Master Thesis

The golden lion tamarin (Leontopithecus rosalia): a flagship species for the Atlantic Forest of Brazil

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The golden lion tamarin (*Leontopithecus rosalia*): a flagship species for the Atlantic Forest of Brazil

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Abstract
Deforestation has a major impact on forest-dwelling species survival, as species lose their habitat or can no longer subsist in the small fragments of forests that are left. In this review, the effectiveness of the golden lion tamarin (Leontopithecus rosalia) as a flagship species to protect the biodiversity of the Atlantic Forest is discussed. The golden lion tamarin was almost extinct in the wild in the 1960s and the captive population was not well established. After research on captive breeding biology, the captive population began to grow in the 1970s and the Poço das Antas Biological Reserve was created to protect the species in the wild. In the 1980s, long-term research was started on the ecology and behavior of golden lion tamarins, along with a reintroduction program of captive-born animals and community environmental education. Zoos contributed the 146 captive-born reintroduced tamarins, and provided critical information on social behavior, nutrition and health used for reintroduction strategies. In 1994, 6 threatened groups that were isolated in small fragments were rescued and translocated to a protected forest. Both translocation and reintroduction programs have been successful as measured by survival and reproduction after release, and both established growing populations, as well as protected habitat. Furthermore, conservation education and habitat restoration have resulted in the development of forest corridors to connect the remaining habitat fragments, allowing dispersal of golden lion tamarins. By saving the golden lion tamarin, more than 12,000 ha of Atlantic Forest is now protected by federal law and with this habitat, many other species are also protected. The Golden Lion Tamarin Conservation Program can serve as a model for conservation activities worldwide, as the program integrates field and captive conservation efforts and shows how extensive research is able to contribute to effective conservation and education activities.

Key-words: deforestation, conservation, Leontopithecus rosalia, golden lion tamarin, Golden Lion Tamarin Conservation Program, Atlantic Forest, captive breeding, reintroduction, translocation, conservation education, metapopulation management, habitat protection.
1. Introduction
As human populations grow, more and more forests are disappearing to make room for farms and pastures, roads, and urban areas. Deforestation is a growing problem worldwide, with more than 13 million hectares that are cut down yearly (FAO, 2006). Since the planet’s forests support an abundance of plant and animal species, deforestation has a major impact on species survival. Arboreal and forest-dwelling species lose their habitat completely, or can no longer subsist in the small fragments of forests that are left. Cascading changes in the types of trees, plants, and insects that can survive in the fragments rapidly reduces biodiversity in the forest that remains. Populations decrease, and eventually some species will go extinct. Because certain forests are characterized by a high degree of endemism, or presence of species that are only found within a specific geographical range, even localized deforestation can result in loss of species.

To slow down the increased loss of biodiversity through deforestation, numerous conservation programs have been developed by conservationists all over the world. Since the number of threatened species worldwide far exceeds the available conservation resources, a lot of conservation actions are concentrated on so-called biodiversity hotspots: biogeographic regions with a high level of endemism and an exceptional loss of habitat. Here, the payoff from conservation actions is greatest. One of the hotspots is the Atlantic Forest of Brazil, where deforestation has caused a 90% reduction of the original forest extend and consequently threatened a lot of species with extinction.

This review focuses on one particular conservation program that is developed to save the biodiversity of the Atlantic Forest of Brazil: The Golden Lion Tamarin Conservation Program (GLTCP). The GLTCP uses the golden lion tamarin (Leontopithecus rosalia), endemic to the Atlantic Forest of Brazil, as a flagship species to raise awareness and stimulate action and funding for broader conservation efforts. By saving the habitat of the golden lion tamarin, the survival of other species living in the same ecological community is also guaranteed. However, before I will discuss the GLTCP as a way to protect the biodiversity of the Atlantic Forest, the impact of tropical deforestation will be highlighted to illustrate the extent of the problem.

1.1 The impact of tropical deforestation
The deforestation of primary forests\(^1\), such as tropical rainforests, has a great impact on biodiversity. Tropical rainforests, characterized by high average temperatures and a significant amount of rainfall, are incredibly rich ecosystems that play a fundamental role in the basic functioning of the planet. They act as major consumers of atmospheric carbon dioxide (CO\(_2\)), which is one of the primary greenhouse gasses, and play a large role in stabilizing rainfall (Whitmore, 1998). Although tropical forests cover only 7% of the Earth’s dry land, they harbor up to 50% of all living animal and plant species (Terborgh, 1992). 40% to 75% of all biotic species are indigenous to tropical rainforests (Terborgh, 1992). A single hectare of tropical rainforest may contain as much as 42,000 different species of insects, 313 species of trees, and 1,500 species of higher plants (Newman, 2002). Furthermore, two-thirds of all flowering plants can be found in rainforests (Newman, 2002). Because of this high biodiversity, tropical rainforests are often called the ‘jewels of the Earth’ and the ‘world’s largest pharmacy’, since over one quarter of natural medicines have been found within these forests (Mathis, 2006). Today, still many species of plants, insects and microorganisms living in tropical rainforests remain to be discovered.

Despite the ecological importance of tropical rainforests, these ecosystems are among the most threatened on the planet due to large-scale fragmentation through human activity. In the past, habitat fragmentation caused by geological processes contributed to the arise of new species (Sahney et al., 2010). However, fast human-driven habitat destruction by tropical deforestation is suspected to be one of the major causes of species extinction. Throughout the 20\(^{th}\) century, tropical

\(^1\) Forests of native species, in which there are no clearly visible indications of human activity, and ecological processes are not significantly disturbed (e.g. tropical rainforests). These forests are characterized by a high biodiversity. (FAO, 2006)
rainforests have been subjected to heavy logging and agricultural clearance, thereby rapidly decreasing the area covered by rainforests around the world (FAO, 2006). South America suffered the largest net loss of forests, with around 4.0 million hectares per year between 2000 and 2010 (FAO, 2010). In this part of the world, large tracts of Amazon rainforest are being cleared for cattle ranches and soybean plantations (FAO, 2010).

The highest rate of deforestation occurs in Brazil, the largest country in South America. Primary forests cover 57% of Brazil’s total land area, which is approximately 476.573 * 10^3 ha (FAO, 2010). Brazil’s primary forests represent 33% of the world’s remaining primary forests (FAO, 2010), and are among the most biodiverse forests on Earth. An estimated 10-20% of all known species live in the tropical rainforests of Brazil (Barreto et al., 2006). The rapid tropical deforestation in Brazil is impacting the habitats of many animals and plants, with the result that many species are threatened with extinction. Between 1990 and 2010, Brazil experienced a net primary forest loss of 0.50% per year (2.766 * 10^3 ha; FAO, 2010). In total, Brazil lost 9.6% of its primary forest cover between 1990-2010 (55.317 * 10^3 ha; FAO, 2010).

**Deforestation of the Atlantic Forest of Brazil**

The Atlantic Forest was the first primary forest to be affected by deforestation in Brazil. This tropical rainforest, stretched across a long latitudinal gradient of over 3300 km of the Brazilian Atlantic coast and extending west into smaller, inland areas of Paraguay and Argentina (Figure 1), once covered 150 million ha in highly heterogeneous environmental conditions (Ribeiro et al., 2009). The Atlantic Forest is characterized by a high biodiversity, including more than 20,000 species of plants, 620 species of birds, 261 species of mammals, 200 species of reptiles, 280 species of amphibians, and many more species that still require scientific description (Myers et al., 2000). The forest exhibits outstanding levels of species endemism, which account for 40% of its vascular flora and 28-90% of its bird, mammal, reptile and amphibian fauna (Myers et al., 2000). The flora and fauna of the Atlantic Forest may include 1-8% of the world’s total species (da Silva & Casteleti, 2003). However, since the arrival of the first Portuguese colonists in the 16th century, the Atlantic Forest has been destroyed and converted to urban areas, cattle pasture, farmland and plantation forestry (Kierulff et al., 2012). The introduction of sugar cane by the Portuguese colonists resulted in the conversion of much of the lowland primary forest into plantations (Dietz, 2000). By 1900, the standing lowland forest had been reduced to less than 5% of the original area due to clear-cutting to supply fuel for railroad steam engines and domestic use, and to clear land for pasture and crops (Dietz, 2000).

![Figure 1. Biogeographic distribution of the Atlantic Forest cover, showing its original extent and current remnants divided into the eight major sub-regional units (adapted from Tabarelli et al., 2010).](image-url)
Nowadays, around 70% of Brazil’s 190 million people live along the Atlantic coastline. The incorporation of human societies and their needs for forest resources has reduced the size of the Atlantic Forest even more, with only 12% of the original extend remaining today (Ribeiro et al., 2009). High levels of deforestation continue in most regions, with annual rates of 0.5% for the whole Atlantic Forest, and up to 2.9% in the São Paulo metropolitan area (Teixeira et al., 2009). Most of the remaining Atlantic Forest exists in small fragments (80% of the fragments are <50 ha, Ribeiro et al., 2009) that are isolated from each other and are composed by secondary forests in early to medium stages of succession (Viana et al., 1997). Almost half of the remaining forest is highly vulnerable to edge effects (<100 m from its edges, Ribeiro et al., 2009). The few large fragments remaining are located in higher areas, where steep terrain made human occupation particularly difficult (Silva et al., 2007). As a result of the present-day deforestation and fragmentation, a large proportion of the Atlantic Forest’s biodiversity is threatened with extinction. For example, more than 70% of the 181 endemic bird species are threatened or endangered (Stotz et al., 1996). Of the 14 species of primate endemic to the Atlantic Forest, 9 are either listed as critically endangered or endangered, and 2 are listed as vulnerable (Bernardes et al., 1990). Approximately 60% of the species on the official threatened species list of Brazil are located in the Atlantic Forest (Bernardes et al., 1990).

1.2 Biodiversity conservation of the Atlantic Forest

It is clear that conservation actions are needed in order to protect the biodiversity of the Atlantic Forest and its remaining habitat. However, the number of species threatened with extinction worldwide far exceeds the available conservation resources. Therefore, priorities need to be identified. To determine where conservation actions would be most effective, biodiversity hotspots are designated, defined as areas with an exceptional concentration of endemic species and an exceptional loss of habitat (Myer et al., 2000). By concentrating on areas where there is greatest need and where the payoff from conservation measures would also be greatest, conservationist can engage in a systematic response to the challenge of large-scale extinctions ahead (Myer et al., 2000). To qualify as a hotspot, a region must meet two criteria: it must contain at least 0.5% or 1500 of the world’s 300,000 vascular plants as endemics, and the region should have lost 70% or more of its primary vegetation (Myer et al., 2000). Worldwide there are 25 areas designated as ‘hotspots’, together harboring 44% and 35%, respectively, of all plant and vertebrate species worldwide (Myer et al., 2000). Some hotspots are much richer than others in terms of their number of endemics. The top 5 hotspots, including Brazil’s Atlantic Forest, contain endemic plants and vertebrates amounting to at least 2% of total species worldwide (Myer et al., 2000). Together, they comprise 20% of all plants and 16% of all vertebrates, and 45% of all the hotspots’ endemic plants and vertebrates, but they comprise a mere 0.4% of the Earth’s land surface (Myer et al., 2000). The hotspot status of the Atlantic Forest has led many groups and organizations to collaborate to protect the biodiversity of this unique area.

One way to guarantee a future for many of the species threatened with extinction in the Atlantic Forest is to focus conservation efforts on the habitats in which the species are found, instead of focusing on every single species. Because each species is part of a major ecological community, conservation efforts on behalf of every single species also have to guarantee the survival of a large proportion of other species necessary for that one species to survive and evolve. If conservation efforts are focused on the protection, preservation and restoration of habitat, the species living in this habitat will naturally follow. One way to best conserve intact habitats is to make use of ‘flagship species’, which are generally defined as iconic animals that provide a focus for raising awareness and stimulating action and funding for broader conservation efforts (WWF, 2012). The iconic animal helps to focus attention on a single species, rather than on the vague concept of species richness or genetic

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2 Forests regenerating largely through natural processes after significant removal or disturbance of the original forest vegetation by human or natural causes, displaying a major difference in forest structure and/or canopy species composition with respect to primary forests. Secondary vegetation is generally unstable, and represents successional stages (FAO, 2006).
diversity. Therefore, flagship species are very important regarding conservation education. The flagship species has the ability to capture the imagination of the public and induce people to support conservation actions, which increases the effect of conservation efforts. The in situ conservation of flagship species will result in the conservation of a significant number of other species across a wide array of taxonomic groups, thereby saving natural ecosystems (Dietz et al., 1994b).

To optimally select a flagship species for conservation of biodiversity, three criteria are often used: (1) the geographical location, (2) the ecological characteristics, and (3) the potential for building public support (Dietz et al., 1994b). First, it is proposed to select an animal that is located in a biodiversity hotspot, like the Atlantic Forest, in order to protect a large proportion of endemic species. Furthermore, it is proposed to select an ecological keystone species, defined as a species that exerts an impact on its community that is both strong and disproportionate to its abundance (Power et al., 1996). These species play a critical role in maintaining the organization and diversity of their ecological communities. For example, keystone species may provide food resources during a season of scarcity or maintain habitat conditions on which other species rely (Dietz et al., 1994b). Extinction of a keystone species may result in loss of many other species that depend on it. Finally, research has shown that public support of conservation efforts is mainly gained through flagship species that are considered attractive, rather than species that are important to the balance of nature (Kellert, 1979; Dietz & Nagagata, 1986). Factors determining preferences are large size, advanced intelligence, phylogenetic relatedness to human beings and complex social organization (Kellert, 1979; Dietz & Nagagata, 1986).

The golden lion tamarin: a flagship species for the Atlantic Forest
Among the inhabitants of the Atlantic Forest is the golden lion tamarin (Leontopithecus rosalia), endemic to the lowland Atlantic Forest of the state of Rio de Janeiro (Figure 1, Serra do Mar), the second most populous state of Brazil (Kierulff et al., 2012). Golden lion tamarins (GLTs) are small squirrel-sized monkeys with silky, bright orange-gold fur and lion-like manes. They eat insects, fruits and small animals and live in family groups that depend on trees for food and shelter (GLTCP, 2012). Due to large scale deforestation of the Atlantic Forest, the habitat of golden lion tamarins has been reduced to approximately 20% of its original range, of which 60% is comprised of patches of 1000 ha or less, 96% of which are less than 100 ha (Kierulff et al., 2008). The average size of the forest patches is 35 ha, which is smaller than the average home range of a single GLT group (Kierulff & de Oliveira, 1996). As a result, the number of golden lion tamarins living in the wild has significantly decreased. During 1991-1992, a full and thorough census on golden lion tamarin population was carried out by Kierulff (1993a,b). The total population size was estimated at 562 (range 470-631), of which 272 individuals were living in 55 groups divided over a total forest area of 104.5 km². The remaining part of the population (290 animals) was located in the Poço das Antas Biological Reserve (Kierulff, 1993a). As a consequence, golden lion tamarins were listed as ‘Critically Endangered’ on the IUCN/SSP Red List in 1996 (Kierulff et al., 2008).

Taking into account the three criteria often used to select a flagship species, the golden lion tamarin is an excellent candidate to symbolize the crisis faced by the Atlantic Forest and its unique biodiversity. GLTs are endemic to the Atlantic Forest hotspot (1), and these arboreal animals occupy large home ranges with different types of habitats for feeding and sleeping (2). Furthermore, the bright orange-gold fur of golden lion tamarins and their complex social structure make them relatively attractive, making it easier to gain public support (3).

1.3 The Golden Lion Tamarin Conservation Program (GLTCP)
The dramatic decline in the number of golden lion tamarins as a result of the increasing deforestation of the Atlantic Forest has led to the establishment of the Golden Lion Tamarin Conservation Program (GLTCP) in 1983. The GLTCP is an international flagship species program with the institutional mission to conserve the biodiversity of the Atlantic Forest focusing on the conservation of the golden lion tamarin (Leontopithecus rosalia) in its natural habitat. Its unique multidisciplinary approach, combining research with conservation, has led the GLTCP and the Associação Mico-Leão Dourado
(AMLD), the Brazilian non-governmental organization implementing the conservation program, to be internationally recognized as a model of conservation science.

The program began as a result of the 1972 Wild Animal Preservation Trust conference ‘Saving the Lion Marmoset’. Following the conference, the National Zoological Park, Smithsonian Institution, USA, launched an intensive program of long-term studies on the reproduction, social behavior and husbandry of the golden lion tamarin in captivity (Kierulf et al., 2012). The initiation of the captive research and management program occurred simultaneously with efforts underway in Brazil by Dr. A. Coimbra-Filho of the Rio de Janeiro Primate Center to protect remaining habitats in Brazil and develop a captive breeding program for endangered Brazilian primates (Kierulf et al., 2012). The fusion of these two efforts became the basis for the multi-disciplinary, multi-national Golden Lion Tamarin Conservation Program.

The scientific monitoring of the entire wild population of tamarins, their habitat and threats since the establishment of the GLTCP in 1983 allowed to set specific conservation goals, develop targeted actions, evaluate their effectiveness, and adjust the goals and strategies as knowledge increases. Incorporating the latest findings into the best predictive models, the long-term goal of the GLTCP (defined in 1984, and modified in successive Population and Habitat Viability Assessment workshops in 1991, 1997 and 2005) is to establish a viable population of 2000 golden lion tamarins living freely in 25,000 hectares of protected and linked Atlantic Forest habitat by 2025. In order to achieve this long-term goal, the short-term goal was set to establish a viable population of 1600 golden lion tamarins living freely in 20,000 hectares of protected and linked forest by 2010 (AMLD, 2004).

In this review, I aim to give an up-to-date overview of the Golden Lion Tamarin Conservation Program, its achievements and effectiveness. How successful is the golden lion tamarin as a flagship species for the biodiversity conservation of the Atlantic Forest of Brazil? An evaluation will be made of the progress of the GLTCP, taken into account the mission statement and its goals. If the conservation program turns out to be a success story, this program could provide a model for other conservation programs as well, thereby contributing to the protection of the world’s biodiversity. The most important conservation efforts of the GLTCP will be discussed, including the extensive research program, the translocation and conservation of wild populations of GLTs, the reintroduction of captive born GLTs, the breeding and management of GLTs in zoos and the education program.

2. Biology of golden lion tamarins (GLTs)

The golden lion tamarin (Leontopithecus rosalia) is one out of four species of lion tamarins (Leontopithecus spp.), including the black lion tamarin (L. chrysopygus), golden-headed lion tamarin (L. chrysomelas), and black-faced lion tamarin (L. caissara) (Figure 2) (Rylands et al., 2002). All are endemic to the Atlantic Forest of eastern and southeastern Brazil and all are threatened with extinction. Concern about the threatening disappearance of these animals began in the 1960s, when Coimbra-Filho called attention to the dramatic decline in golden lion tamarin numbers. By that time, less was known about the other lion tamarins. In fact, L. chrysopygus was considered extinct by 1964, as the species had not been seen for almost 60 years and L. caissara remained undiscovered until 1990 (Rylands et al., 2002). Because of this, international efforts on behalf of lion tamarin conservation centered first on L. rosalia, which became a flagship species for the Atlantic Forest of Brazil. The little that was known about their conservation status and biology was reviewed and an extensive research program was established in the 1980s (Rylands et al., 2002).

Understanding golden lion tamarins is crucial for effective conservation action, both in the wild and in the maintenance of healthy and secure captive populations, which is very important considering the number of golden lion tamarins that remain today. Unlocking the mysteries of golden lion tamarin biology has required research in many fields of science, including their ecology, demography and all aspects of golden lion tamarin behavior, like communication and their social, mating, and rearing system. In this section, I will cover the principal research fields that have played an important role in contributing directly and indirectly to the management of golden lion tamarins.
The golden lion tamarin: a flagship species for the Atlantic Forest of Brazil

2.1 Morphology

The golden lion tamarin (GLT) (*Leontopithecus rosalia*), in Brazil known as the mico-leão-dourado, is a New World monkey of the family Callitrichidae. This family is a subfamily of the family of capuchin monkeys, squirrel monkeys and marmosets (*Cebidae*), and contains 5 genera and 26 species. Callitrichids are only found in the tropical forests of Central and South America and are among the smallest monkeys in the world. The golden lion tamarin gets its name from its bright reddish orange pelage and the extra long hairs that form a striking mane on its cheeks, throat, and ears surrounding its dark, hairless face. The rich color of the coat is thought to be a product of sunlight exposure and the presence of carotenids in their diet (Kleiman *et al.*, 1988). Golden lion tamarin males and females are similarly sized, measuring about 26 cm in length, not including the tail, which measures about 32-40 cm (Dietz *et al.*, 1994b). On average in the wild, adult males weigh 620 g and females between 575-622 g depending on their current reproductive stage (Dietz *et al.*, 1994a). The average lifespan of captive golden lion tamarins is 14.2 years (Rowe, 1996). In the wild, the life expectancy is shorter due to pathogens and predation pressure (Dietz *et al.*, 1994a).

One of the defining characteristics of callitrichids besides their small size, are their claw-like nails (called tegulae) rather than flat nails (ungulae) which humans and other primates generally exhibit (Kierulff *et al.*, 2008). These claws aid in their feeding behaviors and locomotion, allowing them to cling vertically to tree trunks (Sussman, 2000). Because of their patterns in movement and the presence of claws, callitrichids were once thought to be primitive primates, more closely related to squirrels (Cawthon Lang, 2010). However, these traits are highly evolved, having reappeared in golden lion tamarins and others after radiating through South America (Garber *et al.*, 1996). Another special characteristic of this group of primates is the occurrence of twin births (Kierulff *et al.*, 2008). Among wild golden lion tamarins, about 78% of all parturitions are twins (Dietz *et al.*, 1994a). This is in captivity and the wild. There are two take-home messages from this section. First, data required from long-term studies on one or more populations of a species are irreplaceable. Without long-term studies, data on differences and change in numerous life history parameters cannot be obtained (Kleiman & Rylands, 2002). Second, the development of recovery or conservation programs is dependent on scientific research. It is often said that there is more need for conservation and less research, which is a false dichotomy. Conservation and research are not antithetical, but they interact and support each other. Without strong scientific research, adaptive management principles cannot be applied (Kleiman & Rylands, 2002).
very unusual among primates, considering the effort it takes to care for just one infant. The energetic demand of caring for two infants has shaped the social structure and cooperative breeding patterns prevalent in tamarins and marmosets, including the golden lion tamarin (Sussman, 2000).

### 2.2 Range and distribution

Endemic to Brazil, the range of the golden lion tamarin is extremely restricted (Figure 3). The center of the range of *L. rosalia* is considered to be the basin of the Rio São João in the state of Rio de Janeiro. Coimbra-Filho was the first one to clarify the original distribution (Figure 3A) (1969, 1976a; Coimbra-Filho & Mittermeier, 1973, 1977). It covered the majority of the lowland coastal region of the state of Rio de Janeiro, below 300 m altitude. The original distribution included all or parts of the following municipalities: Mangaratiba, Itaguai, Nova Iguaçu, Nilópolis, São João do Meriti, Duque de Caxias, Rio de Janeiro, Magé, São Gonçalo, Niterói, Itaborai, Maricá, Araruama, Silva Jardim, Saquarema, Rio Bonito, Cachoeiras de Macacu, São Pedro da Aldeia, Cabo Frio, Casimiro de Abreu, Macaé, Conceição de Macabu, Campos, and São João da Barra.

The surveys carried out by Kierulff (1993a; Kierulff & Procópio de Oliveira, 1996) during 18 months between 1990 and 1992 covering the entire range of the species showed that a total of ± 560 GLTs remained in 104.5 km² of Atlantic forest fragments in three regions: (1) near the coast (the Centro Hípico de Cabo Frio (±29 individuals); Campos Novos (±36 individuals); (2) the Poço das Antas Biological Reserve and adjacent forests (±360 individuals); and (3) on the hillsides of the Serra do Mar (±74 individuals), here largely restricted to lowland forest patches. A further nine localities contained 12 isolated groups, totaling 60 individuals. These subpopulations were registered in just 4 of the 24 municipalities reported by Coimbra-Filho (1969): Silva Jardim, Cabo Frio, Saquarema, and Araruama. The latter two, however, maintained only a single group each (Kierulff, 1993a).

During the Population Habitat and Viability Analysis (PHVA) in 2005, it was estimated that there are approximately 1500 golden lion tamarins living in 120 km² of Atlantic forest fragments (Holst et al., 2006). The current GLT metapopulation consists of 18 separate populations, which are for the most part genetically isolated from each other (Figure 3B). The largest populations are found in Poço das Antas Biological Reserve (N=350) and the União Biological Reserve (N=200), a population derived from the translocation of isolated groups. Another 550 individuals are found in 28 private properties that are part of the AMLD Reintroduction Program. Together with the remaining fragments, the populations are found in the municipalities of Silva Jardim, Cabo Frio, Buzios, Saquarema and Araruama (Holst et al., 2006; AMLD, 2008; Procópio de Oliveira et al., 2008).

### 2.3 Ecology of wild golden lion tamarins

Survival and reproduction are affected by the way in which animals distribute time among various activities. For primates, many ecological, intrinsic and social factors can constrain time budgets, like the distribution of food resources, predation pressure, formation of social bonds, body size and high metabolic demands (Kierulff et al., 2002a). Ecological constraints on callitrichids such as high predation pressure, may derive from their small size. Callitrichids must spend a large proportion of their time foraging and feeding to meet high metabolic demands, which poses a conflict between resource acquisition and predator avoidance (Kierulff et al., 2002a). This may affect feeding efficiency and other essential activities (Kierulff et al., 2002a). Furthermore, in tropical environments, food availability varies per season due to fluctuations in rainfall and temperature, which forces species to migrate into favorable habitats or shift to alternative diets (Kierulff et al., 2002a).

To protect the golden lion tamarin and its habitat, data on the behavioral ecology is a necessity. The ecological and behavioral data on golden lion tamarins discussed in this section stem principally from two distinct locations where golden lion tamarins have been studied in the wild: the Poço das Antas Biological Reserve and União Biological Reserve (Kierulff et al., 2002a). The studies in the Poço das Antas Biological Reserve were conducted on a native population of golden lion tamarins in their original area of occurrence. The *L. rosalia* population at União Biological Reserve was translocated from small forest fragments; the data included in this study were collected only after groups had established their home ranges (Kierulff, 2000).
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**Figure 3.** (A) The original distribution of *L. rosalia* in the state of Rio de Janeiro, Brazil (based on Coimbra-Filho, 1969). (B) The enlarged area of current fragmented distribution of *L. rosalia*, showing the location of the 18 remaining populations (based on Holst *et al.*, 2006; Procópio de Oliveira *et al.*, 2008). Localities of the current distribution are as follows: (SJ) São João, (EME) Emerências, (SAQ) Saquarema, (CAB) Cabista, (SOB) Sobara, (PDA) Poço das Antas Biological Reserve, (U) União Biological Reserve, (SER) Serra do Mar. The explanation of the remaining abbreviations (V, RV, BE, I, A, B, SQ, MA, CAM, BEN) could not be found.
In total, 4 studies have been conducted, 3 at Poço das Antas Biological Reserve and 1 at União Biological Reserve, which lasted between 3 months and 1.5 years (Kierulff et al., 2002a). All groups were habituated prior to behavioral data collection. The number of groups investigated varied from one to eight, and in all groups individuals received radio collars to assist with locating the groups and facilitate the habituation process (Kierulff et al., 2002a). Despite the fact that the study population at the União Biological Reserve was translocated, it is assumed that both study populations are comparable, since both study populations live in coastal lowland moist forest and both are wild populations of golden lion tamarins.

**Foraging and Feeding**

Golden lion tamarins are faunivorous-frugivores, feeding on a wide variety of food items including fruits, flowers, insects, small vertebrates (including small reptiles), snails, exudates, nectar, and bird eggs (Kleiman et al., 1988; Dietz et al. 1997; Kinzey, 1997). They use their long, slender arms and elongated fingers to exploit small, species-rich microhabitats when searching for animal prey, including bromeliads, bases of palm leaves, woody crevices, lianas, vine tangles, tree bark, rotten logs, and leaf litter (Dietz et al., 1997; Kierulff, 2000). It’s this procedure of micromanipulation that gives lion tamarins their description as manipulative feeders (Stoinski et al., 2003). Small vertebrates, arthropods and snails constitute the majority of prey eaten. Capture of mobile prey or flying insects is relatively rare compared to sedentary and cryptic prey, such as adult orthopterans, and larvae of Coleoptera and Lepidoptera (Dietz et al., 1997).

While insects make up about 10 to 15% of the golden lions tamarin’s diet, a more substantial part of their diet (±80%) consist of small, soft, sweet fruits that have a lot of pulp (Dietz et al., 1997; Kierulff, 2000). Ripe fruits are preferred over unripe and obtained more often from trees than from vines or lianas (Dietz et al., 1997). Melastomataceae is one of the most important families providing fruits for golden lion tamarins (Dietz et al., 1997). Nectar is an important seasonal resource when fruit is scarce. In the Poço das Antas Biological Reserve, golden lion tamarin groups spent 44% of their feeding time during the dry season eating nectar of *Symphonia globulifera* (Dietz et al., 1997).

**Habitat preferences**

In Poço das Antas Biological Reserve, wild golden lion tamarins spend most of their time in swamp and hilltop forests, which are largely undisturbed and intact compared to adjacent hillside forests (Kierulff et al., 2002a). The trees of the swamp forests have cavities that are used as sleeping sites and also have more of a variety of foraging opportunities compared to other areas of the reserve (Dietz et al., 1997; Kierulff et al., 2002a). At União Biological Reserve, golden lion tamarins are seen mainly in swamp and lowland forest, where the abundance of lianas and bromeliads is high (Kierulff et al., 2002a). As in the Poço das Antas Biological Reserve, golden lion tamarins tend to avoid hillside forest, where the densities of microhabitats, such as palm crowns, bromeliads, and lianas, were lower (Kierulff et al., 2002a). In both reserves abundance of lianas as well as bromeliads are important indicators of where golden lion tamarins spend the majority of their time.

The activities in which golden lion tamarins are engaged determine the habitats that they choose to occupy. In a study performed by Peres (1986) different behavior patterns were found in each habitat used by golden lion tamarins. In general, hilltops were used while sleeping and feeding on fruit, flowers and exudates, and swamp forests when foraging for animal prey. The study groups used hillside forests for occasional sleeping sites or while traveling to other vegetation types, whereas quadrats dominated by gingkostrees were almost exclusively used for bromeliad foraging (Peres, 1986). Conversely, the availability of widely dispersed and/or ephemeral resources may influence where lion tamarins choose to spend their time and the amount of time spent in an area (Kierulff et al., 2002a). In the União Biological Reserve, comparisons were made of plant species density and the composition of the different habitats within the home range of each group of golden lion tamarins (Kierulff, 2000). The most important factor affecting habitat selection was the density of trees species most commonly exploited for feeding (Kierulff, 2000).
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Table 1. Percentage of time spent in each activity for *L. rosalia*.

<table>
<thead>
<tr>
<th>Study Site</th>
<th>Travel Mean ± SD</th>
<th>Stationary Mean ± SD</th>
<th>Feed Mean ± SD</th>
<th>Forage Mean ± SD</th>
<th>Other Mean ± SD</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poço das Antas Biological Reserve</td>
<td>33.5 ± 9</td>
<td>17.6 ± 7.3</td>
<td>23.5 ± ?</td>
<td>19.7 ± 10.1</td>
<td>8.5 ± 4.3</td>
<td>Dietz <em>et al.</em>, 1997</td>
</tr>
<tr>
<td>União Biological Reserve</td>
<td>31.9 ± 1.6</td>
<td>30.9 ± 3.6</td>
<td>8.8 ± 2.2</td>
<td>10.9 ± 1.8</td>
<td>6.9 ± 2.1</td>
<td>Kierulf, 2000</td>
</tr>
</tbody>
</table>

Time budgets

In Poço das Antas Biological Reserve, golden lion tamarins were found to spend the majority of their time traveling (34%), and the translocated groups in the União Biological Reserve spent somewhat equal proportions of their time stationary and traveling (31% and 32%, respectively) (*Table 1*) (Dietz *et al.*, 1997; Kierulf, 2000). Feeding and/or foraging was the second most common behavior in the populations studied (*Table 1*). In the Poço das Antas Biological Reserve, golden lion tamarins spent more time foraging for prey (20%) and feeding on fruit (24%) than golden lion tamarins in the União Biological Reserve (13% foraging and feeding on prey; 9% feeding on fruit) (Dietz *et al.*, 1997; Kierulf, 2000). The translocated groups of golden lion tamarins spent more time stationary and resting (40%) compared with the Poço das Antas groups (18%) (*Table 1*) (Dietz *et al.*, 1997; Kierulf, 2000).

Across study sites, golden lion tamarins were active for about 9 to 12 hours each day (Dietz *et al.*, 1997; Kierulf, 2000). They started their activities earlier and stopped later during the warm, rainy season, when the duration of daylight was longer, and they left the sleeping sites later and entered them earlier during the cold, dry season, with shorter daylight hours (Dietz *et al.*, 1997; Kierulf, 2000). Golden lion tamarins tended to leave their sleeping sites between 0500 to 0900 hours in the morning and entered their nighttime den sites between 1400 to 1800 hours (Kierulf, 2000). In general, golden lion tamarins traveled and fed throughout the early morning, concentrating on plants and, as the morning progressed, on animal prey. They spent more time stationary during the middle of the day, and traveled to the night’s sleeping site during the late afternoon (Kierulf, 2000).

As already mentioned, lion tamarins showed seasonal differences in the allocation of time to their various activities. In the União Biological Reserve golden lion tamarins traveled more, foraged more, and fed more on plants during the cold, dry season and rested more and spent more time in social activities during the warm, rainy season (Kierulf, 2000). The type and quantity of food available is related to this variation in seasonal activity levels, and is also reflected in seasonal births (Kierulf, 2000).

Use of space

Population densities vary across study sites due to habitat fragmentation and the extremely low numbers of golden lion tamarins in the wild. Range size and population density appear to be inversely related (Kierulf *et al.*, 2002a). The highest population density is found in Poço das Antas Biological Reserve, with 12 individuals per km² and an average home range of approximately 45 ha (Dietz *et al.*, 1994a; Dietz *et al.*, 1997). The population of golden lion tamarins in the União Biological Reserve is much smaller, resulting in a population density of 3.5 individuals per km² and an average home range of 150 ha (Kierulf, 2000). The large average home range in the União Biological Reserve is probably due to the fact that golden lion tamarins were absent at the release site prior to translocation, which allowed the translocated groups to develop home ranges without the pressure of other groups (Kierulf, 2000). In this case, the home range used was probably influenced more by the resource base available than by competition between groups, as the União Biological Reserve most likely has not met its carrying capacity yet (Kierulf *et al.*, 2002a).
Day ranges correspond to population densities, home range size, resource distribution and the seasonal abundance of food resources. In Poço das Antas Biological Reserve, where home ranges are small and population densities are high, golden lion tamarins move about 1339 m per day and spend most of their time patrolling the edges of their home range to defend their territories from other groups (Dietz et al., 1997; Peres, 1986, 1989). In União Biological Reserve, where home ranges are intermediate and population densities are low, golden lion tamarins move about 1873 m per day and preferentially occupy core areas (Kierulff, 2000; Peres, 1989). With fewer animals per km², competition for resources is not as strong as elsewhere. These groups exhibit little territorial defense and do not spend as much time patrolling territorial boundaries as in Poço das Antas Biological Reserve (Peres, 1989).

The predominant sleeping sites for golden lion tamarins are hollow tree cavities and occasionally vine tangles, palm crowns and bamboo thickets are used (Dietz et al., 1997). They prefer sleeping sites that are between 11 and 15 m off the ground (Dietz et al., 1997). One group of golden lion tamarins can use up to 40 different tree holes within their home range, which are generally alternated between consecutive nights (Kierulff et al., 2002a). By frequently moving their sleeping nests around, groups minimize the scent left behind, reducing the likelihood of predators finding them. Being small-bodied animals, golden lion tamarins are susceptible to predation by raptors, felids, snakes, and other small, arboreal carnivores (Kierulff et al., 2002a).

2.4 Social organization and behavior
Before data from long-term studies on wild golden lion tamarin populations had accumulated, most studies were conducted on captive populations. New data on wild golden lion tamarins have contributed to the current discussion about their true social structure and mating behaviors, as wild golden lion tamarins differ in their behavior from captive golden lion tamarins. A great proportion of the data on wild golden lion tamarins comes from the population in the Poço das Antas Biological Reserve. With regard to the number of study groups and duration of continuous monitoring, this population is the most thoroughly studied of any wild callitrichid population (Baker et al., 2002). In order to find out the true nature of golden lion tamarins, further research in the field is necessary. This may lead to new understanding about wild golden lion tamarin behavior.

In Poço das Antas Biological Reserve, wild golden lion tamarins have been observed living in groups of 2-11 individuals, with a mean group size of 5.4 individuals (Dietz & Baker, 1993). The group composition varies; about 50% of the groups consist of one breeding adult male and female, 40% of the groups include 2-3 adult males and one female, and about 10% of the groups consist one male and two females (Dietz & Baker, 1993). In addition to these dominant, breeding adults, other members include subadults, juveniles, and infants of both sexes which are usually the offspring of the breeding pair(s). If there is more than one breeding adult male within the group, one maintains dominance over the other through aggressive behavior. The dominance relationships between adult males and females are determined by longevity in the group. For example, a newly immigrated male is subordinate to the resident adult female who inherited her rank from her mother, displacing him at feeding sites (Bales, 2000).

Within the wild group, females are generally related to each other (as mother-daughter or sisters), while adult males are usually non-natal. This is a result of the dispersal patterns of young golden lion tamarins. At the age of four, both males and females may leave their natal group. However, if the breeding female dies or disappears before a young female has dispersed, she will inherit her mother’s breeding position in the group. This will lead to the dispersal of the breeding male, presumably her father, to avoid inbreeding (Baker & Dietz, 1996). Young male golden lion tamarins usually do not inherit their father’s breeding position and therefore disperse, forming single-sex groups looking for an opportunity to immigrate into a new group (Baker et al., 2002). They often travel between groups in home ranges that overlap multiple bi-sexual groups, as these roaming bands do not have specific territories (Baker et al., 2002). Looking at immigration, the patterns are highly sex-biased, with males representing 85% of the immigration events (Baker & Dietz, 1996). Males have a significantly higher success of joining a group after dispersing from their natal groups.
comparatively shorter than females. Of the dispersing females, more than 70% die or disappear before joining another group to become the breeding female (Dietz & Baker, 1993). This low immigration success of females is probably due to severe aggression toward immigrant females (Cohn, 1997). Male intruders are generally only chased away by breeding males in an established group, whereas female intruders are chased away by both male and female residents (Baker & Dietz, 1996; Baker et al., 2002).

A male golden lion tamarin may find an opportunity to immigrate into a group when the resident dominant breeding male dies, disappears, or leaves the group to avoid inbreeding. Males may also aggressively take over the breeding position of the resident male, thereby expelling the breeding male from his group (Baker & Dietz, 1996). This aggressive displacement is often done by two immigrant males, which are usually brothers. When this happens, only one of them will become the breeding male and will behaviorally suppress the reproduction of the other through dominance interactions (Baker et al., 2002). In general, both the dominant male and female behaviorally restrict mating opportunities of other adult group members (Baker et al., 200). In groups with two breeding females, they are usually mother and daughter and both will mate with the dominant male (Dietz & Baker, 1993).

2.5 Reproduction and parental care
The mating system of golden lion tamarins is largely monogamous, even for groups containing more than one adult male (Baker et al., 2002). Only the dominant male and female will reproduce offspring. Occasionally, however, the dominant male mates with two females, usually a mother-daughter pair (Dietz & Baker, 1993). In this case, both females can produce offspring, though this is quite rare, as only 10% of the groups consist of one male and two breeding females (section 2.4; Dietz & Baker, 1993). The reproduction of wild golden lion tamarins is seasonal, with most mating occurring from late March through mid-June (during the end of the rainy season) and the majority of births occurring between September and February (during the rainy season) (Dietz et al., 1994a). This pattern of births corresponds to the period of highest fruit availability and foraging opportunities, since nursing is extremely demanding (Dietz et al., 1994a).

Female golden lion tamarins are sexually mature between 15-20 months of age, but in the wild they usually do not reproduce until they are 30 months old due to their social structure (Dietz et al., 1994a). Males reach sexual maturity by approximately 28 months of age (Dietz et al., 1994a). The dominant female physiologically suppresses ovulation in subordinate females (French et al., 2002), which are only allowed to reproduce when they have the status of breeding female. Copulations between the breeding male and female occur throughout the 19 days of the female ovarian cycle, with the peak number of copulations occurring during the highest period of fertility (Kleiman, 1977). Based on intervals between copulatory activity and birth, the gestation period lasts about 125 days (French et al., 2002).

The pregnancy usually results in twins being born, which is one of the defining characteristics of callitrichids. Among wild golden lion tamarins, about 78% of all parturitions are twins (Dietz et al., 1994a). Golden lion tamarins are also known to give birth to triplets and quadruplets, but when a female gives birth to more than two infants, there are usually one or two weaker individuals that will not survive (Kinzey, 1997). In the wild, about 1% of all births are triplets, in captivity 28% (Dietz et al., 1994a). Females generally only bear and rear one litter a year in the wild, but they may reproduce twice if the first litter is lost and food resources are extremely abundant (French et al., 2002). However, even then second litters are born only about 20% of the time (French et al., 2002). In captivity, about one-third of females produce two litters per year (Dietz et al., 1994a).

Golden lion tamarins are cooperative breeders, in which all members of the group participate in the care of young (Tardif et al., 2002). The members of the group take turns transporting and providing solid food for the infants. This cooperative breeding system has probably evolved due to the fact that callitrichids commonly give birth to twins (Tardif et al., 2002). A mother would not be able to provide for her litter on her own without sacrificing the infants’ well-being and therefore needs help of the other group members. These younger members may lose breeding opportunities, but they benefit from cooperative rearing because they invest in the survival of their relatives’
offspring, thereby increasing their inclusive fitness (Bales et al., 2000). Furthermore, they gain valuable parental experience, which can be crucial for the survival of their own future infants. Research has shown that a female with previous helping experience has higher offspring survivorship than one that has never carried or cared for an infant before (French et al., 1996).

Most data on infant development comes from captive studies on parent-offspring interactions in golden lion tamarins (Hoage, 1978; Tardif et al., 2002). During the first 3 weeks, the infants are completely relying on their mother for transport and nursing. After week 3, other group members become the primary transporters as the mother decreases the amount of time spent carrying the infants (Hoage, 1978). During the advanced infant stage (5-16 weeks), the infants spend increasingly less time being carried and more time moving independently and exploring their environment. In this phase weaning begins, and by week 12 the mother stops nursing (Hoage, 1978). Food transfer from other group members to young golden lion tamarins lasts throughout their development until about 21 months of age, but already decreases significantly after 9 months of age (Tardif et al., 2002). During the juvenile stage (17-28 weeks) young golden lion tamarins mostly socialize with other group members and by the time they reach the advanced juvenile phase (29-40 weeks), the mother usually gives birth to a new litter (Hoage, 1978; Tardif et al., 2002). The young subadult phase lasts from 41-52 weeks, in which the tamarins exhibit almost the full suite of adult behaviors. This stage lasts until sexual maturity, at which point the golden lion tamarins will be true adults (Tardif et al., 2002).

2.6 Communication
Golden lion tamarins use visual, vocal, and chemical communication to inform other group members and conspecifics. Visual communication is mostly used during territorial encounters, social interactions within the group, and reproduction and include arch-walking, tongue flicking, postures and piloerection (Kleiman et al., 1988; Kinzey, 1997). However, the structure of the Brazilian Atlantic Forest makes visual communication at a distance relatively inefficient. Because of this, golden lion tamarins rely on effective vocal communication for activities as maintaining group cohesion, warning about predators, and signaling about food sources. The vocalizations of golden lion tamarins have been categorized as belonging to six different categories: tonal, clucks, trills, atonal, multisyllable, and combination (Ruiz-Miranda & Kleiman, 2002). Each vocalization has its own specific function. For example, tonal vocalizations like the whine and peep calls serve as alarm and affiliation calls, respectively (Ruiz-Miranda & Kleiman, 2002). Multisyllable calls include the most important vocalizations for group cohesion: the short and long calls. These are typically heard in the morning when the golden lion tamarins localize their neighbors and throughout the day as individuals keep in vocal contact with other group members (Ruiz-Miranda & Kleiman, 2002).

Olfactory communication is the most specialized form of communication exhibited by golden lion tamarins. Golden lion tamarins have scent glands on their chest and around their genitals which are rubbed along a surface, leaving behind chemical signals to other group members and conspecifics (Ruiz-Miranda & Kleiman, 2002). This chemical communication system is believed to mediate territorial behavior, individual recognition, social regulation, the location of food resources, and reproduction (Epplle et al., 1993). Scent marking is mostly done by reproductive males and females. Dominant males use the scent mark to signify social status and reinforce dominance to other group members (Ruiz-Miranda & Kleiman, 2002). Both males and females mark the edges of their territories and specific sites on their way to food areas within their home ranges, probably to facilitate relocation of food resources among group members (Miller et al., 2003).

3. Threats to golden lion tamarins
A lot of activities throughout the last 500 years have adversely affected golden lion tamarin populations, making the golden lion tamarin one of the most threatened primates in the world. Most of these threats are induced by humans, as the state of Rio de Janeiro is constantly developing. In this section I will highlight those threats that have contributed most to the threatened status of the golden lion tamarin.
3.1 Deforestation of the Atlantic Forest

The primary historical and current threat to golden lion tamarins is habitat loss and degradation. A broad range of human activities, from deforestation for lumber extraction to agriculture, cattle ranching, and charcoal production, have reduced the habitat of the golden lion tamarin to small forest fragments (Kierulff et al., 2003). The deforestation of the Atlantic Forest of Brazil started with the European colonization in the 16th century. The clearing of forest for human settlement and pasture in practice radically changed the environment, as well as the widespread exploitation of brazilwood as a ship-building material (de Gusmão Câmara, 2003). Forest formations near water bodies were particularly affected by keeping livestock, as access to water was needed. In the 18th and 19th century, sugarcane plantations in coastal areas together with mining activities and coffee cultivation further destroyed vast stretches of forests (de Gusmão Câmara, 2003). An exponential acceleration of the deforestation took place in the 20th century, as the human population grew and the industrialization of Brazil began. An extensive rail network was constructed, which led to the opening up of new areas for cultivation. The timber industry eliminated nearly all the Brazilian pine forests, and the Atlantic Forest was contributing nearly half of all the lumber produced in Brazil (de Gusmão Câmara, 2003). An international oil crisis in the 1970s put further pressure on the remaining coastal forests, as sugarcane plantations were established to distill alcohol from sugarcane, which was used as a fuel substitute. Plantations of sugarcane, exotic pines, and eucalypts took over most of the landscape as the reliance on alcohol for fuel increased and the paper and pulp industry exploded (de Gusmão Câmara, 2003).

As a consequence of the large scale deforestation, only 20% of the original habitat of golden lion tamarins remains today, of which 60% consists of small isolated patches that on average are smaller than the home range of a single GLT group (Kierulff et al., 2008; Kierulff & Procópio de Oliveira, 1996). The remaining patches are often isolated from each other and mainly consist of secondary vegetation (Viana et al., 1997) (Figure 4). Despite conservation measures, the deforestation of the Atlantic Forest continues at an annual rate of 0.5% and up to 2.9% in urban areas, as the ever-growing human population looks to more areas for settlement and more supplies from the shrinking forest (Teixeira et al., 2009). Even parts of the legally protected Poço das Antas Biological Reserve are still subject to destruction, as cattle-raising landowners maintain the pastures surrounding the reserve by starting fires that easily spread to nearby forest areas (Kierulff et al., 2008).

Deforestation not only affects the habitat of golden lion tamarins, but in turn also has an impact on juvenile behavior. Juvenile behavior of golden lion tamarins is characterized by social play between individuals of different ages and species. This social play behavior is a key aspect of their social, cognitive, and motor skill development, and influences their behavior when facing competition and predators (de Oliveira et al., 2003). While playing, juveniles mirror the way they act when facing predatory or competitive interactions. Social play mainly takes place in large branches and vine tangles, where juveniles are less vulnerable to predators compared to more dangerous areas like canopy branches and the forest floor (de Oliveira et al., 2003). Deforestation decreases the relatively safe areas for juvenile play behavior, as tree diversity is affected and open areas are created. As a result, play behavior may decrease, which in turn may lead to a decrease in learned survivorship behaviors (de Oliveira et al., 2003).

3.2 Intrinsic factors

The extensive deforestation of the Atlantic Forest caused a population bottleneck for wild golden lion tamarins, which reduced the size of the population drastically. As a result, the remaining wild golden lion tamarin populations are relatively small and isolated from each other. The highly saturated and
isolated environments offer limited opportunities for individuals to disperse into new breeding positions, which increases the likelihood of inbreeding. This leads to a lower genetic variability and a higher degree of homozygosity within individuals, which can increase the chances of offspring being affected by recessive or deleterious traits. This generally leads to a decreased fitness of a population, which is called an inbreeding depression (Keller & Waller, 2002).

A study performed by Dietz et al. (2000) on the golden lion tamarin population in the Poço das Antas Reserve indicated a significant inbreeding depression in this population (347 individuals at the time). Inbred infants had a lower survival rate than non-inbred infants and infant survival decreased with the severity of inbreeding. About 10% of all tamarin offspring born in Poço das Antas Reserve were inbred, which is likely to be an underestimate considering the assumption that all adults were unrelated at the beginning of the study (Dietz et al., 2000). Inbreeding was thought to result when a daughter failed to disperse and bred with a close relative in her natal group or when an individual dispersed into another group that contained relatives. The frequency of the latter type of inbreeding suggest that tamarins do not recognize relatives outside their natal group or do not reject them as mates (Dietz et al., 2000). According to computer models this rate of inbreeding is not a direct threat to the survival of the Poço das Antas population. However, models do suggest that inbreeding may reduce the long-term survival by one-third in small (<50 individuals) isolated populations of golden lion tamarins (Dietz et al., 2000). In addition to the results found by Dietz et al. (2000), a study performed by Forman et al. (1986) confirmed the extremely low genetic variability in wild and captive golden lion tamarins. The low genetic variability is likely to be a result of both inbreeding and a reduction in effective population size as a result of reproductive suppression within breeding groups (Pope, 1996).

3.3 Harvesting and hunting
Wild golden lion tamarins were taken by humans for various reasons. One of the factors that contributed to the severely decreased number of golden lion tamarins living in the wild is harvesting. Golden lion tamarins have been maintained in captivity since the sixteenth century as popular pets for the European aristocracy (Ballou et al., 2002). During the nineteenth and twentieth centuries many continued to be exported for the pet trade as well as for zoos and research laboratories (Ballou et al., 2002). Between 1960 and 1965, an estimated 300 golden lion tamarins were captured annually, which had a major impact on the already threatened population (Coimbra-Filho & Mittermeier, 1977).

Hunting is another factor that has contributed to the near complete extinction of the species in the wild (Kierulff et al., 2003). Relatively large animals like the golden lion tamarin are the most rewarding to hunters and are therefore heavily hunted. Golden lion tamarins are also more susceptible to a decline in population size due to hunting, because they are living in confined forest areas that are easy accessible for hunters.

In 1968, the Brazilian Fauna Protection Law forbade the capture, hunting, purchase, sale and exportation of golden lion tamarins, and since 1975 the international trade has been restricted. Despite regulations, some golden lion tamarins are still trapped and sold into the pet trade because of continuous demand (Ballou et al., 2002). Though the demand is not nearly as high, coupled with the other threats to the population, it may affect the future potential of the population to survive (Cawthon Lang, 2000).

3.4 Introduction of nonnative species and changes in native species dynamics
The introduction of nonnative species has had major effects on the diversity of the Brazilian flora and fauna. When nonnative species are introduced they can outcompete native species, thereby lowering biodiversity (Cawthon Lang, 2000). Species that are problematic for the biodiversity of the Atlantic Forest include pine species, sand olive, patient lucy, guava tree, whiteginger, and eucalyptus (Reaser et al., 2003). Golden lion tamarins are not adapted to these nonnative plant species, and cannot always eat the fruits they produce. Furthermore, as large trees make place for nonnative plant species, lianas that tamarins use as walkways disappear, thus exposing the animals to increased
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Predation by ground dwelling predators (Coimbra-Filho & Mittermeier, 1977). Since the introduced plant species compete with resources used by golden lion tamarins, they form a serious threat considering the small size of the remaining habitat fragments.

In addition to the introduction of nonnative plant species, the recent introduction of exotic primates in the habitat of golden lion tamarins also represents a major threat to the survival of remaining populations. The common marmoset (Callithrix jacchus) (Figure 5B) and the black-tufted marmoset (Callithrix penicillata) (Figure 5C) have been released on different occasions in all of the private forests where groups of golden lion tamarins were reintroduced (Kierulff et al., 2012). These introductions are a result of the illegal wildlife trade in Brazil and are a nationwide problem (Ruiz-Miranda et al., 2011). Not only are concerns raised about genetic pollution of similar species, such as the native buffy-tufted marmoset (Callithrix aurita) (Figure 5A), but marmosets can also increase the risks of extinction of golden lion tamarins due to introduction of new diseases, and competition for food and shelter (Figure 6) (Holst et al., 2006). The marmosets are not yet present in Poço das Antas and União Biological Reserves (Ruiz-Miranda et al., 2000), but they may occupy other forests in the region as the conservation program increases the connectivity of the landscape. In most cases the density of these marmosets is already higher than that of golden lion tamarins in the same fragment (Kierulff et al., 2012). Furthermore, golden-headed lion tamarins (Leontopithecus chrysomelas) were released in Niterói, Rio de Janeiro by a private collector in 2002 (Kierulff et al., 2012). These golden-headed lion tamarins, living in 15 groups with a total of 107 individuals, are native to Bahia state, not Rio de Janeiro. The nearest population of golden lion tamarins is located in Fazenda Rio Vermelho, less than 50 km from Niterói (Kierulff et al., 2012). If the introduced species reaches that locality, there is a high probability that the two species will hybridize, with foreseeable negative consequences for the golden lion tamarin (Kierulff et al., 2012).

Besides the introduction of nonnative species, changes in native species dynamics represent a serious threat to the largest group of golden lion tamarins at Poço das Antas Biological Reserve. Since 1997, an increase in predation resulted in a population decline from 347 to about 220 individuals in the reserve (Franklin & Dietz, 2001). In 2000, five entire groups of golden lion tamarins were predated, with the average groups size in the reserve falling from 5.6 in 1997 to 3.4 in 2000 (Franklin & Dietz, 2001). It is not yet clear what predator is responsible for the killings, although coatimundis (Nasua spp.) or tayras (Eira barbara) are suspected (Rylands et al., 2002). This high level of predation

Figure 5. Local and introduced marmosets (Callithrix spp.) with their original distribution. (A) Buffy-tufted marmoset (C. aurita), native to the Southeastern coast of Brazil, the area of occurrence of the golden lion tamarin. (B) Common marmoset (C. jacchus), native to the Northeastern coast of Brazil. (C) Black-tufted marmoset (C. penicillata), native to the gallery forests of the Brazilian Central Plateau.

Figure 6. Introduced marmoset interacting with a golden lion tamarin over a piece of banana. Notice the ear tufts of this animal: it is a hybrid with tuft shape like a C. penicillata and coloration of a C. jacchus.
could indicate a change in predator-prey dynamics as a result of deforestation. Predators may have changed their foraging patterns due to loss of habitat and a decrease in other prey, which negatively affects golden lion tamarin populations. For effective conservation actions, further study is required to get insight in these predator-prey dynamics.

4. Golden lion tamarin conservation

Because so few tamarins remain in the wild due to ongoing threats, it is important to increase and manage these populations to ensure the genetic diversity needed for the survival of the species. In this section, the establishment of the Golden Lion Tamarin Conservation Program (GLTCP) will be described, as well as the Associação Mico-Leão-Dourado (AMLD) implementing the GLTCP.

4.1 History

Coimbra-Filho was the first to call attention to the dramatic situation of the golden lion tamarin. During the 1960s en 1970s, he witnessed the destruction of the species’ habitat as he travelled through many of the municipalities in the state of Rio de Janeiro in search of remnant populations (Rylands et al., 2002). In 1964, Coimbra-Filho and Magnanini outlined the threatened status of numerous vertebrate species in Brazil, forming the basis for Brazil’s first threatened species list, which included the golden lion tamarin (Coimbra-Filho, 1972). The Brazilian Fauna Protection Law of 1967, along with the Brazilian Official List of Species Threatened with Extinction of 1968, forbade the capture, hunting, purchase, sale, and exportation of threatened species and their products (Rylands et al., 2002). In 1965, the international zoo community was also becoming aware of the endangered status of the golden lion tamarin. The Association of Zoos and Aquariums (AZA) of the USA formally recognized the golden lion tamarin as an endangered species in 1966 and agreed to support a ban on its importation to the United States (Ballou et al., 2002). Furthermore, AZA recommended the golden lion tamarin to be included in the International Union for Conservation of Nature (IUCN) “Red Data Book” for rare and endangered species. In 1967, the World Zoo Organization (WZO) pledged that its members would not import the species and would help to publicize the animal’s endangered status (Ballou et al., 2002). The U.S. Rare and Endangered Species Act of 1969 effectively prevented further acquisitions of golden lion tamarins by zoos in the United States, and, together with the “hands off” importation policy adopted by the international zoo community, helped to end the legal importation of the species (Rylands et al., 2002).

In 1972, the ground-breaking conference “Saving the Lion Marmoset” was held at the Smithsonian National Zoological Park, Washington, DC, USA (Rylands et al., 2002). It brought together 28 European, American and Brazilian biologists, who reviewed and analyzed all available data on the lion tamarins and other callitrichids. As a result, long-term recommendations were made for research and conservation activities, including studies of breeding biology, protocols for captive husbandry and management, medical programs, inter-institutional cooperation, and the establishment of a studbook and data bank to record all aspects of the lion tamarins’ captive propagation (Kleiman, 1972). Devra Kleiman of the Smithsonian National Zoo in Washington, D.C. took over the coordination of the captive golden lion tamarin population, and established a captive management and research program for the species.

The efforts of Magnanini and Coimbra-Filho for the conservation of the golden lion tamarin in the wild resulted in the creation of the Poço das Antas Biological Reserve in de state of Rio de Janeiro in 1974 (Rylands et al., 2002). It was the first Biological Reserve in Brazil and the first protected area for wild golden lion tamarins (Rylands et al., 2002). At that time, the forest area in Poço das Antas was estimated to be about 2000 ha and was highly fragmented, with only about 500 ha of mature forest (Green, 1980). In 1981, the Smithsonian Institution (SI) held the first negotiations with the Instituto Brasileiro de Desenvolvimento Florestal (IBDF - Brazilian Forestry Development Institute, now IBAMA) to initiate a long-term research program for golden lion tamarins initially based in the Poço das Antas Biological Reserve (Rylands et al., 2002). The aim was an integrated in situ and ex situ conservation effort for the species. Research on the demography and socio-ecology of the golden
lion tamarins, a reintroduction program, and a community environmental-education program began in 1983, coordinated by the Smithsonian National Zoological Park Golden Lion Tamarin Conservation Program (SNZP/GLTCP), established by Devra Kleiman and colleagues. From 1983 to 1992, the GLTCP was managed by the Fundação Brasileira para a Conservação da Natureza (FBCN – Brazilian Foundation for the Conservation of Nature) in Rio de Janeiro, and the SI and SNZP had complete responsibility for overseeing the GLTCP in situ and ex situ research and conservation activities, including its total budget. In 1992, the Associação Mico-Leão-Dourado (AMLD – Golden Lion Tamarin Association) was established, a Brazilian non-governmental organization (NGO) which had the authorization to fulfill the mission and goals of the GLTCP in the broadest sense (Rylands et al., 2002).

4.2. The Associação Mico-Leão-Dourado: implementing the GLTCP

The GLTCP, a multi-institutional team of researchers and conservationists based mainly in the United States, along with the conservation programs for the other lion tamarin species, collaborated with the Conservation Breeding Specialist Group (CBSG) of the IUCN/Species Survival Commission (IUCN/SSC) and the Fundação Biodiversitas in organizing the first major Population and Habitat Viability Assessment (PHVA) workshop on lion tamarins in 1990 (Rambaldi et al., 2002; Seal et al., 1990). Results of field and captive research on the golden lion tamarin provided the baseline data, and this important exercise resulted in recommendations for in situ and ex situ conservation of the lion tamarins for the following 7 years. One of the recommendations was the need to establish a Brazilian base and infrastructure for overseeing and coordinating the conservation and research activities for the golden lion tamarin (Rambaldi et al., 2002; Seal et al., 1990). As a result, the NGO Associação Mico-Leão-Dourado (AMLD) was created in 1992, the Brazilian successor to the SNZP’s GLTCP (Rambaldi et al., 2002).

The AMLD has the stated aim of protecting biodiversity in the Atlantic Forest of the lowlands in northern Rio de Janeiro, with the golden lion tamarin as the flagship species (AMLD, 2002; Rambaldi et al., 2002). The mission of the AMLD is (1) to maximize the probability of survival of a naturally evolving population of golden lion tamarins, (2) to expand and apply cutting-edge science in conservation biology, (3) to increase public awareness and involvement in the conservation of golden lion tamarins and their habitat, (4) to enhance professional training in biology and conservation, with a preference for Brazilians, and (5) to integrate activities with other conservation programs with similar methods and goals (AMLD, 2002).

The scientific monitoring of the entire wild population of tamarins, their habitat and threats since the establishment of the GLTCP in 1983 allowed to set specific conservation goals, develop targeted actions, evaluate their effectiveness, and adjust the goals and strategies as knowledge increases. The conservation goal of the GLTCP (defined in 1984, and modified in successive PHVA workshops in 1990, 1997 and 2005) is to establish a viable population of 2000 golden lion tamarins living freely in 25,000 hectares of protected and linked forest by 2025. According to the golden lion tamarin population model used in the PHVA workshop of 2005, those numbers represent a metapopulation with 95% chances of survival for 100 years (given the threats that were known to exist at that time), maintaining 98% of the genetic diversity (Holst et al., 2006). To achieve this long-term goal, the short-term goal was set to establish a viable population of 1600 golden lion tamarins living freely in 20,000 hectares of protected and linked forest by 2010 (AMLD, 2004).

Components of the GLTCP

In order to increase its effectiveness, the AMLD is integrating the management of the golden lion tamarin populations and their habitats with the needs and expectations of the local communities (Rambaldi et al., 2002). The produced conservation program is a combination of applied research and organizational development, and includes multiple components.

First of all, demographic and behavioral studies on golden lion tamarins are conducted since 1983 in the Poço das Antas Biological Reserve, as well as in the União Biological Reserve and in participating zoos (Rambaldi et al., 2002). Research on golden lion tamarins is necessary to provide a
foundation for the goals and conservation strategies of the program, making it a fundamental objective of the program.

Second, a captive breeding program was established, managed by the *Leontopithecus* ICCM. The captive population of golden lion tamarins is managed as a secure genetic and demographic reservoir for the species. It serves as one of multiple populations in the species’ metapopulation and acts as a ‘source’ of sufficient genetic and demographic potential to supply animals, as needed, for reintroduction, for colonization, or as a supplement to other populations without jeopardizing its own genetic and demographic viability (Ballou et al., 2002).

Furthermore, a reintroduction program was created, concentrating particularly on the development of techniques for preparing captive-born golden lion tamarins for the wild, and on establishing populations on private lands (Rambaldi et al., 2002). The main objectives of the reintroduction program are to increase the size of the wild golden lion tamarin population and its genetic diversity, to expand its geographic distribution and to protect additional tracts of the Atlantic Forest (Kierulf et al., 2002).

In response to the results of the extensive survey of wild populations carried out by Kierulf in 1991 and 1992, a translocation program was established by the AMLD to rescue and translocate threatened groups of wild golden lion tamarins to a large and well preserved forest area (Rambaldi et al., 2002). This way, genetic diversity of the wild population is maintained and a new protected population is created (Kierulf et al., 2002b).

Another component of the GLTCP is a habitat restoration and protection program, which has experimented with a variety of alternatives for increasing the amount of habitat available for lion tamarins (Rambaldi et al., 2002). In order for the AMLD to reach its goal, the 18 remaining wild populations of golden lion tamarins have to be managed as a metapopulation. Metapopulation management includes establishing a *metapopulation management area* (MMA), in which the connectivity among isolated fragments needs to be restored through forest corridors to optimize the impact of golden lion tamarin movement on demography, gene flow and spatial distribution over the landscape (Ruiz-Miranda et al., 2010). Furthermore, the AMLD develops techniques for working with private landowners to register their land with IBAMA as permanent private reserves in order to protect the remaining Atlantic Forest remnants (Rambaldi et al., 2002).

Finally, a community environmental education program has been established, which has been a great example for other conservation programs in Brazil. The program works in close collaboration with government agencies for education, agriculture, and the environment, as well as with the relevant community associations (Rambaldi et al., 2002). The program provides teaching possibilities through its Education Center, training programs, and is involved in educating local farmers on sustainable agricultural practices. The different components of the GLTCP and their outcomes will be extensively reviewed in Section 5.

### 4.3 Partners in golden lion tamarin conservation

The Smithsonian National Zoological Park (SNZP), a semigovernmental organization, took the lead in establishing those partnerships in and outside Brazil that resulted in the GLTCP. The SNZP has provided significant resources for every sector of the GLTCP, and developed the infrastructure for the AMLD. After the establishment of the AMLD by the SNZP, numerous conservation organizations have worked together with the AMLD to mobilize and sustain efforts to achieve the goal of saving the golden lion tamarin and its habitat. Like the AMLD, most organizations are NGOs, which are especially important today in a number of areas where government action is insufficient or absent, and some have been crucial in their contribution to the conservation of the golden lion tamarin. NGOs have become important advisory bodies and an essential link between government and local communities, in for example the development and execution of public policies regarding the use and conservation of natural resources from the Atlantic Forest (Rambaldi et al., 2002).

One of the most important international NGOs contributing to golden lion tamarin conservation is the Worldwide Fund for Nature (WWF). WWF has included the Atlantic Forest of Brazil in its 200 Global ecoregions where large-scale conservation action must be mobilized, and recognizes the
endemic golden lion tamarin as a flagship species. WWF has contributed support for the GLTCP field studies component in the Poço das Antas Biological Reserve, and for the administration of field conservation projects, community environmental education, habitat restoration, and public policy (Rambaldi et al., 2002). Furthermore, WWF has given technical assistance and financial support for the institutional development of the AMLD and established a radio communication network between the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) and AMLD with a view to combating fires, patrolling, and security in the Poço das Antas Biological Reserve (Rambaldi et al., 2002). WWF supported all three PHVA workshops for lion tamarins and has used the results to prioritize its conservation investment (Rambaldi et al., 2002).

Another important international NGO is the Durrell Wildlife Conservation Trust (DWCT), which contributed to lion tamarin conservation through an extensive training program for researchers and donations critical to the success of research on the translocation of the golden lion tamarin (Rambaldi et al., 2002). In 1991, Gerald Durrell (founder of the Jersey Zoo) established the Lion Tamarins of Brazil Fund (LTBF) to target specifically the institutions holding lion tamarins in captivity, to mobilize financial support for ongoing field conservation and research efforts, and to launch critical new initiatives (Rambaldi et al., 2002). A newsletter, Tamarin Tales, is edited and published annually by James Ballou of the SNZP, to provide LTBF contributors and participating zoos with information on the field conservation and research efforts (Rambaldi et al., 2002).

The international NGO Conservation International (CI) contributed to the conservation of the golden lion tamarin by identifying the Atlantic Forest as a ‘hotspot’, and pinpointing the regions where the lion tamarins occur as key areas for conservation action. CI has supported all the major recent workshops on conservation of the genus *Leontopithecus*, and was key to the creation of the Margot Marsh Biodiversity Foundation (MMBF) in 1996, which now provides annual support for lion tamarin conservation projects through matching the funds raised by the LTBF (Rambaldi et al., 2002).

In addition to the NGOs, the International Committee for the Conservation and Management (ICCM) of lion tamarins has been created by the Brazilian government in 1981 to act in an advisory capacity to IBAMA, the Brazilian federal environmental agency responsible for issues concerning research, management, and conservation for the four lion tamarin species (Rambaldi et al., 2002). The *Leontopithecus* ICCM comprises national and international experts and institutions involved with lion tamarin biology and conservation, including zoo biologists, studbook keepers, curators, administrators, field biologists, protected area managers, and educators, as well as representatives of NGOs, zoos and Brazilian environmental agencies active in coordinating conservation efforts for the species (Rambaldi et al., 2002). The crucial role of the *Leontopithecus* ICCM is to link the efforts of the diverse institutions involved in lion tamarin conservation and to guide their actions toward achieving the long-term goal of conserving viable populations of the four species of lion tamarins in their natural habitat (Rambaldi et al., 2002). Several important functions of the *Leontopithecus* ICCM are to develop new methods for the conservation of the species, to promote collaboration in research and conservation of the species in nature and captivity, to promote the development of environmental education programs, to make recommendations to IBAMA concerning the distribution and management of the population of the species in captivity, and to promote lion tamarins as flagship species for the preservation of the Atlantic Forest (Rambaldi et al., 2002). Furthermore, the *Leontopithecus* ICCM is responsible for the management of the golden lion tamarin captive breeding program under the guidance of the studbook keeper (Ballou et al., 2002).

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**5. Conservation efforts of the GLTCP**

Since the establishment of the Golden Lion Conservation Program in 1983, numerous conservation efforts have taken place to protect the golden lion tamarin and its habitat, the Atlantic Forest of Brazil. Scientific research played an important role in contributing directly and indirectly to the management of the species in captivity and the wild. Research on genetics, population dynamics, husbandry, sociobiology, and behavioral ecology have not only informed conservation actions, but also extended the current limits within the individual disciplines (see Section 2). Here, I will outline
the most important conservation efforts of the Golden Lion Tamarin Conservation Program, thereby creating new hope for the conservation of the golden lion tamarin and its habitat.

5.1 Golden lion tamarin captive breeding program
Captive breeding programs serve a wide variety of functions, ranging from last-ditch efforts to save species almost extinct in the wild, to maintaining common species simply for education, research, or recreational purposes. The existence of captive populations is also often justified as an insurance policy against possible extinction of the species in the wild. Alternatively, the function of a captive population may be to learn more about the basic biology of the species (Ballou et al., 2002).

The relationship between the function of the captive population and the species’ status in the wild is clearly seen in the case of the golden lion tamarin. The captive population acts as a ‘source’ of sufficient genetic and demographic potential to supply animals, for reintroduction, for colonization, or as a supplement to other populations without jeopardizing its own genetic and demographic viability. Furthermore, the captive breeding program plays an important role in golden lion tamarin conservation education and scientific research on golden lion tamarin biology. In this section I will discuss the establishment of the golden lion tamarin captive breeding program and the success of its genetic and demographic management.

Historical view of the captive breeding program
The first breeding attempts with golden lion tamarins in captivity took place in 1962, as Magnanini and Coimbra-Filho tried to breed *L. rosalia* at the Rio de Janeiro Zoo in the hopes of establishing a reintroduction program (Ballou et al., 2002). By that time, golden lion tamarins were already extinct throughout a large part of their original range (Coimbra-Filho & Magnanini, 1968). From 1972 to 1974 the Tijuca Biological Bank was established by Coimbra-Filho and Magnanini at the Rio de Janeiro Zoo for the conservation and captive breeding of lion tamarins.

As a result of the “Saving the Lion Marmoset” conference in 1972, a long-term investigation into the social behavior, reproduction, and husbandry of the species in captivity was launched by the SNZP to determine the optimal composition of breeding groups, as a lack of knowledge about the mating and social system lead to the uncertainty about whether they were best kept as monogamous or polygynous breeding groups (Ballou et al., 2002). In 1973 the first international studbook on *L. rosalia* was published (Ballou et al., 2002).

Until 1975, the increase of the captive population was minimal, and the survivorship remained poor. It was concluded by Kleiman that the breeding program by that time had little success, and that it would be unlikely to achieve a self-sustaining captive population of golden lion tamarins without a dramatic change in breeding success (Ballou et al., 2002). At the end of 1975, the Tijuca Biological Bank, Rio de Janeiro, held 39 golden lion tamarins, and a further 83 golden lion tamarins were living in 16 institutions outside of Brazil (Ballou et al., 2002). These populations increased little over the following 3 years. Fortunately, research in the 1970s showed that golden lion tamarins breed best in captivity when maintained as monogamous pairs, with one family group (one adult pair plus litters) per cage. This finding on captive breeding group composition resulted in a dramatic increase of the captive population during 1979 and 1980 (Ballou et al., 2002).

To prevent the possibility of golden lion tamarins entering the animal trade, zoos owning the majority of the captive population refrained from selling animals by 1980 (Ballou et al., 2002). In 1981, zoos owning and holding golden lion tamarins on loan became part of an International Research and Management Committee, with all decisions concerning the management of the captive population being in the hands of an elected subgroup (Ballou et al., 2002). The first task of the committee was to develop the Cooperative Research and Management Agreement (CRMA), that stated that (1) all signatories of the agreement would pool their specimens to form a founding stock that would be managed as a single unit, (2) no specimen would be sold, traded, or otherwise used in a commercial transaction, (3) all signatories would agree to abide by the management recommendations of the committee, and no animals would be transferred to another institution or bred without the specific consent of the committee, (4) each institution would submit data on an
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annual basis to the international studbook keeper; (5) any institution wishing to receive golden lion tamarins must be approved through a formal application procedure to the International Research and Management Committee and sign the CRMA, and (6) the agreement would remain effect for the lifetime of the animals and their progeny (Ballou et al., 2002). All institutions holding golden lion tamarins at that time signed the agreement.

In 1990, the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) formally recognized the management committee as the official advisory body to the Brazilian government on conservation issues for L. rosalia (Kleiman & Mallinson, 1998). In 1991, six of the seven institutions holding the majority golden lion tamarins agreed to transfer ownership to the Brazilian government. As a result, the Brazilian government is the owner of all but a handful of the existing specimens of captive golden lion tamarins (Ballou et al., 2002).

Since 1973, the zoo population of golden lion tamarins has been managed globally, and in 1981 L. rosalia was one of the first species to be designated as part of the AZA’s SSP (Species Survival Plan) (Ballou et al., 2002). The population is currently managed intensively by the International Committee for the Conservation and Management (ICCM) of Leontopithecus under the guidance of the studbookkeeper Jonathan D. Ballou of the National Zoological Park, Smithsonian Institution, Washington, D.C (Ballou et al., 2002).

Genetic and demographic management of captive golden lion tamarins
The captive population reached over 500 individuals by the late 1980s as a result of research on captive breeding biology (Ballou et al., 2002). As the management goal was for rapid population growth, little attention was paid to genetics beyond avoiding close inbreeding (Ballou et al., 2002). There were huge differences in reproductive success among breeding pairs, as some individuals were used for behavioral research and produced 55 offspring, while others failed or were not given the opportunity to reproduce (Ballou et al., 2002). The studbook shows that 243 wild-caught animals were brought into the captive population internationally since 1960, but because transferring individuals between zoos was a rarity and breeding was not managed properly, the genetic contribution of many founders was not realized (Ballou et al., 2002). By 1980, the captive population was descended from only 41 true founders (i.e. wild-caught animals that have left descendants in the 1980 population) (Ballou et al., 2002).

The importance of maintaining genetic diversity was widely recognized by 1982, and management protocols now attempt to equalize the genetic contribution of founders, in addition to avoiding inbreeding (Ballou & Foose, 1996). The genetic management had to compensate for the difference in genetic contribution of founders, since genes from two particular founders accounted for almost two-thirds of the diversity in the 1982 gene pool (Ballou et al., 2002). In order to prevent loss of genetic diversity, the challenge to the management group was to identify (and preferentially breed) descendants from underrepresented founders (Ballou et al., 2002). In 1982, the first Global Masterplan was developed, with specific recommendations to breed, transfer, or place in non-breeding groups for all captive individuals (Ballou et al., 2002).

The genetic objectives for the golden lion tamarin captive breeding program were provided by the 1984 Workshop on Genetic Management of Captive Populations. It was recommended that the captive population should be of sufficient size to maintain 90% of the wild species’ genetic diversity for a period of 100 years (Ballou et al., 2002). This resulted in a target population of about 500 captive golden lion tamarins, and demographic objectives were developed to manage the population at this size (Ballou et al., 2002).

As the population approached its target size of 500 individuals, reproduction was controlled through single-sex grouping and selective contraception (Ballou, 1996). Today, breeding is only used to provide animals for reintroduction and to maintain genetic and demographic stability. In order to maintain zero population growth, only 40 pairs are required to breed per year, which is approximately 16% of the captive population (Ballou et al., 2002). The majority of the population is therefore held in non-breeding situations. However, taking into account that animals that do not
breed may be unable to breed in the future through social learning, careful consideration has to be given as to which animals breed, how often, and with whom (Ballou et al., 2002).

As the captive population increased, it became more and more complex to scan and compare tables of founder contributions. Soon after, the concept of ‘mean kinship’ was developed to identify the genetically most important individuals to breed (Ballou et al., 2002). Mean kinship is the average of kinships between a single individual and all other individuals in the population, expressed as a numeric value (Ballou et al., 2002). Animals with a lower mean kinship value have relatively fewer genes in common with other individuals in the population, and are therefore considered more genetically valuable in a breeding program (Ballou et al., 2009). Currently, the breeding recommendations for captive golden lion tamarins are based on mean kinship (pairing animals with low comparable mean kinships), inbreeding coefficients (pairing animals that are not related), and the difference in mean kinship between the male and female (pairing animals with similar mean kinships over disparate mean kinships) (Ballou et al., 2009).

As a result of the mean kinship strategy that is now being used to manage captive golden lion tamarins, the genetic diversity measured by the amount of heterozygosity in the population has been significantly increased (Ballou et al., 2002). By December 2008, the captive population reached 497 individuals living in 144 institutions around the world (Ballou et al., 2009). Approximately 96% gene diversity has been retained, with a mean inbreeding coefficient of 0.031 and zero population growth for the last 10 years (Ballou et al., 2009). The average mean kinship is 0.039. Despite the global distribution of the captive golden lion tamarin population, it is still managed as a single unit and management recommendations are based on analyses of the international studbook (Ballou et al., 2002).

**Captive populations as part of metapopulation management**

The role of the captive population was changed as the PHVA in 1997 concluded that despite reintroduction (Section 5.3) and translocation (Section 5.4) programs, the wild golden lion tamarin population was still not viable over the long term without continued management interventions (Ballou et al., 1998). Therefore, the different populations of golden lion tamarins, including the captive population, are now managed as a metapopulation (Ballou et al., 2002). Although the captive population is still managed as a secure genetic and demographic reservoir for the species, it is no longer managed independently of the wild population (Ballou et al., 2002). The captive population is now used to supply animals for reintroduction, colonization, or as a supplement to other populations, acting as a source of sufficient genetic and demographic material within the metapopulation. However, animals are only supplied without jeopardizing the genetic and demographic viability of the captive population (Ballou et al., 2002).

The question remains if the role of the captive population as a source to supply animals for the reintroduction program will be limited. According to the latest PHVA projection models, the wild population has the capacity to grow steadily in time without reintroducing captive-born animals (Holst et al., 2006). Furthermore, the remaining forest habitat is rapidly being taken by the growing wild population. The question remains if it’s better to leave the reintroduced population to expand on its own, or to continue to reintroduce individuals. Pedigree analysis have shown that, through selectively reintroducing captive-born individuals that are unrelated to previously reintroduced animals, the genetic diversity of the reintroduced population may be enhanced (Ballou, 1992). When the remaining forest fragments will be connected in the future and new habitat will be created through the construction of forest corridors, reintroduction could be useful to strengthen the genetic diversity of the wild population and to recolonize vacant but suitable habitat. In addition, since the viability of the wild golden lion tamarin population varies due to differences in abundance and vulnerability to threats, future extinctions of some fragments are likely (Ballou et al., 2002). In this case, these areas could also be recolonized by reintroducing captive-born golden lion tamarins.

Besides acting as a genetic and demographic source within the golden lion tamarin metapopulation, the captive population is used to achieve other goals as well. One of the most
important functions is the link it provides between in situ and ex situ conservation, as information and educational materials about golden lion tamarin conservation can be displayed in zoos holding golden lion tamarins all over the world (Ballou et al., 2002). This way, zoo visitors are not only able to see golden lion tamarins in real life, but also become more aware of measures that are needed to protect them from extinction. Furthermore, since 1997 the Tamarin Tales newsletter has been sent to all zoos and major donors involved with golden lion tamarin conservation, providing updates on all activities regarding lion tamarin research and conservation (Ballou et al., 2002). Besides the public education value, this newsletter also has great potential for fundraising. It is used to ask for contributions from participating zoos, thereby supporting the Lion Tamarins of Brazil Fund (LTBF), which has raised over 280,000 (U.S.) for field research and conservation of lion tamarins.

It is clear that the golden lion tamarin captive breeding program has been successful in supplying animals for the reintroduction program as well as in keeping a viable captive population of sufficient size to maintain 90% of the wild species’ genetic diversity for a period of 100 years. Furthermore, the captive population has also played a major role in conservation education, informing visitors all over the world about golden lion tamarins and their threats. Future conservation actions will determine the fate of the captive population. If habitat fragments are connected through forest corridors to create more suitable habitat, zoos can introduce genetically important animals, thereby strengthening the wild population of golden lion tamarins. For now, the wild population is thriving and reintroductions are not necessary. In addition, the captive population remains an important source of genetic material in case of natural disasters or changing threats.

5.2 Reintroduction of captive-born golden lion tamarins

Due to habitat destruction and intense hunting pressure, the number of golden lion tamarins living in the wild had declined drastically by 1980. The remaining populations were small and fragmented. Based on a number of criteria, such as available appropriate captive stock, sufficient information about the species’ biology in the wild, available protected and secure habitat in the species’ original range, and the need to increase the numbers and genetic diversity of the wild population, Kleiman recommended that the golden lion tamarin would be an appropriate species for a reintroduction program as a conservation strategy (Kierulff et al., 2002b; Kleiman, 1989).

The IUCN defines reintroduction as an “attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct” (IUCN, 1998). Reintroduction is broadly defined as the return of animals to the wild, but the origin of these animals (born in captivity or in the wild) should be considered as it determines what type of strategy is used for reintroduction (Chivers, 1991). In the case of the golden lion tamarin, the term reintroduction is used for captive-born animals or wild-born animals that spent part of their lives in captivity and were released into the wild in an area without an existing population of conspecifics (Kierulff et al., 2002b).

A reintroduction can be considered a success if it results in a self-sustaining population, measurable in terms of its reproductive success and survival (Kierulff et al., 2002b). Here, I report on the use of this management technique for the golden lion tamarin and its success based on the above criterion.

The establishment of a reintroduction program as part of the GLTCP

The reintroduction of captive-born golden lion tamarins into native Brazilian forest, coordinated by the GLTCP, was made possible starting in 1983 by the emergence of a self-sustaining captive population of golden lion tamarins in the early to mid-1980s (Ballou et al., 2002), the establishment of the Poço das Antas Biological Reserve for the species in 1975, and the beginning of a long-term study of the behavioral ecology of the wild golden lion tamarin population in the reserve (Kierulff et al., 2002b). The objectives of the reintroduction program for golden lion tamarins were to increase the size of the wild population, to increase the genetic diversity of the wild population, to expand the geographic distribution of the wild population, to protect additional tracts of the Atlantic Forest, to contribute to the science of reintroduction, and to enhance programs of public education (Kierulff et
al., 2002b). Note that these goals were not limited to the reintroduction program, but also concerned expanding habitat conservation and education.

Golden lion tamarins were first introduced into the protected Poço das Antas Biological Reserve, and thereafter into privately owned forests surrounding the reserve in order to protect those remaining habitats. This required the collaboration of local landowners adjacent to the Poço das Antas Biological Reserve, allowing the use of their forests for the release of golden lion tamarins. Reintroductions occurred from 1984 to 2000 with a total of 153 individuals (146 captive-born and 7 confiscated wild-born) (Table 2) (Procópio de Oliveira et al., 2008). The reintroduced groups have been established on 28 private farms, comprising a total of 3200 ha of forest (Figure 7). Unfortunately, no data could be found on the number of animals released in the Poço das Antas Biological Reserve and the number released into private forests.

Figure 7. Location of private farms with groups of reintroduced golden lion tamarins in the municipalities of Silva Jardim and Rio Bonito, RJ (adapted from Procópio de Oliveira et al., 2008).
The golden lion tamarin: a flagship species for the Atlantic Forest of Brazil

Table 2. The golden lion tamarin reintroduction program, 1984-2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Number reintroduced</th>
<th>Cumulative number reintroduced</th>
<th>Number reintroduced still alive</th>
<th>Number wild born still alive</th>
<th>Total alive</th>
</tr>
</thead>
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<td>14</td>
<td>14</td>
<td>9</td>
<td>1</td>
<td>10</td>
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Zoos contributed most of the golden lion tamarins that were introduced. The reintroduced captive-born tamarins were born in or had lived at about 30 zoos in North America and Europe (Kierulff et al., 2012). Critical research on social behavior, nutrition and disease was carried out in zoos, and virtually all of the funding for reintroduction came from the Smithsonian National Zoological Park and the Frankfurt Zoological Society, Germany (Kierulff et al., 2012). The Lion Tamarins of Brazil Fund, Copenhagen Zoo (Denmark), and the Frankfurt Zoological Society funded most of the field monitoring for the last 5 years.

As captive animals are thought to require specialized training and preparation to survive and reproduce after reintroduction to the wild, the reintroduction project was also designed as a research program to test the effect of release techniques (pre-release experience and post-release conditions) on golden lion tamarin survival and reproduction, and behavioral studies were conducted to elucidate the mechanisms related to the success of captive-born animals. The different pre-release environments and post-release conditions and their effectiveness will be discussed in the following paragraph, which rely on the publication of Beck et al., 2002.

The effect of pre-release environments & post-release management on survivorship (Beck et al., 2002)

Many of the survival-critical behaviors of mammals are learned, like selecting appropriate habitat, finding appropriate food, recognizing and avoiding predators, locomotion and orientation, and interacting effectively with conspecifics. To make the reintroduction of captive-born animals successful, to increase the cost-effectiveness of the reintroduction, and to decrease suffering and improve the welfare of individual reintroduced animals, training is often said to be necessary in order for enough animals to survive and reproduce. However, despite the widespread acceptance of the effectiveness of training, little research has actually been conducted on if and when training is effective. Therefore, though not by experimental design, the effect of pre-release environments and post-release management was investigated on the survival of reintroduced golden lion tamarins.

Four general types of pre-release environments were used to test the effectiveness on survivorship after reintroduction. The first condition were standard colony cages, indoors as well as outdoors, often seen in zoos or research institutions. Cages usually have climbing structures, and shelter boxes for sleeping and retreat. Keepers typically provide finely cut food and golden lion tamarins are fed at about the same times every day. Water is often provided in a bowl or licker.

A second pre-release condition termed training imposes structured training on the cages condition. To increase the frequency and efficiency of survival-critical behaviors, golden lion tamarins living in cages are exposed to deliberate changes in their environments. For example, food is hidden in specially designed feeders and is presented whole instead of cut. Cage furniture is rearranged periodically to interrupt habitual travel routes and branches of less than 2 cm diameter are provided.
to promote locomotor capacities. Sometimes predators are presented to stimulate anti-predator behavior.

The third condition, which is called free range, allows golden lion tamarins to live in wooded portions of zoos. Free-ranging lion tamarins usually come from the cages condition and some aspects of training may be used while free-ranging. A shelter box is provided for resting, sleeping and security. Cut up food is often provided, but usually in feeders that require manual probing. In this habitat golden lion tamarins encounter a variety of natural vegetation and many different substrates. Predators are encountered and there are frequent competitors for food, water, and the shelter box such as grey squirrels and starlings.

The fourth condition, wild born, is actually the absence of any pre-release environmental condition, which includes golden lion tamarins born to reintroduced animals and their offspring in the Poço das Antas Biological Reserve and surrounding private forests. They depend for their social experience on animals that were previously held in captivity, or on animals that are only a few generations away from being held in captivity.

The comparison among these different pre-release conditions are being complicated by having used two different types of post-release management. The first is called minimal, which was used with captive-born golden lion tamarins mostly in the early years of reintroduction (1984-1985). Food was provided only in the first week after reintroduction and monitoring was no more than biweekly. Shelter boxes were initially provided, but were not moved if the reintroduced animals left the release area. The second post-release condition, intensive, if often referred to as “soft-release”. Animals are monitored and provided with food and water daily for several months after release, and then two or three times a week for up to 2 years. Shelter boxes are provided to each group and are being moved to the animals if they leave the release area. With both post-release conditions, veterinary support was given to ill, injured or very hungry animals.

First, the survival of reintroduced individuals was studied, comparing captive-born with wild-born individuals. The study showed that the probability of losses of reintroduced captive-born golden lion tamarins (with all pre-release conditions combined) turned out to be high in the first year (70%), but then leveled off to match the age-specific mortality typical of wild populations. For golden lion tamarins born in the wild to reintroduced parents, the percentage of loss in the first year was considerably lower. An assessment of the causes of losses in the reintroduced population showed that theft and vandalism by humans was the main single cause (21%). However, problems with adaptation to the new environment, which were readily noticeable after the release of captive-born animals (e.g. inability to find food, and problems with locomotion and orientation), caused the majority of losses if considered together (36%). When comparing the different pre-release training conditions (cage vs. training vs. free range), no differences in group survival were found. Captive-born golden lion tamarins reintroduced directly out of cages, with or without training, and those given the opportunity to range freely before release are all equally likely to survive up to 2 years. These results indicate that the pre-release environments used in this study do no lead to a short- or long-term survival advantage after reintroduction. For golden lion tamarins, the training environments did result in a change of behavior (like short-term increases in foraging effort), but these changes did not translate into improved survival upon release.

Furthermore, the effects of post-release management were investigated, comparing minimal versus intensive management. With intensive post-release management captive-born golden lion tamarins (data for cages, training and free range pooled) are significantly more likely to survive to 2 years. The significantly greater survivorship for captive borns under the intensive post-release condition results in more reproductive opportunities, including captive-born subadults being able to assist their parents in raising wild-born offspring. Furthermore, intensive post-release management leads to increased animal welfare.

Evaluation of success
After 21 years, the population formed by the reintroduced captive-born golden lion tamarins and their descendants was estimated at 589 individuals living in 87 groups in about 3800 ha of forest on
private ranches surrounding the Poço das Antas Biological Reserve (Procópio de Oliveira et al., 2008; Rambaldi et al., 2006) (Figure 8). These forest patches represent approximately 17% of the total amount of forest with wild golden lion tamarins (Procópio de Oliveira et al., 2008), thereby protecting a large part of the Atlantic Forest remnants. The reintroduced population represents approximately 40% of the entire wild population of golden lion tamarins (Procópio de Oliveira et al., 2008). The involvement of local landowners was determinant for the success of the reintroduction (Procópio de Oliveira et al., 2008). Today, more than ten of the ranches have been formally designated as Permanent Private Reserves (Reservas Particulares do Patrimônio Natural: RPPNs) (Kierulff et al., 2010). Additionally, it was discovered that golden lion tamarins also occur on 38 other ranches and farms in the vicinity, and most of these golden lion tamarins probably derive from the reintroduced population (Rambaldi et al., 2006). As the population expanded over the past decade, the golden lion tamarins probably moved off of the densely populated collaborating ranches and settled on other nearby properties that do not yet collaborate formally. This could add an additional 200-300 golden lion tamarins to the reintroduced population, and would substantially increase estimates of the total wild population (Rambaldi et al., 2006).

As the population changed in the wild and became more independent, the management of the reintroduced population changed adaptively. Post-release provisioning was gradually reduced, as golden lion tamarins began to eat natural foods and move through their territories (Kierulff et al., 2000). The wild-born animals become self-sufficient more quickly than captive-born animals, and do not require supplementary feeding and management. The time necessary for a group to become fully independent varied, but all groups were independent 5 years after reintroduction (Kierulff et al., 2002b). In 2005, provisioning was discontinued in all groups; by that time only 8 zoo-born reintroduced golden lion tamarins were still alive (Rambaldi et al., 2006). More than 98% of the reintroduced population has been born in the wild in Brazil. The increased reproduction rate of the reintroduced population reduces the operating costs of the management technique as well as the frequency of future reintroductions. However, some future reintroductions may be necessary to increase the genetic diversity and demographic status of the wild population (Procópio de Oliveira et al., 2008).

Taken into account the above results, it can be said that the golden lion tamarin reintroduction program was successful, despite the high mortality of captive-born individuals during the first year after reintroduction, which was due to the absence of soft-release management techniques at the start of the program. The reintroduced population now represents a major part of the total wild population of golden lion tamarins, and the geographic distribution of the wild population has increased with the collaboration of private landowners, thereby also protecting the remnants of the Atlantic Forest of Brazil, aiming at the institutional mission of the GLTCP. Furthermore, the data represented here strongly suggest that the key to successful reintroduction of captive-born golden lion tamarins is intensive post-release provisioning. By providing dietary supplements and artificial shelters, reintroduced captive-born golden lion tamarins are more likely to survive and give birth to wild-born offspring, which show behavioral abilities comparable with those of the truly wild population (Beck et al., 2002).

Figure 8. Reintroduced golden lion tamarin population 2005. Yellow: reintroduced alive. Green: total alive. Adapted from Rambaldi et al., 2006.
5.3 Translocation of threatened golden lion tamarins

To help save the remaining golden lion tamarins living in the wild, the AMLD established a translocation program. Translocation has been defined by the World Conservation Union (IUCN) as ‘the deliberate and mediated movement of wild individuals to an existing population of conspecifics’ (IUCN, 1998). Many authors have defined translocation as the movement of wild-born animals within the species historical range, with or without an existing population of conspecifics (Caldecott & Kavanagh, 1988; Strum & Southwick, 1986; Nielsen, 1988). In this case, the term translocation is used for those wild-born golden lion tamarins that were captured in forests threatened with deforestation and immediately transferred to a single protected forested habitat uninhabited by conspecifics.

Despite the large number of translocations performed with numerous species, many problems have been observed, related to factors as capture, transport, release, costs, condition of the animals, carrying capacity of the new area, social disruption of resident animals and ecological disruption by translocated animals (Caldecott & Kavanagh, 1988). The primary factor affecting the success of translocation is habitat quality, including food resources, sites for reproduction, predation, competition, overhunting etc. If the habitat is suitable, the species should settle, survive and reproduce (Caldecott & Kavanagh, 1988). The second most important factor is knowledge on ecology and behavior of the species. The number of animals to be translocated and the type of release will depend on the characteristics of the animal (e.g. territorial, lives in social groups) (Caldecott & Kavanagh, 1988). Both factors were taken into account during the establishment of the golden lion tamarin translocation program. The team of researchers leading the program followed methods after studying over 34 references and more than 227 translocated species prior to translocation (Kierulff et al., 2002b). Data on golden lion tamarin ecology and behavior were used in order to determine the translocation technique and to find suitable habitat. This way, the chances of success were increased.

As with reintroduction, a translocation can be considered a success if it results in a self-sustaining population, measurable in terms of its reproductive success and survival (Kierulff et al., 2002b). Here, I report on the use of this management technique for the golden lion tamarin and its success based on the above criterion.

The establishment of a translocation program as part of the GLTCP

The golden lion tamarin translocation program began as a result of a major survey of the forest throughout the original known range of the species, initiated by Maria Cecilia Kierulff in 1991 (Kierulff, 1993a; Kierulff & Rylands, 2003). The distribution of the golden lion tamarin was restricted to four municipalities in the state of Rio de Janeiro: Silva Jardim, Cabo Frio, Saquarema and Araruama. A total of 562 individuals (109 groups) were found, living in 105 km² of forest. These individuals were located in four subpopulations: 361 individuals (70 groups) in the Poço das Antas Biological Reserve and the surrounding forests; 74 individuals in the hillside forests of Serro do Mar, 38 individuals (6 groups) in Campos Novos, and 29 individuals (8 groups) in the Centro Hípico de Cabo Frio. The remaining 60 individuals (12 groups) were surviving in small, isolated secondary forest fragments close to villages (Kierulff, 1993a; Kierulff & Oliveira, 1996; Kierulff & Rylands, 2003).

The size of the fragments where the 12 isolated groups of golden lion tamarins were found varied from 0,2 to 2,5 km². Due to the poor state and size of the fragments, isolation, and threats to survival of the species (deforestation and hunting), the translocation of these groups to a large and well preserved forest was considered a priority for the conservation of the golden lion tamarin (Kierulff, 1993; Kierulff & Procopio de Oliveira, 1996). During the same survey, forest areas were found without resident golden lion tamarins, including the Fazenda União, belonging to the Rede Ferroviaria Federal S.A. (RFFSA - Brazilian Railway Company) (Kierulff et al., 2002b). This area of 3200 ha covers 2400 ha of well preserved Atlantic Forest, and is located in the municipalities of Rio das Ostras and Casimir Abreu in the state of Rio de Janeiro, within the original known range of the species (Procópio de Oliveira, 2008). It is the second largest block of forest next to the Poço das Antas Biological Reserve and the best preserved lowland forest of the coastal region. Because the site was well preserved, distant from other native populations (no risk of transmitting diseases), located in the species historical range, big enough to translocate all groups (considering the average...
home range), and did not harbor native populations (no ecological impact of density), the area was considered ideal for translocation (Kierulf et al., 2002b).

The translocation program for the isolated groups of golden lion tamarins was initiated in December 1993, with the principle objective to rescue local wild populations threatened as a result of habitat destruction and uncontrolled hunting (Kierulf et al., 2002b). Since the threatened groups of golden lion tamarins were located at a considerable distance from the main surviving population in the Poço das Antas Biological Reserve, it was assumed that they were genetically different because linear distance and genetic distance have been found to be positively related in this species (Gratiov et al., 2001; Kierulf et al., 2002b). Therefore, another goal of the translocation program was to protect this additional genetic diversity (Kierulf et al., 2002b). Other objectives of the translocation program were to establish a new protected population, to protect additional tracts of the Atlantic Forest, to contribute to the science of translocation, and to track possible effects of small population size and isolation (Kierulf et al., 2002b).

The initial goal of the program was to monitor the groups of golden lion tamarins in their original areas prior to translocation. However, time was running out as one of the groups was killed by a dog before it could be translocated and numerous fragments showed traces of hunting, deforestation and coal production (Kierulf & Procópio de Oliveira, 1994, 1996). It was decided to change the methodology and immediately translocate the threatened populations. From 1994, the population of the Fazenda União began to be formed with the capture and translocation of 6 of the 12 groups of golden lion tamarins that were found in small, isolated forest fragments during the survey (Figure 9) (Kierulf & Procópio de Oliveira, 1994, 1996). No data could be found as to why only those 6 groups were translocated. The LB group (consisting of 7 individuals), was the first group to be translocated to the Fazenda União in October 1994. In March, April and July 1995 the SJ1 (3 individuals), SJ2 (7 individuals) and SJ3 (6 individuals) groups were translocated, respectively. In April 1997, the fifth group was translocated (B1, 8 individuals) and in October 1997 the sixth group (SQ, 11 individuals) (Kierulf & Procópio de Oliveira, 1994, 1996). In total, 42 individuals were translocated to the Fazenda União. In April 1998, the Fazenda União was transformed into a federal biological reserve (the União Biological Reserve) through the efforts of the AMLD and IBAMA, thereby protecting the translocated population (Procópio de Oliveira et al., 2008).

Figure 9. (A) Original location of the isolated groups of golden lion tamarins that were translocated to the União Biological Reserve. (B) Fragment where one of the isolated groups was found. Adapted from Procópio de Oliveira et al., 2008.

SJ = São João River
LB = Sítio LB Cabo Frio
B1 = Bauen
SQ = Saquarema
All groups that needed to be translocated were captured after the group members gathered to go to sleep inside a hollow tree. All captured animals were immobilized and body measurements and blood samples were taken. All individuals were tattooed and dye-marked for field identification and some received a radio collar. The next morning the group members were released together inside the Fazenda União without placing supplementary feeding in the woods of the tamarins (Kierulf & Procópio de Oliveira, 1994, 1996). The day after release the monitoring of the translocated groups started. Initially, the location of the groups was collected by triangulation (using the radio collars) to prevent interference with their behavior and the establishment of a home range. After the groups had established a home range, they were habituated to the observers and data on ecology, behavior, diet and home range use were collected visually (Kierulf & Procópio de Oliveira, 1994, 1996; Kierulf, 2000; Procópio de Oliveira, 2002).

**Evaluation of success**

In 2006, twelve years after the first translocation, the population of the União Biological Reserve comprised approximately 220 individuals in approximately 30 groups, 25 of which were monitored systematically by the end of 2004. Of the 42 individuals translocated, only 8 (18.6%) were still part of the population in the beginning of 2005 (*Figure 10*). Taken into account the individuals that did not survive, it took only 3 years for the number of golden lion tamarins in the translocated population to exceed the number actually translocated, compared with the 12 years it took for the number of golden lion tamarins in the reintroduced population to exceed the number actually reintroduced. Over 200 births were registered in the translocated population and 150 of these survive in the monitored population. Mortality among offspring declined after the first year, and most deaths occurred in the first weeks of life (Kierulf et al., 2002b). *Figure 11* shows the number of offspring and the number of survivors at the end of each year. The translocated population presents behavior, survival rates and reproduction rates similar to those found in the native population of the Poço das Antas Biological Reserve (Kierulf, 2000). The survival of individuals, the high reproduction rate and the formation of new groups are positive results of adaptation to the new area, showing the success of population management through translocation.

The physical condition of the translocated population was evaluated, considering the weight of adults (>18 months), discarding pregnant females. The average weight of adults upon translocation was 525 g ± 26.9 (n=25), which differs significantly (p<0.05) compared with the average weight of adults after establishment in the União Biological Reserve (544 g ± 44.6; n=159). This difference may reflect a lower availability of food resources in the original areas of the translocated groups, caused by a high degree of fragmentation. A comparison of the mean weight of adults after establishment (n=159) with adults born in the União Biological Reserve (542 g ± 51.9; n=265) showed no significant difference (Procópio de Oliveira et al., 2008).

The translocation of golden lion tamarins to the Fazenda União made it possible to monitor home range establishment without the pressure of other individuals, since an existing population of conspecifics was absent. The home range areas were established in the first six months after translocation (Kierulf, 2000; Procópio de Oliveira, 2002). Social disruption following translocation was common in these golden lion tamarin groups, with the replacement of breeding males in established groups by immigrant males from recently translocated groups (Kierulf et al., 2002b). The low population density and the high amount of unsaturated habitat increased the opportunities for the establishment of new groups by individuals dispersing from the original translocated groups. As a result of the lower density of groups, the home ranges used by golden lion tamarins in the União Biological Reserve were larger than those normally described for the species (Kleiman et al., 1986). However, range size decreased with increasing population density (Kierulf, 2000).

The percentage of golden lion tamarins surviving from the translocation program was 15% of the total number of golden lion tamarins surviving in Brazilian forests by 2006 (220 of an estimated population of 1500), thereby contributing to the maintenance of genetic diversity of the species. The translocation program also contributed to the conservation of the second largest area of Atlantic Forest in the state of Rio de Janeiro, covering a relatively large area of 3200 ha with 2400 ha of...
The golden lion tamarin: a flagship species for the Atlantic Forest of Brazil

The União Biological Reserve is very important considering the high rate of fragmentation and the small amount of Atlantic Forest left elsewhere in Brazil. Furthermore, the continuous monitoring of the translocated population made it possible to further develop and improve the translocation technique. The abnormal movements of individuals after release caused social disruption in some groups, which is one of the negative consequences of this translocation event. The dispersal behavior after the release of lion tamarins must be taken into consideration during any translocation program. Since the golden lion tamarin translocation program has been a success looking at the percentage of the total amount of wild golden lion tamarins originating from the translocated population, it can be applied as a model for the future conservation of other lion tamarin species as well. This has already happened for the translocation of black lion tamarins in the late 1990s (Valladares-Padua et al., 2002). In addition, existing studies on the translocated population have generated information on delineation and mapping of home ranges and overnight sites of the translocated groups, plant species forming part of their diet, behavior, spatial distribution of food resources, habitat quality and preference, phenological studies, seed dispersion by tamarins, demographics of the translocated population, biometric data of all monitored individuals, and hair and blood samples for genetic studies (Kierulff & Procópio de Oliveira, 1994, 1996; Kierulff, 2000; Kierulff et al., 2002a,b; Procópio de Oliveira, 2002). These data are essential to determine the carrying capacity of the União Biological Reserve.

5.4 Habitat restoration and protection
One of the major problems that threaten the survival of golden lion tamarins is habitat loss, resulting in small and isolated golden lion tamarin populations. Besides the larger protected forest fragments of the Poço das Antas and União Biological Reserves, the golden lion tamarin also lives in privately owned forest fragments, where they were introduced with success. However, most of these forest
patches are isolated, each surrounded by cattle pasture or agricultural fields, land cover that golden lion tamarins are unable to cross. These small and isolated populations will suffer from inbreeding, causing an impoverishment of the genetic diversity and a high probability of extinction if unmanaged (Ferraz et al., 2012). Furthermore, these private properties are often not protected by federal law, and are therefore under constant risk of being deforested as a result of industrial development.

The AMLD’s strategic plan to conserve golden lion tamarins, forest and ecological services for local communities concerns making and maintaining connections among golden lion tamarins, local people, protected areas and forest habitat (Ferraz et al., 2012). According to the AMLD’s strategic plan, stakeholders will automatically become invested in the long-term protection of forest and forest corridors when actively involved in regional land-use decision making (Ferraz et al., 2012). This way, they directly contribute to the AMLD’s conservation goal of a viable population of 2000 golden lion tamarins living freely in 25,000 hectares of effectively protected and linked Atlantic Forest habitat by 2025 (Ballou & Padua, 1991). The AMLD tries to involve and connect local landowners, local communities, and local, state and federal governments in this effort (Ferraz et al., 2012).

**Restoring the structural connectivity of the remaining forest fragments**

In order to restore the connectivity of the landscape, the AMLD has been working with local landowners to plant and protect forest corridors to reconnect isolated forest fragments, thus facilitating golden lion tamarin dispersal among the 18 separated populations of the metapopulation (Ferraz et al., 2012). The AMLD has developed and is implementing a first-ever Metapopulation Management Plan for the permanent conservation of a viable population of golden lion tamarins and their habitat in the São João River Basin. The plan has been adopted as part of the Brazilian federal policy for conservation of the endangered mammal species of the Southeast Atlantic Forest (Ferraz et al., 2012). One of the first steps in this innovative conservation program was the identification of the golden lion tamarin metapopulation management area (MMA) and the monitoring of habitat size and quality (Rambaldi et al., 2010). During a workshop held in January 2009, technicians used remote-sense satellite data, landscape analysis and site visits to identify the largest remaining fragments of habitat suitable for tamarins, located close enough to allow connection by forest corridors. The management area includes the seven largest remaining forest patches, a total of 39,054 hectares of forest (Figure 12) (Ferraz et al., 2012). Next, the conservation of golden lion tamarins requires accurate information on the number of individuals and reproductive groups living in each forest fragment in the MMA (Rambaldi et al., 2010). There are several methods used by AMLD wildlife managers to keep track of tamarin numbers. One of the methods is the monitoring of a few “keystone” populations over many years. These intensively studied golden lion tamarins are individually marked, habituated to the presence of human observers and carry radio-telemetry transmitters (Rambaldi et al., 2010). The long-term mapping of golden lion tamarin home ranges provides accurate measures of tamarin densities in different forest habitats. This information is used to estimate the number of golden lion tamarins living in the remaining populations (Rambaldi et al., 2010). Furthermore, the monitoring provides information on local threats such as disease and hunting, and genetic analysis is used to evaluate the extent of gene flow among the isolated tamarin populations, resulting in recommendations for translocation strategies (Rambaldi et al., 2010).

Today, five of the Metapopulation Management Area fragments are connected (fragments 1,7,2,3 and 4), totaling 41,553 hectares (Ferraz et al., 2012). The connected habitat has the potential to hold the 2,000 golden lion tamarins necessary to ensure the survival of the species in perpetuity. However, the fragments of the MMA need to be protected against deforestation in order to maintain this potential. Approximately 14,600 hectares of golden lion tamarin habitat is now protected by private, state, or federal conservation areas (Ferraz et al., 2012). The remaining habitat is property of about 1,000 landowners and is at risk due to the rapidly expanding cities of Rio de Janeiro and São Paulo to the south and by development related to offshore oil drilling and beach tourism to the north (Ferraz et al., 2012). The great danger lies in the loss of remaining forest corridors, which has a major impact on the connectivity between fragments in the MMA. The area of connected forest will drop far below what is necessary to harbor a viable population of golden lion tamarins in the long-term.
Figure 12. Current geographic distribution of golden lion tamarins, 80km northeast of Rio de Janeiro city (22°34'53.08" S 42°22'27.38" W). The numbered colored polygons represent the seven largest remaining forest fragments within the species distribution. When connected by forest corridors being planted by AMLD, and if tamarin densities match predictions, the resulting forest patchwork is predicted to support a metapopulation of GLTs with greater than 98% long-term probability of survival and retention of genetic diversity. Adapted from Ferraz et al., 2012.

Figure 13. Fazenda Dourada Corridor before reforestation (photo on left, 2 September 2009) and after reforestation (photo on right, 2 April 2012). Adapted from Ferraz et al., 2012.
Therefore, AMLD’s challenge for the future is to create new forest corridors, to protect the remaining habitat and to make sure the habitat fragments stay connected (Ferraz et al., 2012).

In the last couple of years, AMLD foresters have planted 24 corridors in the São João River Basin, connecting more than 10,000 ha of forest patches (Ferraz et al., 2012). The first corridors were planted in the Poço das Antas Biological Reserve in 1996 as scientific experiments (Fernandes et al., 2008). From 1997, the AMLD started to build corridors on private properties where golden lion tamarins were either reintroduced or where wild animals were still present (Fernandes et al., 2008). The planning of these corridors began with conversations with landowners, as the costs of converting pasture land into a corridor had to be reconciled with gain, which may include watching golden lion tamarins in the owner’s backyard, and the contribution to golden lion tamarin conservation (Rambaldi et al., 2010). In rare cases, the AMLD even purchases land for conservation. In collaboration with IUCN-Netherlands, Saving Species, ICMBio, and other partners, the AMLD purchased a small cattle pasture in 2007 that separated the União Biological Reserve from the remainder of the golden lion tamarin MMA to the west (Ferraz et al., 2012). The AMLD planted fast-growing native trees and bushes to create a forest corridor on the pasture (Figure 13). These thin stands are quickly colonized by birds and bats that disseminate seeds in their feces. It took only a few years before the corridor began to resemble native forest, and in April 2012 golden lion tamarins were seen crossing the corridor, known as the Fazenda Dourada Corridor (Ferraz et al., 2012). The corridor is also used by many other species, including pumas. Soon, the AMLD will donate the area to the União Biological Reserve.

Currently, the AMLD is working to ensure the connection between the Poço das Antas Biological Reserve and the remaining metapopulation (Ferraz et al., 2012). This is very important, taken into account that the Poço das Antas Biological Reserve is one of the largest forest fragments harboring one of the largest tamarin populations. One of the priority projects of the AMLD, already partially realized, is promoting connectivity between forest fragments located between Poço das Antas Biological Reserve (Silva Jardim) and Rio Vermelho Farm (Rio Bonito) (Fernandes et al., 2008). This farm has the largest fragment of Atlantic Forest located inside private lands at the São João River Basin (Ferraz et al., 2012). To connect segments along this path, multiple corridors are necessary, representing an extension of 35 km and running parallel to the southern portion of the BR-101 highway (Figure 12) (Fernandes et al., 2008). Along the northern portion of the BR-101 highway leading from Poço das Antas (Silva Jardim) to União (Casimiro de Abreu, Rio das Ostras, and Macaé) (Figure 12) a second path with forest corridors is also being implemented, linking forest fragments that harbor groups of lion tamarins that were reintroduced on private property (Fernandes et al., 2008). By the end of 2006, the forest corridors that had already been constructed along both northern and southern parts of the BR-101 highway promoted the integration of more than 9000 ha of Atlantic Forest, and several corridors were already being used by a significant number of species. However, this total is expressed in a discontinuous area, since none of the two paths cited (from Poço das Antas to Rio Vermelho Farm and União) have corridors already in place from one extreme to the other (Fernandes et al., 2008). The major problem the AMLD faces is the presence of the BR-101 highway, which will soon be doubled in width, making it hard to plant forest corridors (Ferraz et al., 2012). One of the recommendations would therefore be to construct wildlife crossings that enable lion tamarins and other wildlife to cross the highway.

Besides planting new forest corridors and purchasing land, the AMLD also develops and implements education strategies to work with local communities as well as municipal governments and water-and-land-management agencies to increase support for and involvement in reforestation and protection of critical forest connections (Ferraz et al., 2012). These critical forest connections are often narrow and very vulnerable. One such connection is the forest corridor between the Pirineus and Gaviões fragments (Figure 14). If this corridor becomes deforested or insufficient for tamarin dispersal, 14,000 hectares will be lost to the metapopulation, and the long-term conservation of golden lion tamarins may be impossible (Ferraz et al., 2012). At this moment, AMLD wildlife managers monitor the movement of golden lion tamarins among fragments to evaluate the success of the above strategies to conserve forest corridors.
Creation of private reserves of natural heritage (RPPNs)

The restoration of connectivity between forest fragments alone does not ensure the perpetuation of these areas. One way to ensure that these remnants are kept intact is through the creation of private reserves of natural heritage (RPPNs), the ideal instrument for legal protection of the remaining habitat of numerous species present on the private property, including the golden lion tamarin (Fernandes et al., 2008). The owners of the private areas that contain remnants of threatened ecosystems should be encouraged to create a RPPN in order to have their areas protected in perpetuity. The AMLD has been developing such actions in the São João River Basin since the early 1990s, representing fundamental results for achieving the institutional goal of 2000 golden lion tamarins living freely in 25,000 ha of protected and linked forest by the year 2025 (Ballou & Padua, 1991). In order to achieve this goal, numerous challenges are faced daily by the AMLD in partnership with landowners (who own most of the remaining forest), IBAMA, municipal governments in the region and many others (Fernandes et al., 2008).

The public areas of fully federal protection in the São João River Basin, managed by IBAMA, are represented by the Biological Reserves Poço das Antas (Silva Jardim) and União (Casimiro de Abreu/Rio das Ostras/Macaé), which together total 8700 hectares (Fernandes et al., 2008). These areas contribute significantly in achieving the AMLD goal of 25,000 ha of protected forest. Together, they have the capacity to support about a hundred groups of golden lion tamarins, which are approximately 600 individuals (Fernandes et al., 2008). However, these protected areas aren’t large enough to maintain a viable population of golden lion tamarins in the long-term. Considering that more than 16,000 ha of forest needed to reach the AMLD goal is located on private properties, the AMLD is trying to promote active participation of private owners in habitat protection by recording their land as Reservas Particulares de Patrimônio Natural (RPPNs – Private Natural Heritage Reserves), a type of conservation unit established by IBAMA in 1990 (Mie Matsuo et al., 2008; Fernandes et al., 2008).

What differentiates a RPPN from other protected areas is that it is obligatorily located in private lands, expresses the will of the owner and is administered according to the guidelines of IBAMA (AMLD, 2013). In agreement with the Federal Decret no. 1922/96, a RPPN has a perpetual character; once recorded, the area will always be a RPPN (AMLD, 2013). The landowners that are interested in the creation of Private Reserves are visited by AMLD’s technicians who inform them of all aspects of...
the creation, the management, the importance of RPPNs for the conservation of biodiversity, and the advantages that these reserves can bring to the property. The landowner of a RPPN has total exemption from ITR - Rural Territorial Tax on the recorded area (AMLD, 2013). They prioritize in the concession of agricultural credit in the official financial institutions and work with programs of managed projects supported by the federal government for private initiative (AMLD, 2013).

To date, the AMLD has worked with landowners to create 29 RPPNs in the São João River Basin and surroundings, comprising 2,650 ha of protected forest, the largest concentration of RPPNs surrounding a public reserve in any state in Brazil (AMLD 2013; Fernandes et al., 2008). Together, the RPPNs comprise 30% of the total protected habitat for the golden lion tamarin (AMLD, 2013). Both wild and reintroduced golden lion tamarins are present in 16 of the 29 RPPNs created, and golden lion tamarins are potentially present in a further 9 RPPNs. No data could be found on the degree of connectivity between these RPPNs and other forest fragments. However, a number of forest corridors are currently being planted to connect the Poço das Antas Biological Reserve with surrounding private forest fragments, including RPPNs.

Significant changes were observed in the attitudes of regional communities in relation to the Atlantic Forest and the importance of protecting the remnants. Since the first years in which the AMLD supported the creation of RPPNs, the idea of ‘environmental protection’ inspired numerous owners. Since then, the mobilization of owners of RPPNs in the São João River Basin and other regions has become increasingly more organized, leading to the creation of the Association of Owners of RPPNs in the state of Rio de Janeiro (APN/RJ), the first in Brazil to bring together these willful conservationists (Fernandes et al., 2008). All this contributed to the creation of a program to support RPPNs in the city of Silva Jardim, adding another unique initiative (Fernandes et al., 2008).

Based on the experience of the AMLD to promote the creation of RPPNs, the most common reasons that lead landowners to establish private reserves are the will to protect remaining forest areas by law, the possibility of financial support for the development of ecotourism and environmental education activities, the contribution to scientific research, the increased likelihood of support from government agencies, research institutions and NGOs, the possibility to share responsibility with the government to conserve fragments of the Atlantic Forest ecosystem, and the opportunity to provide services that benefit the whole society (Fernandes et al., 2008).

Thus, the AMLD, together with various partners, have contributed to biodiversity protection, and the generation of employment and income related to ecotourism activities, organic production of food and handcrafts, as well as the increase in hectares of legally protected areas. The state of Rio de Janeiro now ranks fourth in the ranking of National RPPNs (44 units in the state) (AMLD, 2013). The city of Silva Jardim, in turn, is a national leader in the number of federal private reserves (10 in the municipal district), and became the capital of Brazil RPPNs (AMLD, 2013).

5.5 Education

Some species are highly effective in stimulating human interest. The Brazilian golden lion tamarin is one of these species, and its attractive appearance has been used to support its conservation (Padua et al., 2002). In the past two decades, in situ and ex situ conservation education programs have been designed for the golden lion tamarin, in some cases with great impact (Padua et al., 2002). Outside of Brazil, zoos have successfully used the golden lion tamarin as part of a conservation-oriented campaign and as a method for informing the public about environmental issues (Padua et al., 2002)

In 1983, the first golden lion tamarin education program was started by the Golden Lion Tamarin Conservation Program (GLTCP) to increase participation of local communities in conservation activities by increasing knowledge and concern for the importance of protecting an endangered species and its forest habitat. The golden lion tamarin education program attracts public attention to its goal of conserving coastal rainforest and other endemic species (J. M. Dietz & Nagagata 1986, 1995, 1997). The program targets students and teachers from local schools, visitors to the AMLD education center, regional landowners, and members of the surrounding communities (Mie Matsuo et al., 2008).
In 1984, at the start of the program, a questionnaire was developed to identify the knowledge and attitude of local communities towards wildlife, the Atlantic Forest and the Poço das Antas Biological Reserve, the only protected habitat for the species at the time (Mie Matsuo et al., 2008). The results of this diagnosis provided important information for planning the methodology of the conservation education program (Dietz & Nagagata, 1995). The results showed that local community members had little knowledge about the Poço das Antas Biological Reserve or the golden lion tamarin, although they did demonstrate sympathy for the animal (Dietz & Nagagata, 1995, 1997). Survey responses also indicated that the community did not understand the link between decreasing wildlife and habitat destruction (Dietz & Nagagata, 1995, 1997). One of the challenges, therefore, was to demonstrate interdependencies among living things and their environments (Padua et al., 2002). It was decided that the golden lion tamarin would be used as a ‘flagship species’ to raise community knowledge about the relationships between wildlife, habitat, humans and their well-being (Mie Matsuo et al., 2008). Taking into account the three criteria often used to select a flagship species (geographical location, ecological characteristics, and potential for building public support), the golden lion tamarin is an excellent candidate. Golden lion tamarins are endemic to the Atlantic Forest hotspot, use large home ranges, and, as indicated by the above interview, have a relatively attractive appearance, which makes it easier to gain public support. Although the use of flagship species is a simplified vision on conservation, this strategy helps focusing attention on particular species, rather than on the more complex concepts of species richness or genetic diversity (Dietz et al., 1994b). It also focuses attention to easy transmit goals (e.g. the number of animals, the amount of habitat etc.).

Additionally, there was also a need to build pride among local communities in regard to the remaining natural habitats. It was clear that information needed to be transmitted about the importance of forests, the degree of which they are being destroyed, and the effect of that forest destruction on local communities (Padua et al., 2002).

Conservation education
Since 1986, numerous methods have been developed, tested and implemented by the team: a logo was created (Figure 15) to identify the program and to be used on all education materials, talks and interviews were given on local radio, and educational events and cultural festivities were promoted (Padua et al., 2002). At the same time the SOS Mata Atlântica Fund was created in the state of São Paulo, and was aired on television vignettes about the importance of the biome and the control of threats (Mie Matsuo et al., 2008). The participation of the local and national media was and always will be extremely important in the formation of conscience environmental conferences. The relationship between the golden lion tamarin and the Atlantic Forest was reinforced with the public by these messages, turning the species into a nationally and internationally recognized symbol for the conservation of the Atlantic Forest, which has been one of the major success of the GLTCP (Mie Matsuo et al., 2008). Other educational and promotional materials were produced and distributed regionally, including videos, posters, school notebooks, slide collections for lectures, ecological games, instructional materials for the local teachers, booklets, T-shirts, stickers, buttons and caps with educational messages and the logo (Mie Matsuo et al., 2008; Padua et al., 2002).

It was tried to establish a positive relationship with community leaders to get to know the community and to get suggestions on how to improve the conservation approach and build a long-term relationship (Mie Matsuo et al., 2008). The education program developed many activities, with special emphasis on activities that interested local leaders and that appeared most likely to achieve the greatest results for the least cost (Padua et al., 2002). One of these activities involves the project “Rediscovering the Atlantic Forest“, in which long-term training is provided for teachers of 14 schools in the Silva Jardim municipality (AMLD, 2013). Teachers participate in several periodic courses to discuss ways to implement activities about the Atlantic Forest, such as the physical characteristics of the forest, its native flora and fauna, threats, and conservation actions. These activities are developed by teachers according to the characteristics of their own school or community, taking into account the students’ level and their interest (AMLD, 2013). Furthermore, traveling exhibitions related to AMLD activities are presented at special events such as municipal anniversaries, scientific
expositions and agricultural fairs. At these events panels, boxes with seeds of native Atlantic Forest species, skeletons of animals, games and drawings for children are being displayed to inform people about the golden lion tamarin, its Atlantic Forest habitat, and conservation (AMLD, 2013). Over time, the program began to be viewed positively by both the leaders and the community, mainly because of the engagement of diverse students and volunteers to work together with researchers and educators of the GLTCP (Mie Matsuo et al., 2008).

The impact of the education program was demonstrated by the occurrence of several events over the years. On several occasions, people of surrounding communities helped extinguish forest fires, which is a significant indication of their level of involvement (Mie Matsuo et al., 2008). Another result was the spontaneous return of 20 illegal pet golden lion tamarins to the research and education teams (Dietz, 1998). Furthermore, the created demand in the region for information on the Atlantic Forest, its characteristic fauna, protected areas and other themes is another major impact of the program (Mie Matsuo et al., 2008). People wanted to visit the Reserve and see the monkeys. This demand has stimulated the GLTCP and the Poço das Antas Biological Reserve to create an education environment. In 1989, the first public Educational Center within a Biological Reserve in Brazil was opened: the Educational Center of Adelmar F. Coimbra-Filho (Mie Matsuo et al., 2008).

Two years after the start of the conservation education program, the same questionnaire was carried out to evaluate the first phase of the project. The results indicated significant changes in the knowledge and attitudes of local communities. There was a significant increase in the percentage of respondents who identified the golden lion tamarin, their social organization, and their habitat (Dietz & Nagagata, 1997). Furthermore, a significant change was also observed in the public perception of fauna in general. Although project activities were not aimed at conservation of snakes, a significant decrease was found in the percentage of respondents who said they would kill a snake if they found it in the woods, and a significant increase in the percentage who would ‘leave it alone’ (Dietz & Nagagata, 1997). This change in attitude is an indication of the golden lion tamarins’ flagship role in promoting the broader conservation goal.

Involving landowners and local farmers in conservation
In the 90s, the environmental education program, since 1992 implemented by the Associação Mico-Leão-Dourado (AMLD – Golden Lion Tamarin Association), focused its strategy on farmers in the region. It became a priority to increase the size and amount of protected habitat available for the monkeys, as the Poço das Antas Biological Reserve was insufficient to sustain a viable population of
golden lion tamarins. With this, it became even more important to involve rural communities in the conservation actions of the golden lion tamarin and its habitat (Mie Matsuo et al., 2008).

In order to gain landowner support, one-on-one visits to each ranch were a key activity of the program. During the visits, the objectives of the golden lion tamarin project were explained, and landowners were presented with the idea of possibly receiving introduced golden lion tamarins on their ranches (Padua et al., 2002). Special materials were created to show landowners the tax benefits and other advantages of protecting forests and encouraging conservation in general (Padua et al., 2002). An important finding during visits, which surprised the environmental education team, was that farmers did not so much consider the rural tax exemption as a stimulant to preserve their forests, but particular valued the possibility of becoming a partner in conservation efforts (Padua et al., 2002).

Once the first farms received reintroduced captive golden lion tamarins in the mid 80s, the news spread and aroused the interest of other owners (Kleiman & Mallison, 1998). Landowners showed rapid responses to the messages of the project, and signed an agreement for the unconditioned use of their forests for the reintroduction of captive born golden lion tamarins (Mie Matsuo et al., 2008). The support of farmers has been instrumental for success in the conservation of this species. Currently 28 farms are participating in the reintroduction program, thus enabling a significant increase in the golden lion tamarin population (Mie Matsuo et al., 2008).

Besides gaining landowner support to increase the amount of Atlantic Forest habitat, another goal of the education program was to inform small farmers on sustainable agriculture, since a great proportion of Atlantic Forest remnants is surrounded by agricultural fields. Small farmers from three settlements (Aldeia Velha, Cambucaes/Olhos d’Água, and Sebastião Lã I) adjacent to the Poço das Antas Biological Reserve became important partners of the conservation education program (Mie Matsuo et al., 2008). In the Cambucaes/Olhos d’Água settlement, 19 families were mistakenly settled by the government in an area recorded as a Legal Reserve (318 ha), where they developed agricultural practices such as the production of pineapple, citrus, banana, cassava and small livestock. These practices negatively influenced the Legal Reserve, as forest patches were cleared for keeping livestock and nonnative plant species were introduced, thereby affecting the biodiversity of the remaining golden lion tamarin habitat. In the Sebastião Lã I settlement, 30 families were settled in an unproductive area with peat soil being constantly soaked by the riverbanks of the São João river, causing families to use chemicals to improve the soil (Mie Matsuo et al., 2008). These facts demonstrate the absence of a sustainable agricultural policy by the government caused an increase in the pressure on remaining golden lion tamarin habitat, either by the use of chemicals or by the need for natural resource exploitation. Because of these reasons, the AMLD created an Environmental Extension Program to specifically deal with this audience. By using participatory methodologies and by acting as an interlocutor with local governments and state and federal agencies, the AMLD tried to gain confidence and support of the settlers (Mie Matsuo et al., 2008).

With the use of several training courses, technical visits and the exchange of experiences of the program, farmers of settlements located in the vicinity of the Poço das Antas Biological Reserve now apply sustainable agricultural practices (Mie Matsuo et al., 2008). Some farmers converted their areas for the organic production of vegetables. These practices have added significant value to their products, generating additional income and improving the quality of life of these families. As a result, the remaining golden lion tamarin habitat

![Figure 17. AMLD Extension Coordinator teaches a local landowner to produce and market tree seedlings used in AMLD forest corridors and in reforestation. Adapted from Rambaldi et al., 2010)](image_url)
surrounding these settlements is no longer negatively affected by agricultural practices, thereby contributing to the mission of saving the biodiversity of the Atlantic Forest. In addition, a community nursery with forest species of the Atlantic Forest was established in the Cambucaes/Olhos d’Água settlement (Figure 17). The community nursery has been developed to produce seedlings used for the construction of forest corridors and forest patches, which increase the size and connectivity of Atlantic Forest remnants. The nursery allowed the deployment of 8 agroforestry system demonstration units in the settlements of Aldeia Velha and Cambucaes/Olhos d’Água, which consist of vegetable crops intercropped with native tree species. Currently, the AMLD is working with 74 different species and intends to increase this number, reaching at least 85 species. The results of studies on the diet and use of space of golden lion tamarins conducted in the União Biological Reserve, and an inventory conducted in the Poço das Antas Biological Reserve, were crucial in the selection of species in accordance with the topography of the land (Mie Matsuo et al., 2008).

Today, the golden lion tamarin is recognized worldwide as a symbol for the conservation of Brazil’s Atlantic Forest, thereby demonstrating the success of the golden lion tamarin education program (Padua et al., 2002). A great part of the local landowners are now protecting their remaining forest lands, often with reintroduced golden lion tamarins, and considerable national and international support has been received through multiple grants (Padua et al., 2002). Two decades of extension work, community education and political activism has stopped virtually all illegal deforestation in the region as well as illegal capture of golden lion tamarins for the pet trade (Rambaldi et al., 2010). As part of the efforts of the golden lion tamarin education program, a new biological reserve, União, was created in 1998, thereby protecting another 2400 ha of Atlantic Forest (Procópio de Oliveira et al., 2008). Over its history, the achievements of this program opened several doors for educators in Brazil, leading in its success in involving local communities while at the same time reaching broader audiences (Padua et al., 2002).

5.6 Future conservation efforts: the removal of nonnative primate species
As discussed in paragraph 3.4, the recent introduction of nonnative primates in golden lion tamarin habitat represents a major threat to the survival of the wild population. For the conservation of the golden lion tamarin, it is a necessity to investigate the extent of the problem. This way, adaptive management strategies can be developed in order for the AMLD to reach its goals.

First, it was investigated which exotic primate species were present in the habitat of the golden lion tamarin. Studies have shown that the common marmoset (Callithrix jacchus) (Figure 5B) and the black-tufted marmoset (Callithrix penicillata) (Figure 5C) are present in all of the private forests where groups of golden lion tamarins were reintroduced, as well as hybrids of these two species (Figure 6) (Ruiz-Miranda et al., 2008). Furthermore, golden-headed lion tamarins (Leontopithecus chrysomelas) (Figure 2B) were sighted in Niterói in 2002 (Kierulf, 2010). The common marmoset is native to the Northeastern coast of Brazil, the black-tufted marmoset is native to the gallery forests of the Brazilian Central Plateau and the golden-headed lion tamarin is native to the state of Bahia.

Interviews have indicated that the golden-headed lion tamarins were accidentally released by a private owner, and that there were 3 large releases (>80 individuals) of confiscated marmosets in the region about two decades ago (Kierulf, 2010; Ruiz-Miranda et al., 2008). These have probably been the seed for some of the existing populations. As some marmosets are held as pets, it was investigated if the local citizens contributed to the problem (Ruiz-Miranda et al., 2008). Of the 600 locals interviewed, 25% had released wild animals into the forest, and 3% of these had released marmosets. An intensive campaign was started to educate people on the negative consequences of releasing wild animals acquired through illegal wildlife trade, and a course was given to local law enforcement officers on the topic of invasive species (Ruiz-Miranda et al., 2008).

A survey on the distribution of the golden-headed lion tamarin showed that there are 107 individuals (15 groups) living in a forest fragment of approximately 4000 ha in Niterói (Kierulf, 2012). The nearest population of golden lion tamarins is located in Fazenda Rio Vermelho, municipality of Rio Bonito, less than 50 km from Niterói (Kierulf, 2010). A survey on the distribution of marmosets
showed that the marmosets are present in almost the whole area of occurrence of the golden lion tamarin within the Sao Joao river basin, except from the two Biological Reserves (Ruiz-Miranda et al., 2008). In the areas where marmosets are present, they are even more abundant than the golden lion tamarins themselves. The marmosets do not form an expanding population, but instead are distributed into several isolated populations, limited by habitat fragmentation (Ruiz-Miranda et al., 2008). But what will happen if habitat is connected for golden lion tamarins, as already planned as part of the GLTCP?

Another important question concerns the health of the invasive species, as new infectious diseases could be transmitted. The golden-headed lion tamarins that were introduced in Niteroi are doing well in the area. The population is expanding every year, and individuals look healthy, indicating there is enough food present (Kierulff, 2012). The marmosets on the other hand are not doing that well in some of the forest fragments. Over 250 marmosets were captured and investigated, and many had poor dentition, broken limbs, wounds and the body weight was below normal (Ruiz-Miranda et al., 2008). Over 30% had ectoparasites as opposed to 5% of the golden lion tamarins, and many had a large helminth infestation in their feces (Ruiz-Miranda et al., 2008). This raises concerns about the unhealthy marmosets facilitating the dispersion of disease.

The next question is what to do with the introduced species? Concerns are that marmosets may increase the risk of a disease epidemic and compete with the tamarins for resources. At this moment, the AMLD is working on modeling the effects of exotic marmosets on the survival of tamarin populations, thereby giving some probabilities on the risk of extinction with and without marmosets (Ruiz-Miranda et al., 2008). Concerns regarding the golden-headed lion tamarin are that the two species might also hybridize, with catastrophic consequences for all the efforts that have been made over the years for the protection and conservation of both species (Kierulff, 2012). Whatever decision is made, the conservation costs and benefits should be taken into account, as well as animal welfare.

In the case of the golden-headed lion tamarins, translocation of the introduced populations seems to be an option. In the state of Bahia, a possible release area without conspecifics has been found with a protected forest cover of 3000 ha, which is big enough to receive all groups (Kierulff, 2010). However translocation is expensive, as the golden-headed lion tamarins will have to stay in quarantine and will need to be transported over a distance of 1000 km (Kierulff, 2012). Currently, the AMLD is sending proposals applying for funds to pay for the translocation of the groups to Bahia.

The invasion of exotic marmosets is more complex. There is a consensus that intervention is due, but there are a lot of differences in opinion as to what needs to be done. The options are to intervene, to remove (but what to do with the removed animals?) or to control through sterilizations (Ruiz-Miranda et al., 2008). However, sterilizations can be quite expensive and the population response to sterilization can take many years, during which there is still competition for resources and risk of transmitting diseases (Ruiz-Miranda et al., 2008). Future meetings and further research need to be performed in order to decide was is best for biodiversity conservation.

In addition, one could ask what to do with the forest area in Niteroi after the translocation of golden-headed lion tamarins to Bahia? This forests covers more than 4000 ha, is well preserved and resources are sufficient as indicated by the thriving golden-headed lion tamarin population (Kierulff, 2010). One of the biggest problems for the conservation of the golden lion tamarin is the lack of suitable habitat, with remaining fragments for reintroduction being small and often degraded. When the population of golden-headed lion tamarins is removed from Niteroi, the area could be used to reintroduce new groups of golden lion tamarins, thereby contributing to increase the number of the species in the wild.

**6. Evaluation of the success of the Golden Lion Tamarin Conservation Program**

Approximately 30 years ago, the Golden Lion Tamarin Conservation Program (GLTCP) was established as a result of the dramatic decline in the number of wild golden lion tamarins due to increasing deforestation of the Atlantic Forest. The GLTCP is an international flagship species program with the
institutional mission to conserve the biodiversity of the Atlantic Forest focusing on the conservation of the golden lion tamarin (Leontopithecus rosalia) in its natural habitat (AMLD, 2000).

The conservation goal of the GLTCP is to establish a viable population of 2000 golden lion tamarins living freely in 25,000 hectares of protected and linked forest by 2025 (GLTCP, 1983). According to the golden lion tamarin population model used in the PHVA workshop of 2005, those numbers represent a metapopulation with 95% chances of survival for 100 years, maintaining 98% of the genetic diversity (Holst et al., 2006). To achieve this long-term goal, the short-term goal was set to establish a viable population of 1600 golden lion tamarins living freely in 20,000 hectares of protected and linked forest by 2010 (AMLD, 2004). Currently, the most recent estimate is 1600 golden lion tamarins living in 15,000 ha of forest (Holst et al., 2006). The short-term goal has not yet been met regarding the amount of protected forest habitat, but major results have been achieved regarding the number of golden lion tamarins now living in the wild. The golden lion tamarin that was almost extinct in the wild before 1983, had its IUCN Red List category changed in 2003 from Critically Endangered to Endangered, as a result of the achievements of the GLTCP (IUCN, 2011).

During the last PHVA, the golden lion tamarins were divided into 6 potential viable populations and 12 small and isolated populations (Holst et al., 2006). Three of the six existing, potentially viable populations were the result of reintroduction (n>600 individuals) and one the result of translocation (n>300), together representing more than 60% of the entire wild population. The reintroduction of captive-born golden lion tamarins was used to increase the size and genetic diversity of the wild population, whereas translocation was used to rescue threatened wild groups undoubtedly representing significant genetic diversity for the species. Both programs have been successful as measured by survival and reproduction after release, and both techniques have established growing populations (Ruiz-Miranda et al., 2010).

Both reintroduction and translocation programs have been major contributors to the protection of habitat for the species. As a result of the translocation program, the União Biological Reserve was created in 1998, covering 2400 ha of protected Atlantic Forest. Golden lion tamarins were reintroduced on 28 private properties, covering about 3800 ha of forest remnants. Today, more than ten of the ranches where golden lion tamarins were introduced have been formally designated as Permanent Private Reserves (Reservas Particulares do Patrimônio Natural: RPPNs), thereby protecting the remaining Atlantic Forest (Kierulf et al., 2010). Furthermore, the reintroduced and translocated populations have also contributed to the retention of overall genetic diversity, reduction of the effects of genetic drift and inbreeding, and in adding new genetic diversity from captivity and from the isolated coastal populations (Kierulf et al., 2012).

The geographic distribution of the golden lion tamarin increased by 60%, with many private landowners protecting remaining forest as a result of the education program. In total, 10,604 hectares are permanently protected by 2 federal biological reserves (Poço das Antas and União) and 19 private reserves (AMLD, 2012). More than 100 rural properties are participating in the management, restoration, and protection of golden lion tamarins in their natural habitat. The conservation education program of the AMLD also taught landowners how to produce tree seedlings used in forest corridors and reforestation. As a result, 27,529 hectares of forest are now connected by planted forest corridors, allowing the dispersal of golden lion tamarins from one fragment to another (AMLD, 2012).

The golden lion tamarin conservation program is one of the best and long-lasting examples of the integration of field and captive conservation efforts on a global scale. Through a variety of venues, the zoo community has probably supported well over 50% of the research and recovery work on golden lion tamarins (Kleiman & Rylands, 2002). Zoo behavioral research and the data-based species management for golden lion tamarins set the global standard for captive endangered species management programs. The golden lion tamarin program is probably the only zoo-based program of its kind in which the ownership of the vast majority of the captive population, owned for decades by zoos, has been returned to the range country, a symbolic but significant message to the citizens of Brazil (Kleiman & Rylands, 2002).
The conservation needs of the golden lion tamarin have led to the creation of a number of national nongovernmental organizations (NGOs) in Brazil, that are having a powerful effect on attitudes about the natural environment in a country struggling with the need for development while trying to preserve its natural heritage (Kleiman & Rylands, 2002). The golden lion tamarin is the symbol for conservation of the Atlantic Forest and, indeed, for this entire country. It has been the theme of special stamp issues and the focus of considerable national media attention. Recently, the golden lion tamarin was chosen by Brazil’s Central Bank to adorn the R$20 currency bill (AMLD, 2012).

The education and outreach programs for the golden lion tamarin can take full credit for the popularity of these animals in Brazil; the creative use of the media to bring the conservation message to the public has been the major factor driving the engine of public opinion (Kleiman & Rylands, 2002). Twenty years ago, the Brazilian public neither knew nor cared about these unique primates, nor for that matter about most environmental issues (Dietz & Nagagata, 1994). Today, there is hardly any Brazilian with access to TV, radio, and print media who is ignorant of the golden lion tamarins, and most understand and are proud that these species are unique and special to Brazil (Kleiman & Rylands, 2002). In addition, more than 83 educators have been trained and are developing conservation actions with local schools and communities to save the Atlantic Forest of Brazil. Furthermore, the golden lion tamarin education program has become a classic example of adaptive management at work: strategies have changed as (1) the threats have changed and (2) research results have provided data suggesting improved methodologies for reaching different target groups (Kleiman & Rylands, 2002).

The GLTCP is now using the knowledge obtained and the database created over 25 years to manage the wild populations as a metapopulation (Holst et al., 2006). The metapopulation management includes establishing connectivity among isolated populations through forest corridors and translocations, and will require new techniques; for example, where, when and how animals should be moved so as to optimize the impact on demography, gene flow and spatial distribution over the landscape (Ruiz-Miranda et al., 2010). The map of the current distribution of the golden lion tamarin is a shocking reminder of how much of the Atlantic Forest, one of the world’s richest in endemism and biodiversity, has been lost (Kleiman & Rylands, 2002). The metapopulation management program, which approximates the management of endangered species in captivity, is the only way survival of both lion tamarins and their habitats can be ensured in the foreseeable future. The ultimate goal must be to re-create continuous forest to maintain golden lion tamarin populations of sufficient size and genetic diversity to permit the continuation of natural evolutionary processes (Kleiman & Rylands, 2002). What we humans have done in the name of development, we now need to undo in the name of a sustainable future for our descendants.

As can be concluded from the above sections, the Golden Lion Tamarin Conservation Program has been very successful in the conservation of the golden lion tamarin. But how successful is the conservation program looking at its original mission: using the golden lion tamarin as a flagship species to protect the biodiversity of the Atlantic Forest? As a result of the conservation program, approximately 15,000 ha of Atlantic Forest habitat is now protected. Unfortunately, no data could be found regarding the number of species that live in this protected habitat. It seems like all the attention is focused on the effect of the conservation program on the number of golden lion tamarins, but the most important part, the original mission, is nowhere to be found in discussions concerning the GLTCP. My recommendation would therefore be to look into more detail to the forest remnants that have been preserved by the conservation program, in order to make conclusions on the amount and composition of Atlantic Forest biodiversity that is being protected. However, the Golden Lion Tamarin did contribute to biodiversity conservation of the Atlantic Forest in another way: it functioned as a great model for other conservation projects. The reintroduction and translocation techniques developed by the GLTCP are now being implemented in the conservation activities for the other lion tamarin species as well.
7. References

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