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Does the golden lion tamarin, *Leontopithecus rosalia* (Primates: Callitrichidae), select a location whithin the forest strata for long distance communication?

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ABSTRACT. The effectiveness of auditory signals for long distance communication depends on environmental, biological and behavioral factors. Because the environment is not homogenous, it is expected that vocalizing animals would emit signals from locations (perches) that would facilitate call propagation and perception. Perching behavior has been widely documented in birds, but not in primates. The aim of this study was to ascertain whether golden lion tamarins – *Leontopithecus rosalia* (Linnaeus, 1766) – emit long calls from places (perch) within the forest strata that are higher above the ground with respect to places used for baseline behaviors. We compared the forest stratum (upper, middle and lower strata) and habitat type (hill, swamp and lowland forests) used for long calls with those used for other behaviors. The focal animal technique (n = 4) of 10 minutes with instantaneous sampling at two minutes were used if the subjects were not emitting long calls, and the all-occurrences technique if a focal individual emitted a two-phrase long call. Golden lion tamarins used all strata in all habitat types, including the ground, when they were not emitting long calls, but vocalized long calls most often from the upper strata, just underneath the canopy, in the three habitats studied. From a total of 29 bouts of long calls, 21 were initiated by individuals that were in the lower stratum; however, these individuals subsequently migrated to the upper stratum, while still vocalizing. Calling from the upper strata of the forest, just underneath canopy could improve sound transmission, perception, visual contact or a combination of these types of communication. Based on these considerations, we hypothetize that by placing themselves in the upper strata of the forest when emitting calls, golden lion tamarins enhance their likelihood to locate other callers, not only be improving sound reception, but also by increasing their chances to make visual contact with them.

KEY WORDS. Bioacoustics; communication; perching.

Studies of birds and primates have shown that long distance communication depends on the acoustic structure of the vocalization, the sound propagation properties of the environment and on aspects of the biology and behavior of the species such as auditory perception and call repetition rate (Richards & Wiley 1980, Morton 1982, 1986, Endler 1992, Embleton 1996, Bradbury & Vehrencamp 1998). The acoustical properties of the environment are not homogenous and vary according to vegetation type, height from the ground and distance to the canopy. One question is whether vocalizing animals are cognizant of differences in habitat structure and whether they emit signals from locations that would facilitate call propagation or perception.

Studies with birds show that the position of the animal within the habitat influences sound transmission and perception. By "perching" on higher branches and by positioning themselves between the undergrowth and the dense canopy, forest birds can improve their perception of bird songs and the distance their own songs travel through the environment (Dabelsteen *et al.* 1993, Holland *et al.* 1998). Studies on New and Old World primates show that the acoustic structure of the long distance calls of some species allows sound transmission without degradation over long distances relative to the size of their territory (Waser & Waser 1977, Mitani 1985, Waser & Brown 1986, Whitehead 1995). These larger primate species emit calls that are loud and composed of low frequencies (<1 kHz). Calling individuals may further improve signal transmission by calling from locations high within the forest strata. The behavior of perching to call (i.e., emitting calls from selected higher strata) has not been assessed in the smaller, New World monkeys. These species emit high frequency calls (5-12 kHz) that are likely to degrade quickly within a forest environment. For this reason, in order to emit successful, long distance calls, these small primates would need to vocalize from a location within the environment that is optimal for sound propagation.

The aim of this study was to ascertain whether golden lion tamarins show perching behavior while emitting long calls. Golden lion tamarins, *Leontopithecus rosalia* (Linnaeus, 1766), emit two-phrase long calls for long distance communication

within and between social groups (Kleiman *et al*. 1988, Ruiz-Miranda & Kleiman 2002). Similar to other callitrichids, golden lion tamarins engage in antiphonal calling within and between groups (Ghazanfar *et al*. 2001). The calls contain biologically relevant information on group identity and the sex of the caller (Ruiz-Miranda & Kleiman 2002). The two-phrase long calls have an average total duration of 5 seconds and consist of two phrases arranged in two sequences of syllables of ascending frequencies (c.a. of 4 to 12 kHz) (Halloy & Kleiman 1994). These calls degrade quickly within the Atlantic Forest lowland habitat (Sabatini & Ruiz-Miranda 2008): at 80 m from the source, the first phrase is highly degraded and the second phrase is completely degraded. An experiment using play-backs of natural long calls showed that calls emitted from different heights show differences in total attenuation of the long call at 80 m from the source, the main effect of height on sound degradation being on the syllables of the second phrase. The latter corresponds to the highest frequencies and is also were information on sex and group differences is contained (Sabatini & Ruiz-Miranda 2008). These findings suggested that it would be advantageous for golden lion tamarins to consider their position within the forest strata while emitting vocalizations.

MATERIAL AND METHODS

The study was conducted at the União Biological Reserve (UBR), a fragment of the Atlantic Forest situated in the northeast (22°27'S, 42°02'W) of the State of Rio de Janeiro, Brazil. The climate is subtropical with a wet season (September to March) and a dry season (April to August). The UBR is a 31.26 km^2 area of composed of a mix of well preserved and strongly impacted secondary and mature evergreen forests (23.68 km^2). Even though there are no primary forest formations in the area (including lowlands and hills) due to logging activities in the past, most of the remaining forest is well-preserved. The forest ranges from 50 to 376 m above sea level (Sema 2001).and includes swamps, hills and lowland habitats (Procópio de Oliveira *et al*. 2008), all of which are occupied by the Golden lion tamarins (Kierulff *et al*. 2002). The UBR is situated within the original distribution range of the golden lion tamarin (Coimbra Filho 1969), but its original population is extinct. The present population was introduced in the reserve in 1994, when six groups from small forest fragments in Rio de Janeiro were relocated to the UBR. During the present study, the local population consisted of approximately 150 individuals.

Breeding pairs were studied in two social groups: the 'Funil' group (August 2001) and the 'Saquarema' group (January 2002). The total observation time was 48 hours (7 days) for the first group (60.6% of the total observations) and 42 hours (11 days) for the second group, resulting in 2,057 total behavioral records obtained from 6.45 a.m. to 1.00 p.m. The Funil group consisted of a breeding pair, an adult male and a sub adult offspring female. The Saquarema group consisted of a breeding pair, an adult male, three sub adult offspring males, an adult offspring female, and two newborn siblings. The groups were found by radio telemetry and identified by a dye mark on the body of each individual.

Whether golden lion tamarins show "perching" behavior for long distance communication was assessed by comparing their height within the forest strata when emitting long calls with their height during other behaviors. We herein define perching behavior as the use of a location (perch) within the forest strata that is higher than that used for other behaviors. The focal subjects of the Funil group were FT13 (male) and FT4 (female), and from the Saquarema group were ST3 (male) and ST2 (female). Baseline behavioral data were collected using a focal animal technique (n = 4) of 10 minutes with instantaneous sampling at two minutes. When the focal individual emitted the two-phrase long call (LC), the behavior was sampled with an all-occurrences technique. The following variables were recorded: 1) height above the ground, in meters, 2) location within the forest stratum (upper, middle, lower strata), and 3) habitat type (hill, swamp and lowland forests, explained below). These variables were recorded when the focal animal was emitting long calls (both during and outside encounters with other groups) or engaged in other behaviors in which long calls were not emitted (i.e. foraging, resting, eating, grooming and locomotion). The reliability of the measurements of the height above ground (meters) and the forest stratum used by focal animals were estimated by previously training the two observers and by corroborating the principal observer's assessment – Sabatini V. – during the observations. The habitat types of the home ranges of the studied groups were defined as follows: 1) lowland habitat, a mature and secondary well-preserved forest, seasonally flooded in some areas, with an average canopy height of 10 m and emergent trees reaching 27 m; 2) hill habitat, mature and secondary well-preserved vegetation occurring in elevations up to 140 m, with an average canopy height of 10 m with the emergent trees reaching 25 m; and 3) swamp habitat, a continuous or seasonally flooded habitat with denser understory than the other two habitats and main canopy from 5 to 7 m with the emergent trees reaching 15 m.

The height, in meters, was an unreliable measure for comparisons across habitats or contexts, for three reasons: first, canopy height varied among the three habitats; second, the amount of time groups spent in each habitat was different each day; third, foraging for fruits occurred at and above the canopy on emergent trees. Even though we provide the average heights measured, we only used the location within the forest strata in our analyses.

The Chi-square test was used to test the null hypothesis that focal subjects did not show preference for a specific stratum to emit the long calls. Each subject was analyzed by means of a 2x3 contingency table to test the frequencies of the stratum used (upper, middle or lower), when they were emitting or not long calls. All statistics were calculated using Statistica software, version 6.0.

RESULTS

In all three types of habitat studied, the focal subjects emitted long calls most often from the upper stratum, which was seldom used for other behaviors (Fig. 1; Tab. I). There was a significant association between calling behavior and forest strata for each individual: T13 ($\chi^2 = 45.95$, $p < 0.0001$), T4 ($\chi^2 = 19.45$, $p < 0.0001$), T3 ($\chi^2 = 37.08$, $p < 0.0001$), T2 ($\chi^2 = 34.46$, $p < 0.0001$).

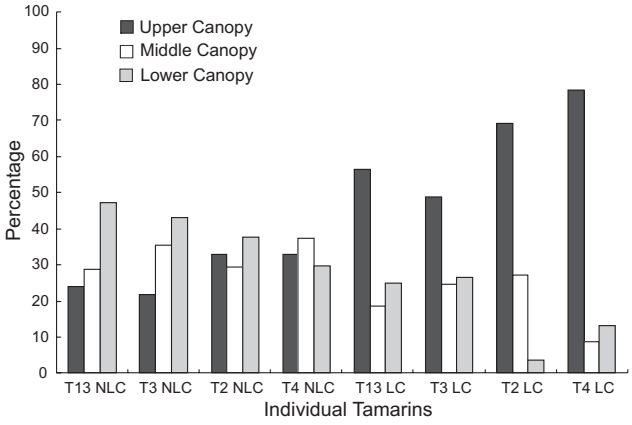

Figure 1. Mean percentage utilization of forest strata (upper, middle or lower stratum) by the reproductive pair (males: FT13, ST3; females: ST2, FT4) of two groups (Funil-F and Saquarema-S) of golden lion tamarins (*Leontopithecus rosalia*) when they were emitting (LC) or not emitting long calls (NLC).

Table I. Average height from the ground (in meters) location of golden lion tamarins when emitting long calls and during baseline behavior (not calling) for each habitat type within the União Biological Reserve. Low-high values are shown in parentheses.

Habitat type	Calling	Baseline
Swamp	5.1 (1.7-11)	4.1 (0-12)
Hill	9.1 (3-20)	9.1 (0-22)
Lowland forest	10.1 (4-20)	6.5 (0-22)

We also analyzed whether the preferred stratum differed for long calls emitted in two different situations: spontaneously (to advertise presence) or during territorial group encounters. A Chi-square analysis of the association of long calls emitted in and out of group encounters and forest strata was not significant ($\chi^2 = 1.46$; df = 2; $p = 0.48$). Despite this non-significant difference, 61% of the long calls emitted from the lower stratum were not in group encounters and 39% were during encounters (upper or middle strata = 47% encounter, 53% non-encounter). In 21 of a total of 29 bouts of long calls emitted from the lower stratum, the subjects subsequently climbed up to the upper stratum and continued to vocalize from the upper stratum.

DISCUSSION

The preference to emit long calls from higher branches, a behavior akin to the "perching" behavior of singing birds, was evident from the analysis of height by categories of forest strata. Males and females preferred to emit long calls from the upper stratum of the forest, near the main canopy, but not necessarily above it. Therefore, we rejected the null hypothesis that golden lion tamarins have no preference to use a stratum to emit the long calls.

The golden lion tamarins studied here used all strata in all habitat types, including the ground, when they were not emitting long calls, but vocalized long calls most often from the upper strata, just below the canopy, in the three habitats studied. Calling from the upper strata of the forest just underneath the canopy could improve sound transmission, sound perception, visual contact, or a combination of these types of communication. Sound transmitted from high locations above the forest ground shows improved propagation (Waser & Waser 1977, Dabelsteen *et al.* 1993, Holland *et al.* 1998). Marten *et al.* (1977) argued that heights between 1 m above ground up to 1 m below the canopy are the best for sound transmission in tropical forests, because both transmission through the canopy or near the ground increased signal attenuation. Above the canopy, sound can degrade rapidly by wind turbulence and refraction when temperature above the canopy is higher than the temperature underneath of it (Embleton 1996, Bradbury & Vehrencamp 1998). In temperate forests, the position of the caller relative to the dense canopy has been demonstrated to be more important than the height itself (Mathevon *et al.* 1996, Blumenrath & Dabelsteen 2004). Birds in temperate forest zones sing from perches that are higher than those used for other behaviors. In tropical forests, however, many species sing from the same height where they forage (Morton 1996, Mathevon & Aubin 1997).

Our studies of two-phrase long call propagation at the UBR forests indicate that perching may benefit ranging of calls rather than improving transmission (sensu the ranging hypothesis, Morton 1986). This hypothesis may explain why the long calls were also sometimes emitted from the lowest stratum of the forest. Golden lion tamarin long calls have frequencies between 4.0 and 12.00 kHz (Halloy & Kleiman 1994, Ruiz-Miranda & Kleiman 2002), and degrade rapidly within the lowland forest, especially the second phrase of the call (Sabatini & Ruiz-Miranda 2008). The second phrase of the call contains information related to population and sex (Benz *et al.* 1990, Ruiz-Miranda & Kleiman 2002). A study on the transmission of synthesized long calls in the lowland habitat of the UBR (Sabatini & Ruiz-Miranda, unpub. data) showed that the degradation of synthesized syllables was significantly higher at 7.5 m (between the middle and upper canopy) than at 2 m above ground. The increase in

sound degradation over distance at this height (7.5 m) may provide ranging cues to receivers in the middle and the upper canopy. By contrast, when golden lion tamarins are foraging or moving within the low stratum, the detection and perception of the information content of the two-phrase long calls would be improved, because the sound propagation at this height (2 m above ground) degraded less than at the middle canopy.

Golden lion tamarins may also move to a high perch to vocalize long calls in order to improve visual communication. When individuals from different social groups were on visual encounters near their common territory borders, golden lion tamarins usually moved upward (toward the canopy) during long call emissions, while increasing the rate of calling as they approached their rivals. Since vision is a primary sensory modality in primates, staying in the upper strata may improve an individual's ability to see and to be seen by others, facilitating the visual recognition of neighboring groups in the dense lowland subtropical forest. Based on these considerations, we hypothetize that, by placing themselves in the upper strata of the forest when emitting calls, golden lion tamarins are better able to locate other callers, not only by improving sound ranging, but also by increasing their chances to make visual contact with them. More studies are necessary to confirm the golden lion tamarin's ability to range calls and to modify call structure or behavior to improve long call propagation.

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