Identifying and Prioritizing Forest Patches Key for the Survival of the Golden-Headed Lion Tamarin (Leontopithecus chrysomelas)

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IDENTIFYING AND PRIORITIZING FOREST PATCHES KEY FOR THE SURVIVAL OF THE GOLDEN-HEADED LION TAMARIN (*LEONTOPITHECUS CHRYSOMELAS*)

Sara L. Zeigler

Introduction

Through habitat loss and fragmentation, species often experience a loss in space and resources with associated changes to metapopulation dynamics and gene flow as continuous habitat is divided into small, isolated patches. The result is a decrease in survival and reproduction, ultimately reducing population abundance, range extent, and genetic diversity (reviewed in Fahrig, 2003) and leaving the species vulnerable to extinction through demographic and environmental stochasticity, genetic drift, inbreeding depression, and Alleé effects (Fischer & Lindenmayer, 2007).

Brazil's Atlantic Forest provides a prime example of how habitat loss and fragmentation can threaten native species. It is one of the world's most endangered biomes and provides habitat for a disproportionate number of species, many of which are endemic (Myers et al., 2000). Only 11.73% of the original vegetation in the Atlantic Forest remains, the majority of which is found in small fragments (< 50 ha; Ribeiro et al., 2009). Deforestation has been attributed primarily to clear cutting for timber harvest, charcoal production, cattle ranching, and monoculture plantations (Morellato & Haddad, 2000; Pinto & Wey de Brito, 2003) and has been linked to widespread extinctions and population declines for a variety of species (e.g. Chiarello, 1999; Pardini et al., 2005; Uezu et al., 2005). One species affected by the loss and fragmentation of the Atlantic Forest is the endangered golden-headed lion tamarin (GHLT; *Leontopithecus chrysomelas*), an arboreal primate endemic to a small region of southern Bahia, Brazil (Figure 1). GHLTs preferentially use lowland primary forest, secondary/regenerating forest, and shade-cocoa agroforest (Oliveira, 2010; Pinto and Rylands, 1997; Raboy and Dietz, 2004) as habitat. A survey conducted between 1991 and 1993 provides the most recent published population estimate at over 6,000 individuals covering an area of 19,462 km^2 (Pinto and Rylands, 1997). However, recent surveys suggest that the population has declined and that the total range has been reduced by 15% over the last 13 years (Raboy et al., 2010; Raboy, unpublished data).

Persistence of the GHLTs primary habitat types is uncertain. The majority of native vegetation throughout Brazil is found on private land where pressure for agricultural expansion is highest (Ferreira et al., 2012; Sparovek et al., 2010). Between 1987 and 2007, 13% of forest cover was lost within the GHLT range (Zeigler et al., 2010), and recent changes to Brazilian forestry laws are likely to increase deforestation rates country-wide by reducing levels of enforced protection of certain areas of existing forest (Calmon et al., 2011). In addition, since the early 1990's, the price of cocoa has fallen dramatically and fungal epidemics put entire plantations at risk. Thus, it is becoming increasingly more profitable for farmers to clear cut their land for timber extraction (Alger and Caldas, 1994) or for conversion to other agricultural systems like cattle ranching or management-intensive monoculture plantations that do not provide habitat for endangered species (Cassano et al., 2009; Schroth and Harvey, 2007).

Given the uncertain future of remaining habitat for GHLTs, determining which habitat patches are most valuable for GHLT populations is a conservation priority. Such knowledge is especially critical for the proactive protection of existing habitat and populations, preventing the severe population declines and limited opportunities for recovery associated with other Atlantic Forest species (e.g. Kierulff et al., 2008a; Kierulff et al., 2008b, c). The objective of this paper is to synthesize recent, published results of range-wide landscape analyses of GHLT habitat to prioritize habitat for further study and protection.

Methods

Between 2010 and 2011, three major studies were published that analyzed the spatial distribution of GHLTs and their habitat over time. Zeigler et al., (2010) created a binary forest/non-forest map of the species' range using supervised classification of Landsat 5TM remotely sensed imagery taken from 2004-2008 (the '2007 forest map'). They determined that only 5% of forest patches were greater than 36ha, the smallest recorded territory size for a group of GHLTs in primary and degraded habitat (Rylands, 1989). The authors also used the population viability analysis (PVA) program Vortex (Lacy, 2000) to calculate the minimum required area of habitat required for viable populations of GHLTs that were of sufficient size to be able to recover from threats such as disease epidemics and fire. They then located patches meeting those size requirements on the 2007 map. They found that 22 patches could support a viable population of GHLTs over 100 years (98% probability) under a baseline scenario (i.e. no additional threats), although this number decreased to 20, 9, and 6 habitat patches when they included the additional threats of disease, fire, and disease with fire, respectively. Only two patches were large enough to support a viable population that could also retain 98% of its genetic heterozygosity under the baseline, disease, and fire scenarios, and only one patch could support such a population under the disease with fire scenario.

In the second study, Zeigler et al. (2011) used a graph theoretical approach and the 2007 forest map (Zeigler et al. 2010) to determine patterns of habitat connectivity throughout the GHLT range. Assuming that the average GHLT would travel a maximum of 100m in non-forest matrix (J. Mickelberg, unpublished data), 95% of all

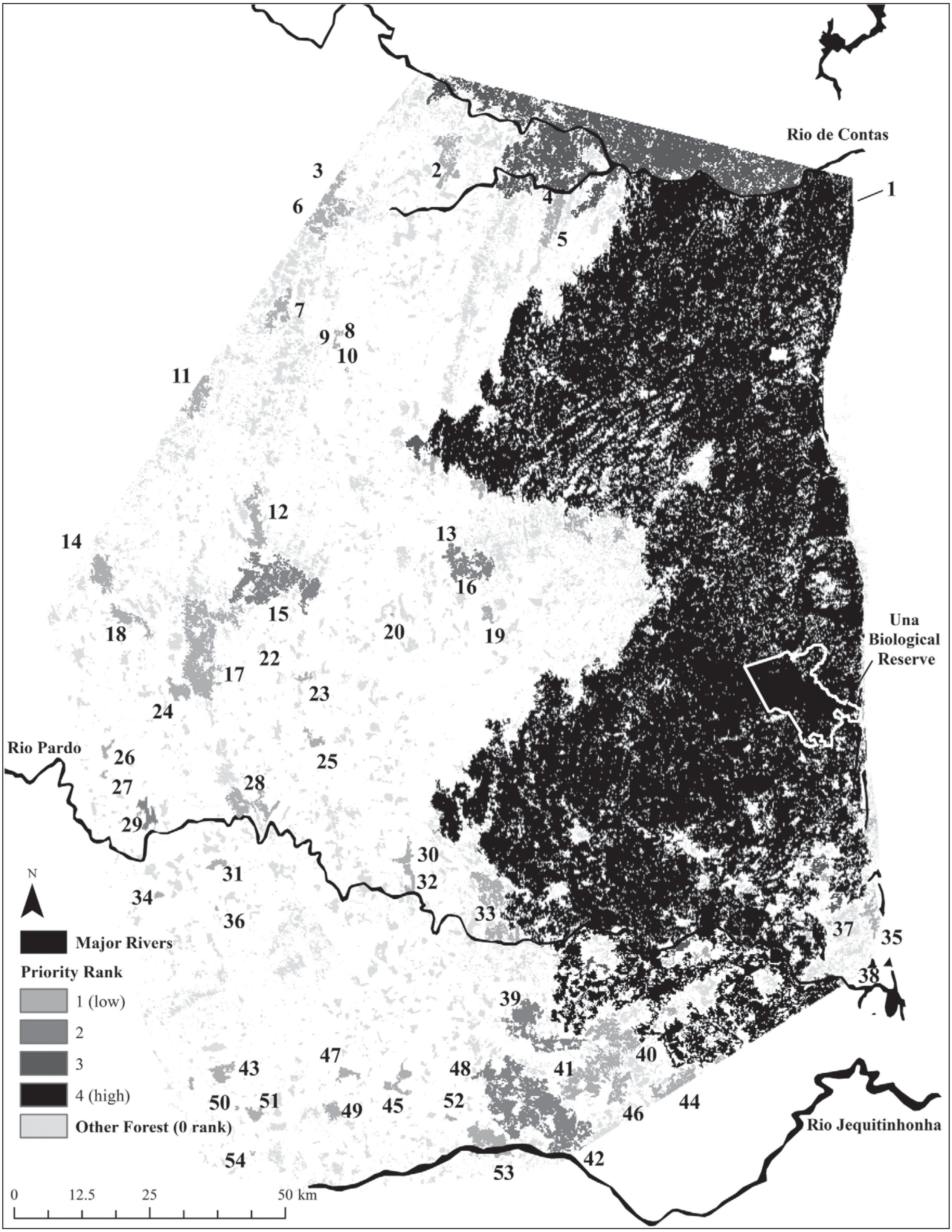

Figure 1. Priority forest patches for the conservation of golden-headed lion tamarins. Each patch was given a point if it was large enough to sustain a minimum viable population, large enough to support a genetically viable population, important for promoting functional landscape connectivity, or occupied based on positive survey results (Raboy et al., 2010). Patches meeting all of these requirements (patch ranking = 4; shown in black) may be disproportionately important for GHLTs and should be prioritized for further research and protection. All patches with at least one point (displayed in darker shades of gray) are designated with a number that corresponds to Table 1, where additional information about each patch is given (some patches are too small to be visible at this resolution).

Table 1. Priority forest patches for the conservation of golden-headed lion tamarins (GHLTs). Each patch was given a point if it was large enough to sustain a minimum viable population, large enough to support a genetically viable population, important for promoting functional landscape connectivity, or occupied based on positive survey results (Raboy et al., 2010). Descriptions of patches meeting at least one of these criteria are listed here (Rank = 1-4), and patches meeting all criteria (Rank = 4) may be especially important for protection and research in the future. See Figure 1 for the locations of these priority forest patches.

Patch Number	Patch Area (ha)	Occupied by GHLTS?*[a]	Genetically Viable Population?*[b]	Viable Population?*[c]	Forest Connectivity?*[d]	Total Rank
1	741973.30	1	1	1	1	4
2	1929.87	0	0	1	0	1
3	1555.83	0	0	1	0	1
4	4.50	1	0	0	0	1
5	1731.06	0	0	1	0	1
6	1467.54	0	0	1	0	1
7	1347.39	0	0	1	0	1
8	109.71	0	0	0	1	1
9	7.92	0	0	0	1	1
10	126.18	0	0	0	1	1
11	1492.02	0	0	1	0	1
12	1985.49	0	0	1	0	1
13	3054.60	1	0	1	0	2
14	1809.45	0	0	1	0	1
15	7149.96	1	0	1	0	2
16	4.50	1	0	0	0	1
17	8004.69	0	0	1	0	1
18	1140.03	0	0	1	0	1
19	432.99	1	0	0	0	1
20	35.64	1	0	0	0	1
21	1.80	1	0	0	0	1
22	9.72	1	0	0	0	1
23	243.72	1	0	0	0	1
24	956.97	1	0	0	0	1
25	477.99	1	0	0	0	1
26	231.84	0	0	0	1	1
27	85.68	0	0	0	1	1
28	2080.71	0	0	1	0	1
29	896.31	1	0	0	1	2
30	532.89	1	0	0	0	1
31	393.75	1	0	0	0	1
32	702.99	0	0	0	1	1
33	2026.44	0	0	1	0	1
34	160.65	0	0	0	1	1
35	806.58	1	0	0	0	1
36	44.55	0	0	0	1	1
37	59.76	1	0	0	0	1
38	4.41	1	0	0	0	1
39	4006.98	1	0	1	0	2
40	2662.92	0	0	1	0	1

Patch Number	Patch Area (ha)	Occupied by GHLTS?*[a]	Genetically Viable Population?*[b]	Viable Population?*[c]	Forest Connectivity?*[d]	Total Rank
41	4003.65	0	0	1	0	1
42	13734.72	0	1	1	0	2
43	928.44	0	0	0	1	1
44	1531.08	0	0	1	0	1
45	924.03	1	0	0	0	1
46	1189.35	0	0	1	0	1
47	501.21	0	0	0	1	1
48	21.60	0	0	0	1	1
49	720.18	0	0	0	1	1
50	53.73	0	0	0	1	1
51	497.70	0	0	0	1	1
52	134.28	1	0	0	0	1
53	2621.97	0	0	1	0	1
54	37.44	0	0	0	1	1

[*] In these columns, "1" denotes that the patch met this requirement, and "0" denotes that it did not.
[a] Researchers found evidence of GHLTs in these patches during surveys of the landscape (Raboy et al. 2010).
[b] Patches meeting this requirement are large enough to support a population of GHLTs that has at least a 98% probability of surviving for 100 years and is able to maintain at least 98% of its original genetic heterozygosity (Zeigler et al. 2010).
[c] Patches meeting this requirement are large enough to support a population of GHLTs that has at least a 98% probability of surviving for 100 years under baseline conditions (i.e. no added threats from disease, fire, etc; Zeigler et al. 2010).
[d] Patches meeting this requirement were found to be disproportionately more important for maintaining functional habitat connectivity throughout the landscape (Zeigler et al 2011, Zeigler et al unpublished data).

habitat patches had no neighboring patches within this distance, and the median component size (i.e. forested area of a group of patches less than 100m apart) was 80ha. In general, they determined that habitat connectivity for this species was low and that 15 habitat patches were disproportionately important for maintaining habitat connectivity in the landscape (Zeigler, unpublished data). Finally, Raboy et al. (2010) conducted a range-wide survey to establish the location of possible GHLT populations using play-back studies and interviews with local people. By overlaying positive points that established the presence of GHLTs from this survey with the 2007 forest map, it was determined that 21 patches in the landscape were probably occupied by GHLTs (Zeigler et al., 2010).

Using the results of these three studies, I calculated a simple ranking scheme to prioritize forest patches throughout the range of the species. I created four separate geographical information system (GIS) layers in the program ArcGIS ver. 9.3 (ESRI). In the first layer, I gave each forest patch a point if it was large enough to support a minimum viable population under baseline conditions according to Zeigler et al. (2010; 22 patches). In the second layer, I gave forest patches a point if they were large enough to support a genetically viable population under baseline conditions, also according to Zeigler et al. (2010; 2 patches). The third layer contained forest patches, all given a point, if they were considered important for maintaining functional connectivity based on the results of Zeigler et al. (2011; 15 patches). Finally, I gave forest patches a point in the fourth layer if they were known to be occupied based on positive survey results according to Raboy et al. (2010; 21 patches). I then added the four GIS layers together in the raster calculator in ArcGIS to produce a single map in which forest patches could have a value ranging from zero (not meeting any of the above conditions) to four (meeting all of the above conditions).

Results

Within the GHLT historical distribution, only one forest patch had a ranking of '4' while 5 and 48 patches had rankings of '2' and '1', respectively (Table 1; Figure 1). All other remaining forest patches were too small to support viable or genetically viable populations of GHLTs, were not important for maintaining connectivity between patches, and were not occupied by GHLTs according to recent surveys.

Discussion

The ranking scheme described here offers a simple first step for prioritizing habitat patches for the conservation of GHLTs. An ideal next step would be to conduct additional surveys on forest patches highlighted here to understand land ownership, likely plans for substantial changes to forest patches by landowners, habitat quality, and the size and condition of any GHLT groups on these patches. They can then be further prioritized, based on the best available science, for protection or as reintroduction sites.

As described in the Introduction, habitat throughout the GHLT range is vulnerable to deforestation for a variety of reasons. Ultimately, the survival of GHLTs and other Atlantic Forest species will depend on the creation of federally mandated protected areas, the promotion of private reserves, and the implementation of positive incentives for farmers to continue biodiversity-friendly agroforestry practices (reviews in Alger and Caldas, 1994; Cassano et al., 2009; Langholz and Lassoie, 2001; Rambaldi et al., 2005; Tabarelli et al., 2005). In addition, it will be critical to protect forested areas throughout the species' range in an effort to preserve redundant populations and the species' full complement of genetic variability. Currently, protected areas within the GHLT range are exclusively found in the eastern half of the region (Schroth et al., 2011) despite the fact that deforestation has historically been heaviest in the west (Zeigler et al., 2010). Further research and protection of western forest patches highlighted here may be especially pertinent.

Forest patches of high quality that meet one or more of the four criteria could also be prioritized as potential reintroduction sites for captive-bred GHLT populations. A large and well-managed captive breeding program currently exists for GHLTs (Ballou et al., 2002), yet these populations have rarely contributed to wild populations. Reintroductions of captive golden lion tamarins (*Leontopithecus rosalia*) have significantly improved the status of the wild population, contributing to the species' nearly unprecedented downlisting from Critically Endangered to Endangered in recent years (Ballou et al., 2002; Kierulff et al., 2008a). A similar program for GHLTs, where captive individuals are reintroduced into ranked forest patches highlighted in Figure 1 (particularly in the western portion of the species' range), could also provide substantial conservation benefits for this species.

Finally, only one forest patch (area: 741973 ha), which contains Una Biological Reserve (Figure 1), meets all four criteria in my ranking scheme (Table 1) and, therefore, may be especially important for the long-term survival of GHLTs. Although I do not advocate strict protection of this entire forest patch, efforts to minimize its fragmentation are critical. This patch was primarily composed of shade-cocoa agroforests as of 1995 (Landau et al., 2003) and is vulnerable to forest loss and fragmentation as small yields, low cocoa prices, and fungal epidemics make landcover conversion more profitable (Alger and Caldas, 1994; Cassano et al., 2009; Schroth and Harvey, 2007). Government subsidies, price premiums for "shade" or "fair-trade" cocoa production, and other incentives for maintaining biodiversity-friendly cshade-cocoa/forest mosaics over cattle pastures and management intensive monoculture plantations will be critical for the persistence of GHLTs (and other Atlantic Forest species) and should be encouraged (Cassano et al., 2009; Schroth et al., 2011). Such mechanisms would allow farmers to be profitable while supporting biodiversity conservation.

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