switzerland).

During the first week, a maximum of 3 observers monitored the four animals daily, for 6h a day. This was a measure of precaution, because of possible conflicts with other species or problems involving park visitors. After this critical period, we changed the monitoring routine to avoid intense contact with the monkeys, which could be detrimental to their behavior and adaptation. A maximum of 2 observers went to the field to collect spatial data with the handheld GPS. We designed the field routine in order to record 3 positions a day for each monkey, with a minimum interval of 1h between individual data. During this interval, the observers either left the animals alone or followed one of the individuals, observing its feeding behavior during 1h. We utilized the spatial data for home-range estimates, and subsequent inferences.

Figure 4: Male howler bearing Telenax® TGB-315 radiotransmitter on left ankle.

Home-range Estimation

I used the spatial data collected in the field to model home-range areas for all four individuals, utilizing two distinct home-range estimators. The first was the simple method called the Minimum Convex Polygon (MCP; Mohr, 1947), which consists in connecting the dots representing the most external localizations of each individual to form the smallest polygon possible. The MCP can be calculated for the complete set of spatial points collected for each individual or by subsets that exclude the outermost points, to reduce the probability of overestimation. Thus, for each animal, I calculated the MCP with both 100% and 95% of the data.

The second estimator I utilized was the fixed kernel (Worton, 1989), which describes the home-range as a probability density function, based on the distribution of localizations (Silverman, 1986; Seaman & Powell, 1996). I considered only 95% of the spatial localizations collected for each animal. The fixed kernel estimator has a smoothing parameter (h), which influences the way that the model interprets each localization in terms of the occupied area it represents. Worton (1989) recommended the use of a calculation to determine the reference smoothing factor (h_{ref}), which is based on the variation of the coordinates of the spatial data. Thus, I calculated and utilized h_{ref} values for the fixed kernel home-range estimates.

I utilized two metrics of spatial aggregation as proxies of social cohesion: MCP centroid distance and the overlap percentage of fixed kernel home-ranges. Since the estimated home-range is dependent on the number of data collected, it is important to test the validity of home-range estimations by checking if the data collected is sufficient to capture a reliable home-range (Harris *et al.*, 1990). Thus I re-sampled the spatial data for each individual, to re-calculate the home-range area from subsets of data using 95% MCP. Following instructions by Harris *et al.* (1990), localizations were added at random, and the area was estimated after the addition of each new point. I performed this re-sampling process 1000 times for each animal, and obtained the mean values of home-range sizes from all runs. Then I plotted the home-range sizes against the respective sample sizes, to verify if the curves reached an asymptote.

All estimations were performed with the software R 3.2.5 (R Core Team, 2016), using the packages rgdal (Bivand *et al.*, 2016), rgeos (Bivand & Rundel, 2016), sp (Pebesma & Bivand, 2005), maptools (Bivand & Lewin-Koh, 2016) and adehabitatHR (Calenge, 2006).

RESULTS

Release and difficulties faced

The four animals released at Tijuca National Park started feeding on native tree leaves on the day of release. The animals explored the trees near the soft release pen, but stayed close (< 50m) to the release site for the first two weeks. After this period, the animals started making occasional incursions to greater distances, but remained close to the pen, especially for sleeping. Howler feces collected as part of another project have shown the presence of native fruit seeds. These registers are still anecdotal, and the seeds are yet to be identified.

The radio-transmitter of two animals (M1 and the F2) ceased working by the first month after the release. We were still able to find these two individuals whenever they were nearby the other two howler monkeys, and on rare opportunistic encounters. Fortunately, the four individuals remained together for most of the first month after release, which allowed monitoring during the initial adaptation phase, but F2 detached from the group. Subsequently she disappeared; the individual has not been found in the field since November 5.

Starting at September 14, M2 started to exhibit abnormal behavior, detaching from the group and walking on the ground of the forest. He also started following people, approaching researchers, park staff and visitors. On September 16, 2015, the animal was returned to the soft release pen, so he could be examined by a CPRJ veterinarian. The animal had lost weight, and showed symptoms of a respiratory tract infection. He was medicated, supplied with extra fruits (1 kg a day, provided inside the soft release pen to avoid stealing by the other individuals) and released again in September 19. This individual remained walking on ground level and intermittently spending a great amount of time by himself. He also started to walk, sit and lay down on the park's roads, which put him in danger of being hit by vehicles. We made several attempts to attract the animal back to the trees, including startling him while he was on the ground or about to descend from a tree, capturing and moving him back to the company of the other individuals and providing food on the trees to attract him. As the animal was at risk of car accidents, feeding on items provided by tourists or eventual abduction, we decided to withdraw the animal, which was captured and transported back to CPRJ in November 23.

The two remaining animals were monitored regularly until the end of the year. By November we started noticing a swelling on the abdominal region of the older female, F1. The individual, who was permanently associated to the dominant male until then, started to move on her own, staying close to the release pen. In February 18, 2016, we spotted an infant howler on her back, the first howler monkey born at TNP since the probable extirpation of the species. Her collar stopped working around this time, leaving us with no functioning radio-tracking device on the field.

In mid February, 2016, M1 started to exhibit similar behavior to M2. The animal walked on the floor, approached people and rested on the roof of the Park Administration building. Since the previous experience showed efforts of deterrence of ground-dwelling behavior to be unfruitful, we decided to capture and relocate this individual to a different, less visited sector of TNP, with no road access. The animal was captured on March 13. On March 14 the animal was sedated and examined by a CPRJ veterinarian, who helped with the replacement of the telemetry device. The animal was transported inside a large crate while unsedated, and released on March 15, near a previously installed feeding platform, in which we planned to provision 1 kg of fruits daily during the first week. The new telemetry device ceased to work on the second day in the field, and M1 seemed to have abandoned the release site, since the provisioned fruits were left uneaten during 3 days and he has never been spotted afterwards.

Home-range Estimation

The home-range sizes for the four howler monkeys are shown in Figure 5 and Figure 6. The plots of home-range size versus number of fixes, however, failed to achieve asymptotes (Figure 7), which limits inferences about the values. The values of estimated areas are presented at Table 1.

The distances between the MCP centroids of all animals are presented at Table 2. Distances varied between 2.34 and 31.91 m, and were bigger between the two males. The overlapping proportions of fixed kernel-estimated home-ranges for all animals are presented at Table 3. The home range of F2 is contained within the home ranges of the other 3 individuals (Fig. 1A; Table 3).

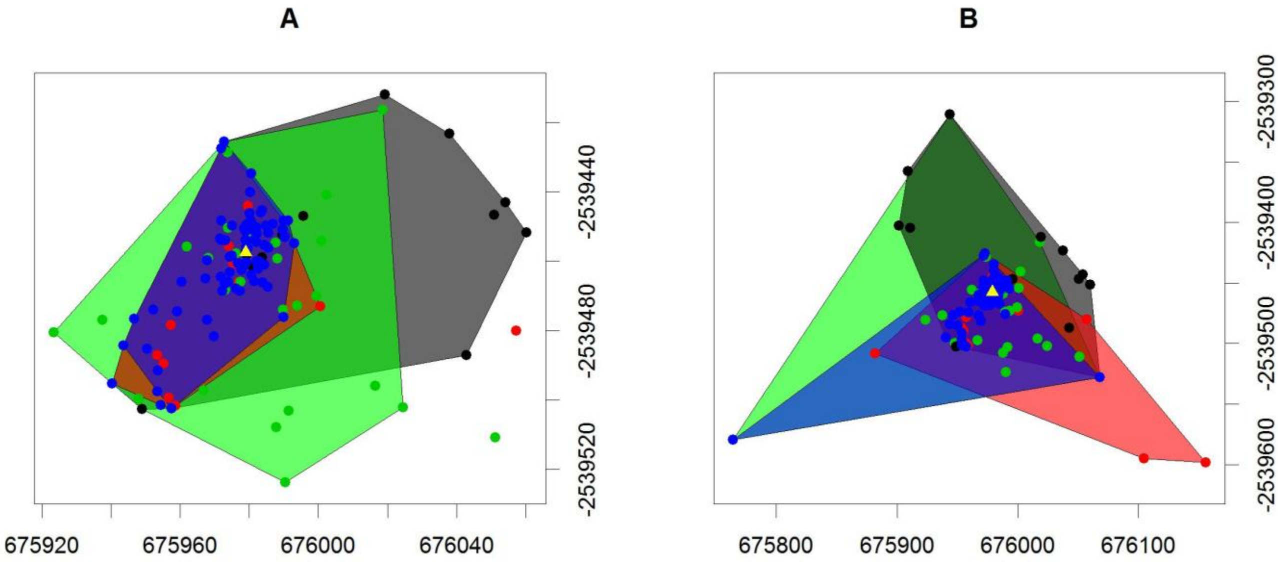

Figure 5: Ninety five (A) and 100% (B) Minimum Convex Polygons (MCP) representing the estimates of home-range areas of the four howler monkeys released at TNP. The collored areas represent the polygons derived from the spatial points (collored dots). Each color represents one individual. Green: M1; Black: M2; Red: F1; Blue: F2. The yellow triangle represents the position of the soft-release pen.

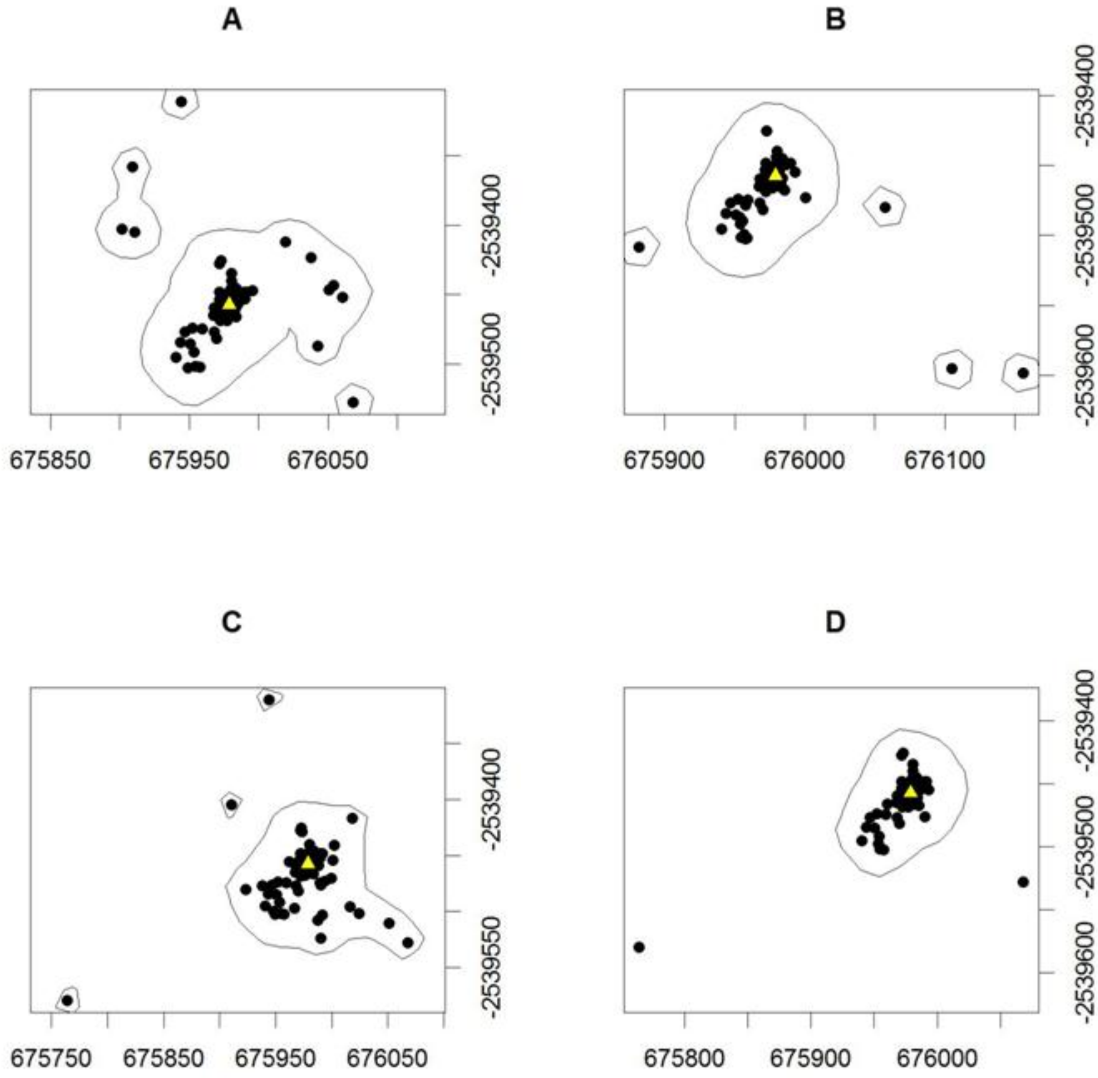

Figure 6: Ninety five percent fixed kernel estimates of home-range areas of the four howler monkeys released at TNP. (A) M1; (B) M2; (C) F1; (D) F2. The yellow triangle represents the position of the soft-release pen.

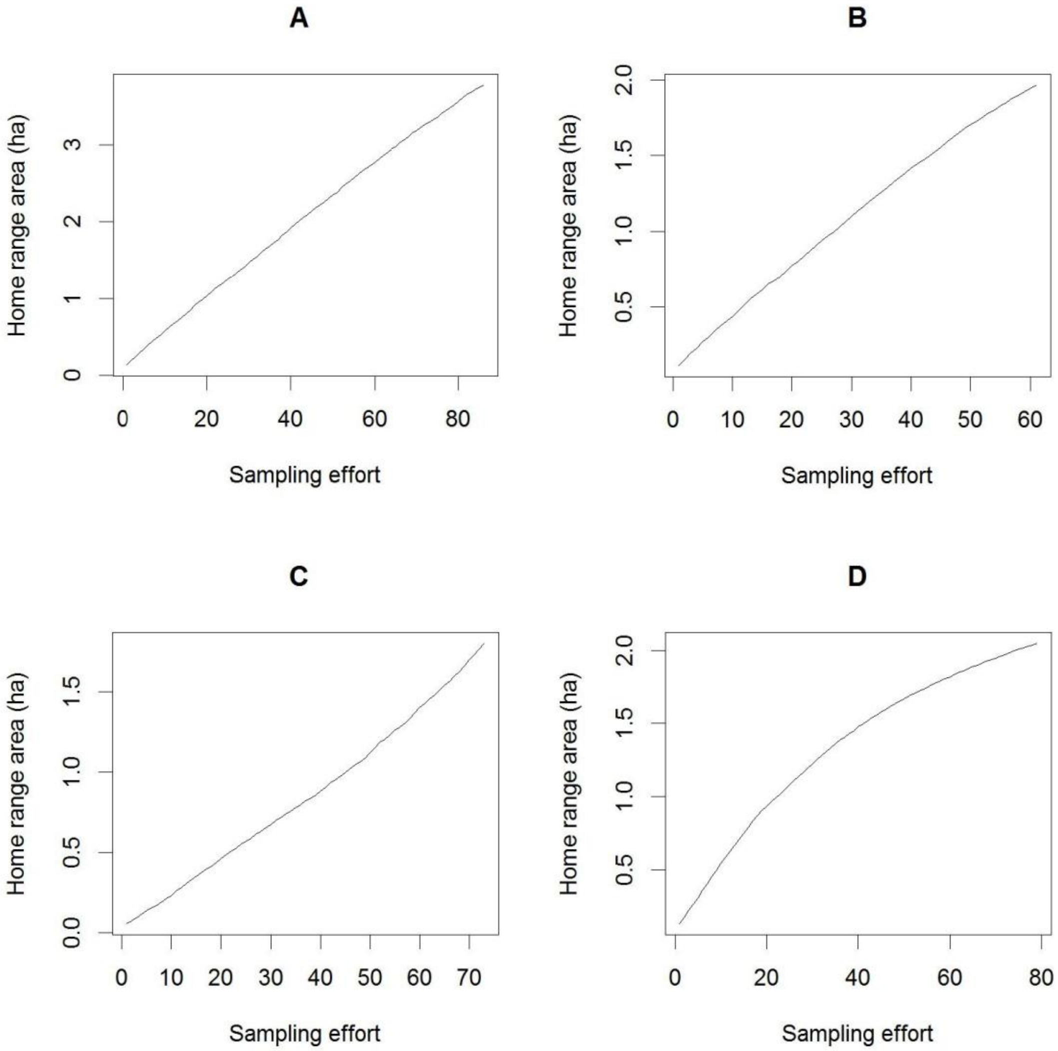

Figure 7: Validation curves for the home-range estimates, representing mean areas estimated by 100% MCP plotted against simulated sampling effort. N = 1000 simulations. (A) M1; (B) M2; (C) F1; (D) F2.

Table 1: Estimated home-range areas for the four howler monkeys released at TNP, using 3 different estimators. MCP: Minimum Convex Polygon.

	95% Kernel	95% MCP	100% MCP
M1	1.740 ha	0.712 ha	2.046 ha
M2	1.187 ha	0.233 ha	1.964 ha
F1	1.602 ha	0.695 ha	3.775 ha
F2	0.813 ha	0.205 ha	1.802 ha

Table 2: Distances between the centroids of estimated home-ranges (by 95% MCP) of the four howler monkeys released at TNP.

	M1	M2	F1
M2	31.91 m	-	-
F1	20.84 m	13.32 m	-
F2	31.77 m	2.34 m	14.32 m

Table 3: Overlapping proportions of home-ranges of the four howler monkeys released at TNP. Home-ranges estimated with 95% fixed kernel.

	M1	M2	F1	F2
M1	100%	58.51%	69.79%	42.98%
M2	67.07%	100%	75.36%	49.27%
F1	68.76%	64.78%	100%	42.35%
F2	100%	100%	100%	100%

DISCUSSION

This chapter summarized the methods and results of the first brown howler monkey release at TNP. We faced many difficulties on this first release, culminating on an uncertain scenario where one of the animals had to return to captivity and the monitoring of the remaining individuals relies on opportunistic encounters. In this section, I discuss the reintroduction as a whole, list the main problems faced by our team and discuss alternative decisions which may prevent a similar scenario in future releases.

We released four howler monkeys at Tijuca National Park, a secondary Atlantic rainforest remnant composed of both native and alien plant species. At least two of the monkeys (the older couple) survived the first six months after release, and the female gave birth to an infant. Those are two good indicators of the animals' nutritional and overall health status. It is not possible to determine if conception occurred at the park, or if F1 was transported while pregnant, but the latter hypothesis is more probable as the gestational period of howler monkeys is of approximately 180 days (Glander, 1980; Crockett & Sekulic, 1984; Strier *et al.*, 2001). We also cannot determine yet which male sired the infant, but it is reasonable to suspect that the dominant male monopolized copulation opportunities (Van Belle *et al.*, 2009). Additionally, the dominant male was constantly seen roaming with the respective female.

We did not collect sufficient spatial data to design reliable home-range estimates. This is in part because of equipment malfunction, which prevented us from keeping a uniform field routine. The fact that the group dissolved after release is unfortunate, but not uncommon in howler monkey reintroductions (Richard-Hansen *et al.*, 2000; Porfirio, 2005). Hypotheses to explain this phenomenon include: (1) stress associated with the translocation and adaptation to the new environment; (2) interaction with other resident animals (in our case, there is no occurrence of conspecifics, but encounters with capuchin monkeys might represent an additional source of stress); (3) lack of previous knowledge of the habitat, resulting in greater possibility of individuals losing track of each other during group movement (Richard-Hansen *et al.*, 2000). All three hypotheses could be involved on the fission of our group, as well as a fourth hypothesis: artificially formed social interactions may be weaker than the long-term social bonds in naturally occurring howler monkey troops. Regardless of the explanation, it is possible that the release of additional groups in the future helps to solve this problem, as other translocation projects found group fission to be common, but reversible at higher densities because the animals tend to aggregate when they meet opportunistically (Kierulff, personal communication).

The final problem to be discussed is that of animals dwelling on the ground and following people. There are reports on the literature of increased levels of tameness on captive animals (Snyder *et al.*, 1996), especially for hand-reared individuals (Myers *et al.*, 1988). Although the older male was a wild-born individual, he also exhibited low aversion towards humans, which may be related to an extended (more than one year) captivity time in contact with human caretakers. It is important to notice that none of the female howler monkeys exhibited ground-dwelling behavior or curiosity towards people, but with such a low number of individuals it is difficult to draw significant hypotheses. Low aversion to humans has been associated to low predator avoidance for some species (*Alectoris graeca*, Zaccaroni *et al.*, 2007; *Peromyscus polionatus subgriseus*, McPhee, 2003), and other issues like increased risk of conflict (*Puma concolor*, Belden & McCown, 1996). Future releases should rely as much as possible on wild-born animals, and the release-site should be more isolated from roads and frequently visited places. The choice of building the soft release pen near the Park Administration building was influenced by our concerns about the safety of the animals if they were released on a remote site, with low surveillance by park staff, but the risks associated with road and visitor proximity should be considered in the future.

The fact that at least two howler monkeys successfully established themselves for six months, feeding on native fruits and leaves and generating offspring is encouraging for the future of the project. If knowledge gained from this first release enables us to expand the present success, it may be possible to establish a self-sustaining howler population which, in turn, will raise a plethora of new scientific questions about ecological processes, spatial ecology and behavior.

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GENERAL CONCLUSIONS

The present work is focused on the topic of translocating social animals and learning from the process in order to increase the probability of success of future reintroductions. The results of the first chapter show that taking the sociality of a translocated species into account when designing the methodology to be followed can increase the overall probability of success, as illustrated by a greater proportion of successful translocations among case-studies which explicitly incorporated some sort of social conditioning during the pre-release phase. This finding informed our decisions about the reintroduction project discussed on the second chapter, influencing our decision to promote the bonding of four howler monkeys prior to release, with attention to the species' sociality.

The first release of the reintroduction, discussed in Chapter 2 enabled us to learn about the problems of releasing howler monkeys close to areas utilized by people, because of the risk of interaction and feeding by visitors and the even more alarming risk of injury or death by car accidents. Additionally, it is important to notice that the spatial data collected was insufficient to draw reliable estimates about home-range size, because the animals seemed to still be exploring the new environment. Future releases should be monitored more intensively, if the problems with the monitoring equipment do not reoccur.

Finally, the process of evaluating the success of a translocation demands long-term monitoring, in order to collect sufficient data to draw reliable conclusions about population growth or stability. Reintroduction biologists and other people involved in translocations should always have this in mind, to be able to publish articles and reports from which conservation practitioners can obtain valuable knowledge. Our project is still far from this stage, but it is possible that, with the maintenance of new group releases and an increasingly well informed monitoring regime, the brown howler monkey at TNP will attain the status of a re-established population. This would contribute not only to the field of Reintroduction Biology, but also to the ecosystem to which the species once belonged.