Short Communication

Spider Monkey (*Ateles geoffroyi*) Travel to Resting Trees in a Seasonal Forest of the Yucatan Peninsula, Mexico

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Abstract
Resting by primates is considered an understudied activity, relative to feeding or moving, despite its importance in physiological and time investment terms. Here we describe spider monkeys' (*Ateles geoffroyi*) travel from feeding to resting trees in a seasonal tropical forest of the Yucatan Peninsula. We followed adult and subadult individuals for as long as possible, recording their activities and spatial location to construct travel paths. Spider monkeys spent 44% of the total sampling time resting. In 49% of the cases, spider monkeys fed and subsequently rested in the same tree, whereas in the remaining cases they travelled a mean distance of 108.3 m. Spider monkeys showed high linear paths (mean linearity index = 0.77) to resting trees when they travelled longer distances than their visual field, which suggests travel efficiency and reduced travel cost. Resting activity is time consuming and affects the time available to search for food and engage in social interactions.

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Resting by primates is considered an understudied activity, relative to feeding or moving [Korstjens et al., 2010], despite its importance energetically and in terms of time investment. For example, *Ateles belzebuth* and *A. geoffroyi* spend 63 and 54.1% of their time resting but only 22.2 and 10.8% of their time feeding, respectively [Klein

and Klein, 1977]. Similarly, a study on spider monkeys (*Ateles paniscus*) in Manu National Park, Peru, found that the mean percentage of resting time was 45 vs. 29% feeding [Symington, 1988]. More recently, a study of *A. geoffroyi* in Lacandona rain forest, Mexico, found that resting comprised the highest percentage of daily activity time (approx. 35%), followed by feeding, and that activity was higher in the dry season than in the wet season [Chaves et al., 2011].

In other Neotropical primate species, like *Alouatta palliata* and *A. pigra*, resting contributes to more than 50% of total time budgets [Cristóbal-Azkarate and Arroyo-Rodríguez, 2007; Zárate et al., 2014]. Caparú woolly monkeys (*Lagothrix lagotricha*) rested for 29.9% of the time [Defler, 1995] and spent 23.2% of the total activity budget resting in Yasuní, Ecuador [Di Fiore and Rodman, 2001]. The results of these studies indicate that the time spent resting ranges from approximately 20% to more than 50% of the total sampling time. Considering the large amount of time primates spend resting, we might expect this activity to influence other behaviours, particularly those related to energetically explicit behaviours, such as travelling and feeding.

Movement is considered a vital process that influences ecological aspects such as searching for food, mates, or sleeping sites [Mueller and Fagan, 2008]. In addition, it plays a key role in determining the fate of individuals and structuring the dynamics of populations and communities [Swingland and Greenwood, 1983; Dingle, 1996; Turchin, 1998]. In terms of movement behaviour, resting may influence primate travel decisions because individuals have to search for places to rest during the day to recover energy, to digest their foods, or to reduce overheating due to high temperatures [Herbers, 1981; Roberts and Dunbar, 1991; Hill, 1999]. In addition, stopping to rest while travelling between feeding sites may have important ecological implications, such as seed dispersal, since individual monkeys can disperse a large number of seeds in scattered or clumped patterns and this is related to the probability of successful seedling recruitment as density- and distance-dependent mortality near parents decreases [Howe, 1989; Muller-Landau and Hardesty, 2005]. Here we describe the travel paths between feeding sites and subsequent resting sites of the Central American spider monkey (*A. geoffroyi*) and discuss the importance of resting in terms of movement behaviour.

We carried out field work in the communal shared land (*ejido*) of Nuevo Becal, Calakmul, in the south-eastern state of Campeche, Mexico. Common activities of the human community in the *ejido* are crop cultivation, honey extraction, selective logging, and subsistence and sport hunting, mainly of collared peccaries (*Pecari tajacu*) and white-tailed deer (*Odocoileus virginianus*) [Weber et al., 2006; Reyna-Hurtado and Tanner, 2007]. This *ejido* comprises 520 km^2 half of which is designated as a permanent forested area. Vegetation is characterized mainly by medium semiperennial forest, with trees of 15–25 m tall, and low flooded forest with trees of 5–15 m tall. The mean annual temperature is 24.1°C, and the mean annual precipitation (from 1950 to 2013) is 1,002.8 mm [Instituto Nacional de Estadística y Geografía, 2014].

Spider monkeys are threatened across most of their range mainly due to habitat degradation driven by logging and forest clearing [International Union for Conservation of Nature, 2014]. All spider monkey species are listed as Endangered or Critically Endangered apart from *A. paniscus* which is listed as Vulnerable [International Union for Conservation of Nature, 2014]. *A. geoffroyi* usually inhabits primary forests and is considered a ripe-fruit specialist, with only a small number of plant species comprising more than 70% of its total feeding time [Chapman, 1988; González-

Zamora et al., 2009; Chaves et al., 2012]. These processes suggest that spider monkeys are strongly selective in their food choices and highlight their vulnerability to disturbances that decrease the availability of their preferred foods.

We collected data on a single spider monkey community of approximately 20 individuals. We randomly selected adult or subadult individuals from the first subgroup contacted in the mornings and followed them for as long as possible using focal animal sampling. Given the dense vegetation at the site, poor visibility in the canopy, lack of trails, rapid movements of spider monkeys, heavy rains, and the fact that the monkeys were not individually identifiable, it was impossible to follow focal animals for long periods. We followed spider monkeys early in the mornings (starting at 7:30 a.m.) with a mean observation period of 3 h per day, ranging from 1 to 7 h, with a mean of 7 days of observation per month (August to November 2014), totalling 26 follow days and 78 h of observation. During follows, we recorded resting, feeding, travelling, and social interactions every 15 min with focal samples of 5-min duration. When spider monkeys fed, we recorded the tree species and plant part eaten (fruits, flowers, leaves, branches, or bark). In addition, we recorded the location of focal individuals every 5 min and at every feeding location with a GPS device (Garmin GPS map 62s) to determine travel routes.

We uploaded waypoints into ArcGIS (V 10.3) to measure the Euclidean distances between feeding trees and subsequent resting trees, and to analyse travel distances and travel routes used between feeding and resting trees. A travel route is composed of the number of GPS readings for the period during which spider monkeys were followed in a day. We plotted the locations of feeding trees and subsequent resting trees used, considering feeding trees as starting points and resting trees as end points. We then joined the GPS readings with straight lines between feeding and resting trees to construct route segments, which represent portions of the travel route of a given day. Once we identified route segments, we calculated the linearity index to measure how linear (directed) the travel was between feeding and subsequent resting trees, making sure that route segments had at least 3 GPS readings and a distance longer than spider monkeys' visual detection field, which is a maximum of 80 m [Valero and Byrne, 2007]. The linearity index is calculated by dividing the direct distance from the starting to end points by the sum of distances between each GPS reading [Valero and Byrne, 2007].

Spider monkeys spent 44% of the focal time resting, 28% feeding, 25% travelling, and 3% in social interactions, which highlights the great amount of time spider monkeys devoted to rest at our study site. Spider monkeys rested between 0 and 422 m from feeding trees, and on average, they rested 55.3 m away from feeding trees (SD = 100 m). Of the 47 cases where feeding trees could reliably be paired with subsequent resting trees, in 23 cases (49%), spider monkeys rested directly in feeding trees. The mean distance travelled to a resting tree when these cases were removed was 108.3 m (SD = 119 m). In 13 cases monkeys travelled between 5 and 100 m and in 11 cases they travelled more than 100 m from feeding trees.

We identified 13 route segments longer than spider monkeys' visual detection field, with an average distance travelled of 286 m (SD = 206 m), and a mean direct distance between starting (food trees) and ending points (resting trees) of 196 m (SD = 101 m). The mean linearity index of route segments was 0.77 (SD = 0.17), which reflects highly linear paths to resting trees. In 8 of these route segments when focal individuals left the resting tree, the next stop represented another resting tree, and in

the remaining segments focal individuals travelled to a feeding tree after leaving the resting tree.

Spider monkeys tended to remain in feeding trees to rest when feeding trees were large. In 6 of 23 records where monkeys fed in and rested in the same tree, monkeys fed and rested in *Brosimum alicastrum* trees, with an average DBH of 28 cm. In 5 of these cases, they fed and rested in trees of the species *Manilkara zapota*, and in 4 cases, they fed and subsequently rested in *Pimenta dioica*. The latter 2 tree species had an average DBH of 22 cm each. In the 2 cases where monkeys left feeding trees to rest in unidentified trees, the average DBH of the feeding trees was small: one of the species was a climbing vine (*Malpighia* spp.), and the other had an average DBH of 13 cm.

The high linearity of travel route segments suggests that spider monkeys travel efficiently through the forest [Cunningham and Janson, 2007], moving in a directed way to the resting trees. The fact that in 39% of route segments the next stop after leaving the resting tree was a feeding tree could point to the possibility that spider monkeys were actually travelling to those feeding trees, which could suggest some knowledge of food location. Given that route segments had an average travelled distance of 286 m (exceeding 3.5 times the distance of the visual detection field), and considering brachiation as a costly mode of locomotion [Parsons and Taylor, 1977], it is possible that spider monkeys needed to stop to rest during such long travels to recover. Highly linear paths could be therefore associated with a minimized-cost travel strategy. Interestingly, the ending points of the remaining 61% of the segments were followed by other resting trees, but it is difficult to assume that those trees were intended targets. One plausible explanation could be that spider monkeys were travelling to a certain area of their home range and stopped to rest to monitor the fruiting state of potential food trees, since on most occasions the monkeys were not sleeping but were simply inactive.

The tree species that comprised more than 70% of the total feeding time (*B. alicastrum*, *M. zapota*, *P. dioica* and *Licaria peckii*) were mostly visited to consume unripe fruits, particularly in the case of *B. alicastrum,* which represented 36% of the monkeys' feeding time. Unripe fruits have more fibre and secondary metabolites than ripe fruits, so this item is difficult to digest and is likely related to resting time. Also, we cannot discard the possibility that high temperature and low precipitation in the study site influenced the time devoted to rest. These climate factors may force spider monkeys to seek shelter to reduce thermally costly activities, like travelling. Overheating could have a negative effect since it increases core body temperature [Mount, 1979] and thus can affect organs that are sensitive to fluctuations in temperature, like the brain [Precht et al., 1973]. Moreover, behavioural thermoregulation can be costly in terms of time and energy because it constrains the time available for other critical activities, such as feeding or drinking [Hill, 2006; Korstjens et al., 2010].

Tree size appears to affect whether spider monkeys rest in feeding trees or travel out of them after eating. Larger trees may provide greater protection from terrestrial predators, like jaguars (*Panthera onca*) and pumas (*Puma concolor*), which occur in our study site. It is also possible that the risk of intraspecific conflict over feeding resources is reduced in trees with larger DBH and thus larger fruit crops [Chapman et al., 1992]. Greater availability of food resources in larger trees may mitigate the need to leave feeding trees to rest and thus allow the spider monkeys to reduce travel costs. Future studies could focus on the role of fruit abundance and nutritional value of food items in trees that monkeys remain in after feeding, versus those they leave after feeding [Rothman et al., 2012].

B. alicastrum and *M. zapota*, which were the tree species most used for feeding (36 and 16% of the total feeding time, respectively) and resting (both 17.3% of the time considering route segments), are large species targeted for selective logging in the Calakmul region; thus, the extraction caused by logging may represent a serious threat to spider monkeys [Morelos-Juárez et al., 2015]. Furthermore, removing large trees used for feeding may increase intraspecific competition due to a reduction in resource availability. Moreover, large trees are also an important resource for resting during daylight hours and for sleeping during nights. Thus, a decrease in the abundance of large trees due to selective logging may force spider monkeys to travel longer distances to find suitable places to rest, spending more energy that could be used for other essential activities, thereby compromising their fitness [Velázquez-Vázquez et al., 2015].

This study highlights the importance of resting in terms of time and energy costs for spider monkeys. Future studies are needed to determine the influence of climatic variables (precipitation, temperature, and relative humidity) on spider monkey movements and behaviour in specific locations. This information could be used to develop predictive models that show the effects of climate change on spider monkey populations in the long term and to promote reforestation programmes to reduce the potential effects of high temperatures and low precipitation on resource abundance.

Acknowledgements

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