

Vocalizations as a conservation tool: an auditory survey of the Andean titi monkey *Callicebus oenanthe* Thomas, 1924 (Mammalia: Primates: Pitheciidae) at Tarangue, Northern Peru

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Abstract

Titi monkeys (*Callicebus*), morphologically cryptic primates, have been difficult to survey using traditional sighting-based line transect methods. *Callicebus*-species regularly engage in loud, ritualized singing bouts, which could allow for the use of alternate, potentially more accurate call-based survey methods to monitor populations. The Andean titi monkey, *C. oenanthe*, is endemic to a small region of northern Peru, an area subject to widespread and rapid deforestation and human colonization. We conducted a call-based survey of *C. oenanthe* at Tarangue, a 74 ha private reserve near Moyobamba. Triangulation of calls was used to map groups of titi monkeys on and around the reserve. 73 mapped calls were used to estimate the presence of between three and six groups per listening area - a total of 23 groups entirely or partially within the borders of Tarangue, yielding an estimated population density of 1.41 individuals per ha. Observations were much greater than those resulting from a visually-based survey conducted at Tarangue three years earlier. These higher estimates are probably not only due to this more suitable survey method; incessant destruction of habitat occurring in the area surrounding Tarangue may have caused the reserve to become a refuge for displaced individuals, with diminished opportunities for dispersal and establishment of new territories. Immediate measures to prevent further fragmentation within the Andean titi monkey's geographic range are essential in order to allow the species to persist. We recommend the use of triangulation of calls for future surveys of titi monkeys.

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Introduction

Point counts, strip and line transect methods are commonly used to estimate densities of mammal populations (Brockelman and Srikosamatara, 1993; Greenwood, 1996). For visually cryptic species, many of which have special conservation needs (e.g. Nekaris and Jaffe, 2007), the assumptions associated with such methods may be problematic (Duckworth, 1998; McDonald, 2004; Nekaris *et al.*, 2008), partially because most encounters may be auditory only (Davies, 2002). For visually cryptic and/or vocal species, auditory survey methods may be more useful than visual methods - particularly for those species which tend to vocalise consistently at specific times of day or in predictable circumstances. Traditionally used for birds (e.g. European bitterns, Gilbert *et al.*, 1994; corncrakes, Peake and McGregor, 2001), such methods are becoming more common for primates, including Dian's tarsiers (Merker *et al.*, 2005), howler monkeys (Estrada *et al.*, 2002; Estrada *et al.*, 2003), and gibbons (Brockelman and Srikosamatara, 1993; Tallents *et al.*, 2001; Buckley *et al.*, 2006; Geissmann and Nijman, 2006).

Titi monkeys (*Callicebus*) are small arboreal primates native to South America. Behaviourally cryptic, they hide when threatened, which may have resulted in low density estimates in previous surveys (Kinzey, 1997; Moynihan, 1976). They do, however, engage in daily ritualized bouts of song that probably function to define and reinforce strict territorial boundaries (Kinzey, 1981; Robinson, 1981; Kinzey and Robinson, 1983; Robinson *et al.*, 1987). This high audibility could be used to survey populations that are difficult to locate visually (c.f. Dallmann and Geissmann, 2001).

The Andean titi monkey *C. oenanthe* Thomas, 1924, is classified as Vulnerable, although extreme habitat loss in its restricted range suggests it is better classified as Critically Endangered (Mark, 2003; Rowe and

Martinez, 2003; Rylands, 2003; deLuycker, 2006). The known range of *C. oenanthe* appears to be based entirely upon six specimens collected in three locations (Aquino and Encarnacion, 1994, van Roosmalen *et al.*, 2002). It is limited to the upper Rio Mayo valley in northern Peru, between 750 and 950 m (van Roosmalen *et al.*, 2002). Researchers currently in the field may have found that the Andean titi monkey's range is larger than had been previously recognized (Bóveda Penalba, pers. comm.).

In two previous visual-based surveys at several sites within their range, *C. oenanthe* was either only detected auditorily (Rowe and Martinez, 2003), or was heard more frequently than seen (Mark, 2003). The only other study of this species was on the behaviour and ecology of a single group in an isolated forest fragment (deLuycker, 2006). Rowe and Martinez, Mark and deLuycker all mention the urgent need for further survey work and conservation action.

We conducted a survey of *C. oenanthe* at a private reserve near Moyobamba in northern Peru. Vocalizations were used to estimate the number of groups present at the study site. We discuss the advantages of using this survey method, and the implications of our results for this population of Andean titi monkeys. We reiterate the urgent need for conservation action in the Alto Mayo region.

Methods

Study site

Data were collected between May and August, 2006 at Tarangue (southernmost point: 5°58'54.4"S 76°59'37.6"W), a reserve owned and protected by Peruvian/French conservation organization Ikamaperou. Located 8 km NNE of the city of Moyobamba, Tarangue ranges in elevation from 800-850 m asl. Approximately 20% of Tarangue's 74 ha is cleared of forest. The remaining area consists of secondary growth in various successional stages, ranging from tall, 'old' secondary forest (> 50 years old, in places incorporating remnants of primary growth) to *shambupale* (unproductive, fern-covered areas), and includes a large, seasonally-flooded stand of *caña brava* (*Gynerium* spp.) and scattered remnant plantations of cacao and citrus trees. Apart from one isolated 1.5 ha fragment, the forested area at Tarangue is continuous. Crop fields and pastures surround the reserve, as do several fragments of tall secondary forest. Deforestation

around Tarangue is extensive and continues persistently. During the study period, much of the surrounding area (and part of the reserve itself) was visibly transformed by aggressive and sometimes illegal clearing and burning.

Tarangue is in Peru's Alto Mayo region where the average annual precipitation is between 1500-1700 mm (Börner, 2000, CONDESAN, 2006), with a rainier season from October to March, and a drier season during June to August. The average annual temperature is from 21-23°C (Börner, 2000; CONDESAN, 2006; deLuycker, 2006).

Survey design

Brockelman and Ali's (1987) survey method, in which calling groups are mapped by triangulation, was adapted for use at Tarangue. "Bad weather days" were defined and excluded from the study, although data were experimentally collected on one day of heavy rain. As expected, no calls were heard. Data from this day were not included in the final analysis.

The boundaries of Tarangue were roughly mapped using a Garmin GPSmap 60 unit and blank map grids. The site was divided into five listening areas, determined by the boundaries of the reserve, calculated to cover as much area as possible, while remaining small enough to ensure audibility of all singing groups within that area's boundaries. Each listening area consisted of three named listening points located between 183-305 m apart. Such spacing ensured audibility of all groups within the boundaries created by those points and within at least a 200 m radius of each listening point, as the loud calls of male titi monkeys can be heard up to 500 m away, with a 'critical distance' of about 250 m (Robinson, 1981). Five day sampling periods were allotted for each listening area, which allowed us to derive the percentage of groups expected to sing within a given number of days, based upon known singing frequencies (Brockelman and Ali, 1987):

$$\hat{p}(m) = 1 - [1 - p(1)]^m$$

where p = the proportion of groups expected to sing in (m) days.

Singing frequency was not available for *C. oenanthe* at Tarangue, and practical constraints precluded the collection of this information. We thus conservatively used 66% - the lowest singing frequency published for non-isolated groups of *Callicebus* - to calculate the required sampling period (Kinzey *et al.*, 1977).

Data collection

Listening areas were manned by one researcher per listening point for five days, consecutively where possible. *Callicebus* at Tarangue were never heard to call before 06.30 am. Therefore, data were collected from 06.30 am until 09.30 am or until the last audible group finished calling. At each listening point, location and date were noted and for every audible *Callicebus* call, the following information was logged: time call began and ended; compass bearing to the location from which the call was first and last audible; number of individuals or groups calling at that location; distance to calling individual, group or groups. Whenever sightings occurred, researchers noted group size and age/sex composition. Data on atmospheric variables and anthropogenic disturbance were collected daily.

Data analysis

The geographical coordinates of each triangulated call (defined as those calls heard by two or more researchers simultaneously, whose bearings met when drawn on the map) and sighting were mapped using Garmin MapSource 6.0. Groups were delineated using spatial and temporal data obtained in the field; for example, if two groups were heard singing simultaneously, then it was known that the triangulated points resulting from those calls represented separate groups.

Previous surveys following Brockelman and Ali's methodology have generally been conducted on a much larger spatial scale than the present study (Brockelman and Ali, 1987; Buckley *et al.*, 2006; Geissmann and Nijman, 2006; Tallents *et al.*, 2001). Because this was an intensive survey in a small study area, it was possible to 'cover' the area completely, thus eliminating the need to extrapolate information about density from the sampled area to the whole study area. This meant, however, that audibility of groups from different listening areas overlapped. The delineation of core mapping areas, although resulting in the loss of some data, should have cost only *duplicated* data, as probability of all groups present within each listening area singing at least once had been maximized by the use of five day sampling periods.

Mean group size was calculated based upon all logged sightings in which group size was estimable. Garmin MapSource 6.0 was used to estimate the amount of forested area within each listening area, and population densities were calculated. As the listening areas

were unequal in size, the weighted mean was used to increase accuracy (Greenwood, 1996).

Results

We mapped 132 calls and recorded groups 33 times visually. An estimated 85% of individuals calling were not observed visually. Of the 132 calls, 59 fell outside the boundaries of the listening area under study and were excluded from analysis. Thus 73 mapped calls were used to estimate the presence of between three and six groups per listening area. A total of 23 groups of *C. oenanthe* totally or partially within the borders of Tarangue. Additionally, at least four groups were mapped entirely outside the reserve on neighbouring land to the north-west, and two groups were located in patches of forest beyond pastureland to the south of the reserve. Thus the combined total in the study area was at least 29 groups.

The majority of mapped groups were concentrated in the northern half of the reserve. Only seven mapped groups (30%) called from within 150 m of the river. Discounting the approximately 20% of non-forested area on the reserve, the estimated population density of *C. oenanthe* at Tarangue is 0.38 groups, or 1.40 individuals per ha. Group size could be confidently discerned in 29 of the 33 recorded sightings (Fig. 1), yielding a mean group size of 3.62 (\pm SD 1.91). 62.0% of observed groups contained 2-4 individuals. Four of the observed 'groups' were lone titis, and six of the groups consisted of six or more individuals, with a maximum of eight individuals.

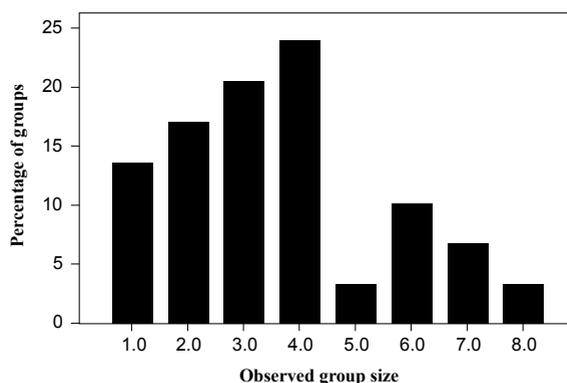


Fig. 1. Number of individuals in groups at Tarangue, showing the prevalence of groups with 3-4 individuals ($n = 33$).

Discussion

Similarities in the behaviour and social organization of gibbons and titi monkeys means that the triangulation survey method, based upon morning vocalizations, is applicable for use with *Callicebus* species with little adaptation necessary (Brockelman and Ali, 1987, Brockelman and Srikosamatar, 1993). The assumptions that this method requires in order to be accurate were not perfectly met in the present study, as singing frequency is not known for *C. oenanthe*. However, we feel that the small size of the study area, combined with information about the behaviour of other closely-related *Callicebus* species, compensated for this lack of information to an acceptable degree. Further, the assumptions that are not met in this study could be met, given a longer study period - while problems meeting the assumptions for visually based survey methods may be more difficult to overcome (Brockelman and Ali, 1987, Karanth et al., 2004). Given that 85% of encounters during the present study were purely auditory, and that it was often impossible to see an animal even when it clearly very close by, the titi monkeys in our study could not be surveyed by line transects as this necessitates the animals to be seen on the transect line.

Mark (2003) working in the same area in 2003 estimated numbers based on visual encounters only, found 13 groups in and around the reserve. In contrast to Mark's (2003) study in which the majority of individuals were recorded within 20 m of rivers or streams, only 30% of groups recorded in our survey called from within 150 m of the river. Our study furthermore detected a population three times larger than estimated by Mark (2003) three years earlier. During the interval between the two studies the reserve expanded by some 40%, but there is a discrepancy between the two popu-

lation estimates. This may be partially explained by an influx of displaced titis from surrounding areas in response to habitat destruction, but different methodologies certainly contribute to the discrepancy.

Twenty-three groups of *C. oenanthe* are estimated to occur entirely or partially within Tarangue's forested area, with an estimated density of 1.41 individuals/ha, or 141 / km². This estimate is considerably higher than the norm for *Callicebus* species (Robinson et al., 1987), and is exceeded only by Mason's (1968) estimated 400+ *C. cupreus* / km². Population densities from other studies are summarised in Table 1; the mean population density for *Callicebus* is 79.4 (±126.9, range 17-400) individuals/km², meaning our density estimate is still much higher on average, even when Mason's very high estimate is included. When his estimate is excluded, the mean population density is only 39.3 (± 43.5), or a median of 20 individuals/km².

It is likely that, in light of the continuous destruction of habitat in areas surrounding the reserve, Tarangue serves as a refuge for groups of displaced *C. oenanthe* (cf. Defler, 2004). As deforestation advances, and the reserve becomes increasingly isolated from other fragments of forest, opportunity for dispersal to unoccupied territory and the establishment of new territories will decrease (Turner, 1996). These factors could result in unsustainably high population densities within the reserve (cf. Bowers and Matter, 1997; Debinski and Holt, 2000; Onderdonk and Chapman, 2000; Laurance et al., 2002).

Titi monkeys often seem to thrive in moderately disturbed areas or secondary forest (Peres, 1993; Ferrari et al., 2000; van Roosmalen et al., 2002). *Callicebus moloch* and *C. cupreus* are frequently found in both natural and man-made edge habitats, and close to areas inhabited by humans (van Roosmalen et al., 2002). But the long-term effect of widespread habitat

Table 1. Abundance estimates of *Callicebus* in previous studies, showing method used to obtain the estimate.

Species	Common name	Estimate	Method	Reference
<i>Callicebus moloch</i>	Dusky titi	400/ km ²	Extrapolation from home ranges in small forest patches	Mason, 1968
		57/ km ²	Line transects	Robinson, 1987
		20/ km ²	Line transects	Wright, 1985
		17/ km ²	Line transects	Stallings, 1984
<i>C. torquatus</i>	Widow titi	32/ km ²	Line transects	Defler, 2004
		16/ km ²	Line transects	Kinzey, 1981
<i>C. cupreus</i>	Coppery titi	14.6/ km ²	Line transects	Bennett et al., 2001
<i>C. personatus</i>	Masked titi	17/ km ²	Line transects	Müller, 1996
<i>C. oenanthe</i>	Andean titi	113/ km ²	Vocal survey	this study

disturbance and occupation of secondary habitat on *Callicebus* species is unknown. The apparent preference of some titi monkeys for disturbed forest may indicate the suitability of such habitats, or the genus' adaptability to less than optimal conditions in response to increased competition for resources elsewhere. Although frugivores, many species of titi monkey include large proportions of leaves in their diet (Crandlemire-Sacco, 1988; Heiduck, 1997; Kinzey, 1997), perhaps placing them at an advantage in disturbed forest as the leaves of edge vegetation contain proportionally more protein (Onderdonk and Chapman, 2000). Despite their ability to utilize disturbed habitats, the titi monkeys at Tarangue still face cumulative pressures resulting from fragmentation and increased anthropogenic disturbance (Laurance *et al.*, 2000, 2002), decreased gene flow, and inbreeding depression (Haipeng *et al.*, 2003).

We have demonstrated that titi monkeys can be effectively surveyed using auditory methods and that this is a more suitable method for monitoring populations than more traditional census techniques. Auditory surveys have been demonstrated as effective conservation tools for monitoring some of the larger species of primates (gibbons - Buckley *et al.*, 2006; Nijman, 2006; Tallents *et al.*, 2001; howler monkeys - Estrada *et al.*, 2002, 2003) to which we may add the smaller-bodied titi monkeys. Despite us finding a significantly larger population of *C. oenanthe* in the Tarangue reserve than previously reported (by extension raising the possibilities that other similar populations are larger as well) continued forest destruction in the Alta Mayo results in an ever-decreasing distribution range of the species. We urge other researchers working in Alta Mayo, as well as researchers working on other *Callicebus* species throughout South America to adopt auditory survey techniques as to increase our understanding of the real abundances of these cryptic species.

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