

Preliminary observations of complex object manipulation in a wild population of *Sapajus cay* Illiger 1815 (primates: Cebidae) in a fragment of upper Paraná Atlantic Forest, Rancho Laguna Blanca, eastern Paraguay

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Abstract Capuchin monkeys are known for their cognitive abilities, including object manipulation and use of a variety of tools. The hooded capuchin (*Sapajus cay*) is the only representative of its genus found in Paraguay and is critically understudied in the country. This paper reports on preliminary observations of a group of hooded capuchins, in Rancho Laguna Blanca, San Pedro, Paraguay, using two different first-order object manipulation techniques to open the seeds of the tree *Cariniana estrellensis* (Lecythidaceae). Some individuals held the seed in both hands and stood bipedally, using their entire body weight to smash the seed against a branch. The more commonly observed technique involved the monkeys holding the seed in one hand and repeatedly striking the branch with the fruit until they could extract the seed. Only adults were ever observed to be successful in opening the fruits.

Keywords Combinatorial activities · Destructive foraging · Hooded capuchin · Paraguay · Upper Paraná Atlantic Forest

Introduction

Complex objection manipulation and tool used to process or access food has been observed in a number of primate species (Biro et al. 2003; Eshchar et al. 2016; Goodall 1970; Inoue-Nakamura and Matsuzawa 1997; Malaivijitnond et al. 2007). Japanese macaques have been observed washing sweet

potatoes before consuming them (Kawai 1965). Chimpanzees display a wide repertoire of tool use and object manipulation including termite fishing, nut cracking (Inoue-Nakamura and Matsuzawa 1997) and pounding using a pestle (Yamakoshi and Sugiyama 1995). Olive baboons (*Papio cynocephalus anubis*) in Nairobi National Park use twigs to extract stone fragments from a clay matrix (Oyen 1979). Long-tailed macaques (*Macaca fascicularis*) in Thailand and sea islets in the Andaman Sea use stones to crack open oyster shells, bivalves and crabs (Carpenter 1887; Malaivijitnond et al. 2007). Blonde and black-capped capuchins (*Sapajus flavius* and *S. libidinosus*) living in the Brazilian Caatinga use hammer stones and anvils to smash hard shelled nuts (Ferreira et al. 2009). An adult male white-faced capuchin (*Cebus capucinus*) in Costa Rica was observed using a branch as a club to kill a venomous snake (*Bothrops asper*) (Boinski 1988). Here, I present an observation of fruit-smashing behaviour in a wild population of hooded capuchins (*Sapajus cay*) in a small fragment of the Upper Paraná Atlantic Forest in eastern Paraguay.

Capuchins monkeys (*Cebus*, Erxleben 1777 and *Sapajus*, Kerr 1972) are classed as destructive or extractive foragers (Izawa 1978, 1979). They have long been famed for their ability to manipulate objects and use a variety of tools (Fragaszy et al. 2004a; Ottoni and Izar 2008; Struhsaker and Leland 1977; Visalberghi 1990). Activities in which capuchins combine objects and surfaces are known as “combinatorial actions” (Fragaszy et al. 2004b). The use of combinatorial actions is believed to allow capuchin monkeys to gain access to foods that they could not otherwise obtain (Fragaszy et al. 2004b), allowing capuchins to live in areas where other primates would struggle to survive (Struhsaker and Leland 1977).

One example of capuchins’ use of combinatorial actions to access food is fruit smashing behaviour (Izawa and Mizuno

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1977). This activity is an example of “First-Order” object manipulation, in which an object is combined with a fixed substrate or another stationary object (Fragaszy et al. 2004b). Fruit smashing can be either a “simple” or “specific” first-order action. Simple first-order combinations only require that an object be brought into contact with a stationary substrate; whereas specific first-order actions are more complicated in that they require an alignment between the substrate and the object (Fragaszy et al. 2004b; Izawa and Mizuno 1977). Capuchins have been observed to pound the longer axis of elliptical objects perpendicularly to straight tree limbs, utilising the tree limb as a fulcrum (Boinski et al. 2000; Fragaszy et al. 2004b; Panger 1998). The use of surfaces for smashing hard-shelled fruits is thought to be “taxon-specific” behavioural patterns for robust capuchin species (Ottoni and Izar 2008).

Simple and specific first-order object manipulation to obtain difficult to access fruits has been observed in wild *Sapajus macrocephalus* (formally *Cebus a. apella*) in Colombia (*Astrocaryum chambira* (Arecaceae): Izawa and Mizuno 1977; *Astrocaryum chambira*: Struhsaker and Leland 1977), *Sapajus apella* (*Cebus apella*) in Suriname (Boinski et al. 2000), *Cebus capucinus* in Costa Rica (Panger 1998) and *Cebus olivaceus* in Venezuela (Fragaszy and Boinski 1995). Capuchin monkeys are also known to manipulate food items that contain caustic chemicals or irritating structures (*Cebus capucinus*: O’Malley and Fedigan 2005; *Sapajus libidinosus*: Sirianni and Visalberghi 2013).

Study site and subjects

This behaviour was observed at Rancho Laguna Blanca (RLB), San Pedro, Paraguay (23° 49' 52.0" S 56° 17' 42.2" W). This 804 ha reserve is located in the transitional zone between the Cerrado and Atlantic Forest ecoregions. The reserve contains a small fragment of 243 ha of young secondary Upper Paraná Atlantic Forest, characterised by deciduous, mesophytic, broadleaf plants (Lowen et al. 1996). The forest fragment has a history of selective logging until 2010 when it was classified as a reserve. The protected status expired in February 2015.

Hooded capuchins (*Sapajus cay*) are diurnal, arboreal primates that are omnivorous, eating a large variety of seeds, fruits and arthropods, nestlings, frogs and small mammals (Fragaszy et al. 2004b). The species is the only representative of the genus *Sapajus* in Paraguay (Lynch Alfaro et al. 2012a). The reserve is home to two groups of semi-habituated capuchins. The larger group (O Group) consists of 3 adult males, 5 adult females, 5 sub-adults, 4 juveniles, and 1 infant (Smith and Briggs 2016) and the smaller group (F Group) of around 12 individuals including 2 infants born in December 2015, although group demographics are still unconfirmed. Age

classes were defined as: “Adults”-Individuals with robust facial features, complete adult dentition, and the largest relative body sizes (Fragaszy et al. 2004b). “Subadults” were classified as individuals approaching adult body size but lacking the characteristic robust facial features and tufts of the adults and “Juveniles” were classified as individuals that were less than three quarters of the average adult size, not including tail length (Bezerra et al. 2014; Oliveira and Langguth 2006). “Infants” were classed as only those individuals observed being carried by an adult (Smith and Briggs 2016).

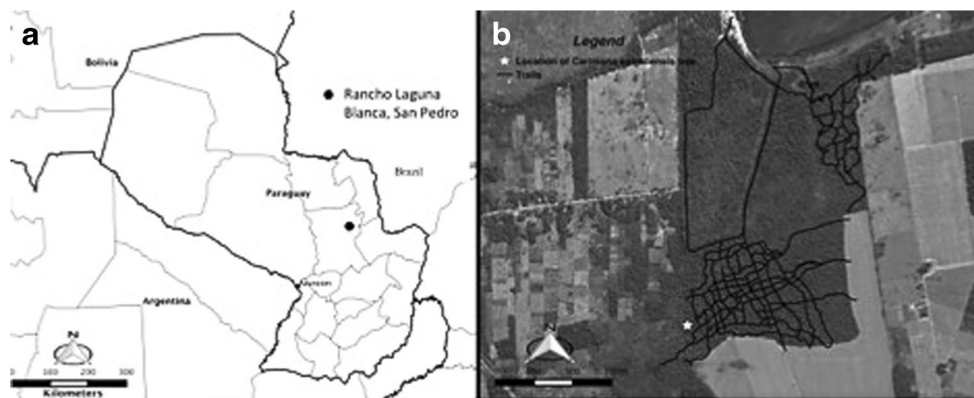
Observation

A grid network of trails across the 243 ha of forest was used to follow the study groups. The trails allowed the groups to be followed into areas of low accessibility. The trail grid was walked during daylight hours, year-round to locate the monkeys. Most commonly, the monkeys were located by their calls or sounds of movement in the trees. When found, the GPS locality of the group was recorded along with the time and date. Additionally, the number of individuals visible, the group and activity upon location were recorded. (Fig. 1)

Over periods of 3 days in March 2015 and 5 days in August 2015 (6 h of observation in total), O Group was observed by the author, feeding on the seeds of the *Cariniana estrellensis* in the Atlantic Forest fragment of RLB (S23° 49' 56" 9 W056° 17' 50" 7). *Cariniana* is a genus of trees in the family Lecythidaceae and is native to South America. *Cariniana estrellensis* is the only species known in Paraguay. It is an emergent tree that can reach up to 40 m in height (Mori 2014). This tree is known as the Ka’i ka’ygua (or “Monkey’s Cup”) in the Guaraní language. In RLB, this species has been found to fruit for short periods of time throughout the year. The fruits of this tree are large and oval shaped, around 7 cm long and 2 cm wide (Fig. 2); with a very hard, fibrous exterior that protects an elongated operculum and several winged seeds (Oliveira-Filho and Galetti 1996). This tree is not common in RLB, and at present, the locations of only five mature individuals of this species are known in forest fragment.

Observers were alerted to the presence of the capuchins by the hollow knocking sound of the fruit being struck against the branch. All of these observations were made during the habituation process during which time the capuchins would abandon their activity and flee when approached by the observers. As a result, only one adult female and two of the adult males in the group were individually recognisable and all observations of fruit smashing behaviour were made from a distance of around 150 m using binoculars, with the observers hidden from view. Observers were able to watch each feeding bout for between 30 to 45 min. As observers arrived after the beginning of each feeding bout and each bout was ended by the

Fig. 1 a Location of Rancho Laguna Blanca in Paraguay and b map of trail system in RLB Atlantic Forest and location of observations. Map Created using QGIS 2.14



capuchins seeing the observers and fleeing, further observations are required to determine how long the capuchins spend feeding on the *Cariniana estrellensis* fruit. Further study is necessary to confirm individual variation in the use of the two different techniques as well as individual success rate for opening the *C. estrellensis* fruits.

When selecting a fruit, the capuchins cupped each fruit in their hands and tried to insert their index finger into the hard casing. Two juveniles and one male adult were observed attempting to bite down on the shell before beginning to process the fruit. In total, three adult males, one adult female and three subadults were observed processing or trying to process the *Cariniana estrellensis*. One juvenile was observed begging for fruit from an adult female. The adult capuchins displayed two distinct techniques to access the well-protected seeds of the *Cariniana estrellensis*:

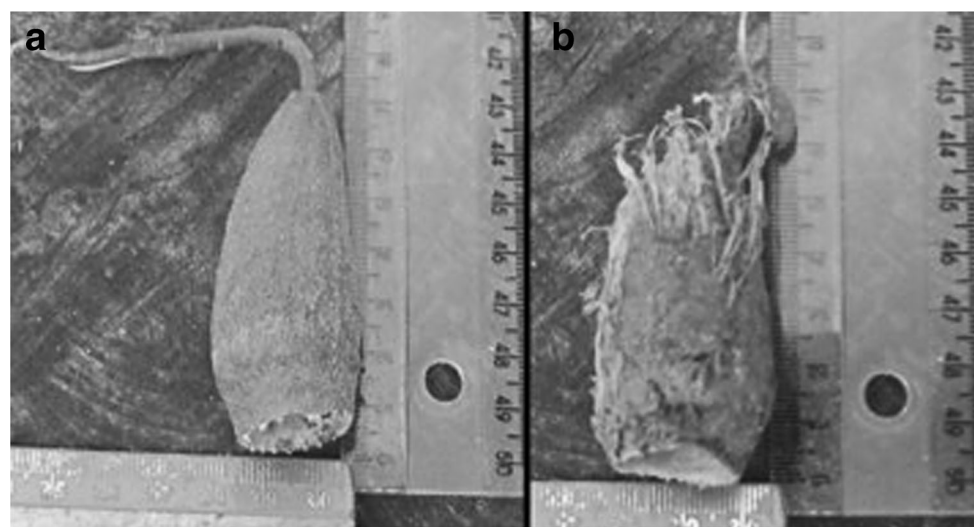
1. Only one adult female was observed to use this technique. She was seen using this technique to open fruits on three separate occasions. Holding the fruit with both hands, the adult female stood bipedally and used its entire body weight to strike the fruit off the tree branch. Remaining

crouched low to the branch, the adult female quickly followed this first strike with a second strike using only one hand and hitting the top end of the seed on the tree trunk. The individual was then able to hold the fruit in its left hand while using the index finger and thumb of the right hand to extract the seed from the hard casing.

2. Holding onto the branch with the left hand, the monkeys used their right hand to strike the seed against the branch a number of times in rapid succession. Using both hands to hold the fruit, the subject then used its index finger, and occasionally teeth, to extract the seeds one by one from the casing. This was observed more frequently than Technique 1 and was consistently used by the group's three adult males.

During these preliminary observations it did not appear that fruit smashing is a social behaviour in *Sapajus cay* in Rancho Laguna Blanca. Individuals were never observed to use the same branch at the same time to smash fruits. Except for one incident of a juvenile individual watching an adult female smash a fruit before displaying begging behaviour, the

Fig. 2 a Seed of the *Cariniana estrellensis* and b seed of the *Cariniana estrellensis* after capuchin processing



subadult monkeys were not observed to watch the adults as they manipulated the fruits.

It was apparent that younger individuals are not as adept at opening the *Cariniana estrellensis* fruit as the older monkeys. Of the three subadults that were witnessed attempting to open the fruit, none appeared to be successful. The younger monkeys used a combination of techniques to try to open the fruit. The most frequently observed technique was the rolling of the fruit across the branch. Sitting low to the branch, the capuchins placed the oblong-shaped fruit on the branch with both hands on top. Moving their hands back and forwards they rolled the fruit repeatedly before attempting to remove the seed. This was never observed to be successful. Two of the subadults were also observed attempting to smash the fruit using the branch (Fig. 3). The technique of the younger monkeys differed slightly to the adults in that no bipedal stance was observed during strikes. Every observed attempt resulted in the fruit being dropped from the tree.

Discussion

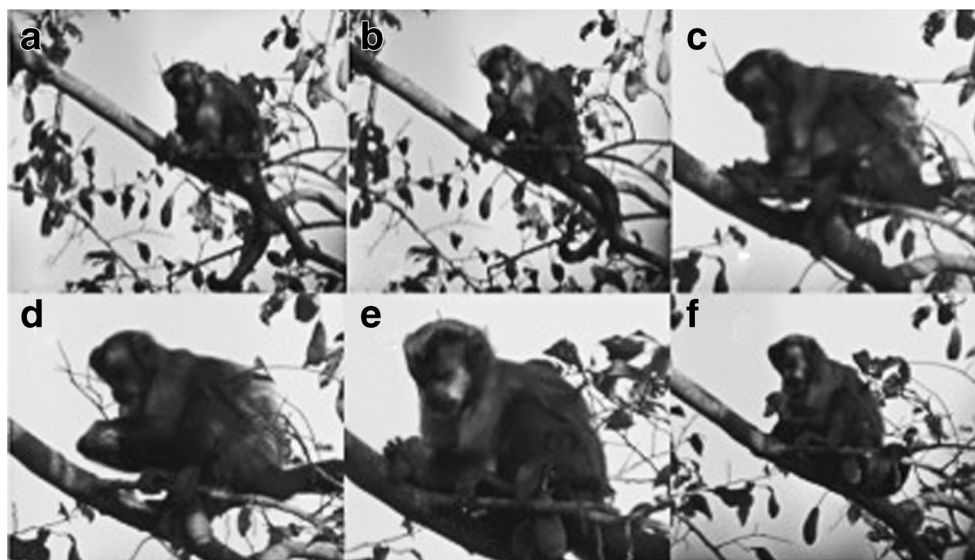
The methods employed by *Sapajus cay* individuals in Rancho Laguna Blanca are extremely similar to those described in other *Sapajus* species. *Sapajus macrocephalus* in Colombia have been observed using both the single-handed and double-handed techniques to open the hard fruits of the *Astrocaryum chambira* (Arecaceae) palm (Izawa and Mizuno 1977). In this species, the selection of the branch used as the anvil for hammering the fruit appeared very important to the capuchins with lower ranking males waiting up to 15 min for access to specific locations (Izawa and Mizuno 1977). Other groups of *Sapajus macrocephalus* in Colombia have been observed using a variation of this single-handed technique to open the

fruits of *Astrocaryum chambira*, hammering the fruit on both a vertical and horizontal branch with one hand. This group was also observed holding a fruit in each hand and smashing them off one another (Struhsaker and Leland 1977), a technique never observed in the capuchins of Rancho Laguna Blanca. In Suriname, *Sapajus apella* hammer hard fruits and seeds from a variety of trees. However, when processing fruits of the Brazil nut (*Bertholletia excelsa*: Lecythidaceae) this species has only been observed using a double-handed technique, similar to Technique 2 (Boinski et al. 2000).

The three adult males of the group were always observed to use Technique 2 to open the seeds. Adult male capuchins are 19.5–27% larger than adult females (mean 24%) (Ford and Davis 1992; Kay et al. 1988) and it may be the case that the greater physical strength of the adult males allows them to be more successful at opening the *C. estrellensis* seeds with a single hand, without first using the double-handed technique, than the females or subadults (Liu et al. 2009). Adult males also possess canine teeth that are 16–22% larger than females', and it may be that they do not need to hammer the seed with as much force if they can use their larger canine to extract the seed (Campbell et al. 2007; Kay et al. 1988).

Object manipulation and tool use in primates has been shown to develop over time with variability of actions decreasing and efficacy of strikes increasing as individual's age (Corp and Byrne 2002; Inoue-Nakamura and Matsuzawa 1997; Resende et al. 2014) and socially facilitated learning is involved in the development of these skills (Eshchar et al. 2016; Fredman and Whiten 2008). Young capuchin monkeys in captivity have been observed to exhibit all forms of basic manipulation from the age of 6 months (Adams-Curtis and Frigaszy 1994) and juveniles between 1 and 3 years old manipulate objects more frequently than other age groups (Byrne and Suomi 1995; Frigaszy and Adams-Curtis 1991). Wild

Fig. 3 Technique of subadult capuchin of unknown sex trying to open a *Cariniana estrellensis* fruit. **a** and **b** Subadult strikes the fruit off the branch. **c**, **d** and **e** Subadult rolls the fruit along the branch. **f** Subadult tries to remove the seed from the fruit casing



Cebus apella (*Sapajus nigritus* Lynch-Alfaro et al. 2012b) in Brazil began to show simple object manipulation between 8 and 12 weeks of age and combinatorial actions appeared prior to, or simultaneously with, this simple manipulation (Resende et al. 2008). Nut cracking attempts by young capuchins at Fazenda Boa Vista in Brazil quadrupled when older individuals in the group were cracking nuts, and immature monkeys were three times as likely to be near an anvil stone when another individual was cracking nuts than when the stone was not being used (Eshchar et al. 2016). These initial observations of Paraguayan *Sapajus cay* indicate that younger capuchin monkeys are not as successful as adults at opening the hard fruits of the *C. estrellensis*, and further studies are required to determine how this ability develops as the individuals get older and whether or not social learning is involved in the development of this skill.

The diets of capuchin species are very flexible and can become specialised in times of food shortage such as the dry season, or in disturbed or marginalised habitats. Capuchins have been known to rely almost completely on bromeliads or seed predation in response to food stress (Campbell et al. 2007; Sussman 2000). In habitats where food is limited, complex object manipulation or the use of tools to access hard shelled fruits or embedded food items has been suggested to allow capuchins to survive by improving foraging ability (Moura and Lee 2004). In contrast, in other areas, it has been suggested that use of tools to access hard shelled fruit occurs opportunistically and is not correlated to the availability of soft fruits and invertebrates (Spagnoletti et al. 2012). The ability of *Sapajus cay* living in the Paraguayan Atlantic Forest to manipulate and access hard fruits may contribute to their survival and success in small, isolated fragments such as the forest of Rancho Laguna Blanca. Further studies of this group are necessary to determine how much of their diet is dependent on hard-to-access dry fruits such as *Cariniana estrellensis* and whether these fruits are relied upon more heavily in times of food scarcity.

This preliminary observation of complex object manipulation in wild Paraguayan hooded capuchins opens up interesting areas of further study. Long-term observations of the behaviour of this group will determine whether complex object manipulation of *Cariniana estrellensis* is a socially learned behaviour and how much variation is present between individuals in their use of the two techniques, how important this fruit is to the diet of these capuchins and whether or not these capuchins use more complex tools.

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Compliance with ethical standards

Ethical approval This article does not contain any studies with human participants performed by the author. Our research was approved by the Secretaria del Ambiente and complied with all local laws. The study was non-invasive and followed the American Society of Primatology Code of Best Practises for Field Primatology (2014).

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