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RESEARCH ARTICLE

Wild Capuchin Monkeys (*Cebus libidinosus*) Use Anvils and Stone Pounding Tools

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We conducted an exploratory investigation in an area where nut-cracking by wild capuchin monkeys is common knowledge among local residents. In addition to observing male and female capuchin monkeys using stones to pound open nuts on stone ''anvils,'' we surveyed the surrounding area and found physical evidence that monkeys cracked nuts on rock outcrops, boulders, and logs (collectively termed anvils). Anvils, which were identified by numerous shallow depressions on the upper surface, the presence of palm shells and debris, and the presence of loose stones of an appropriate size to pound nuts, were present even on the tops of mesas. The stones used to crack nuts can weigh >1 kg, and are remarkably heavy for monkeys that weigh <4 kg. The abundance of shell remains and depressions in the anvil surface at numerous anvil sites indicate that nut-cracking activity is common and long-enduring. Many of the stones found on anvils (presumably used to pound nuts) are river pebbles that are not present in the local area we surveyed (except on or near the anvils); therefore, we surmise that they were transported to the anvil sites. Ecologically and behaviorally, nut-cracking by capuchins appears to have strong parallels to nut-cracking by wild chimpanzees. The presence of abundant anvil sites, limited alternative food resources, abundance of palms, and the habit of the palms in this region to produce fruit at ground level all likely contribute to the monkeys' routine exploitation of palm nuts via cracking them with stones. This discovery provides a new reference point for discussions regarding the evolution of tool use and material culture in primates. Routine tool use to exploit keystone food

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INTRODUCTION

Using a stone (or log) to pound open nuts placed on a solid surface (or ''anvil'') is considered the most complex form of tool use by any nonhuman species routinely seen in nature, because it involves producing two spatial relations in sequence (between the nut and the anvil, and between the pounding tool and the nut) [Fragaszy et al., 2004; Matsuzawa, 2001]. Wild chimpanzees in certain areas of western Africa use a stone or log to pound nuts open on a stone or exposed tree root (anvil) [Boesch&Boesch-Achermann, 2000; Matsuzawa, 2001]. In this first report of routine tool use by wild monkeys, we describe how capuchin monkeys crack open nuts using a similar technique, and provide initial data on their anvils and stone tools.

MATERIALS AND METHODS

Site and Group Composition

On 4–7 September 2003, during the dry season, we visited a biological reserve (about 250 ha) managed by Fundacão BioBrasil in a dry woodland habitat of Piauí, Brazil. The site (9° south, 45° west) is a plain edged by sandstone ridges and mesas rising approximately 20 m or more above the plain. We observed a group of 10 wild capuchin monkeys (*Cebus libidinosus*)[1] composed of two adult males, four adult females, and four immatures. Aside from palms (*Atalea spp*., *Astrocaryum sp*., and other, unidentified species), the habitat appears to offer scarce food resources for capuchin monkeys, especially in the dry season, and local people report that the monkeys crack open palm nuts throughout the year. The size of the palm nuts varies according to the species: the largest (*Atalea sp.*) have an oval shape (5 cm diameter in width, and 6 cm diameter in length), the smallest (*Astrocaryum sp.*) are round and 2.5–3 cm in diameter. The fronds and fruit clusters of the palm species in this area emerge from the soil, rather than above ground. Local people collect these nuts and transport them home to crack them.

Behavioral Assessment

We observed from a blind built in front of one of the nut-cracking sites habitually used by the monkeys, at a distance of about 15–20 m from the stone anvils. The site (about 30 m in diameter) is adjacent to a vertical cliff face, and contains natural vegetation (e.g., several mature hardwood trees, grasses and other herbaceous plants, and palms). The blind is about 600 m from M.G.O.'s residence, and the closest village is about 24 km away. The site contains 13 boulders and exposed stones used as anvils scattered over the area, all of which are within a few meters of a tree. It also contains about 10 loose stones on or near the anvil stones. These stones were present at the time the blind was constructed,

[1]For the species name, we follow the most recent classification of the genus [Groves, 2001; Rylands et al., 2000; see also Fragaszy et al., 2004]. The capuchins living in the area were previously classified as *Cebus apella libidinosus* [Hill, 1960].

and humans have not provided any additional loose stones. M.G.O. has placed nuts from the local palm species at the site daily, near anvil stones, for the past 3 years. This was done to attract the monkeys to the site so that observers could view nut-cracking from the blind. A sufficient quantity of nuts was provided so that the monkeys could crack nuts without exhausting the supply. Monkeys from several groups now come to the area up to several times a week. To facilitate focused observations, we removed most of the pounding stones in the vicinity during the period of our observations, leaving just two (700 g and 1,375 g) at one anvil stone. During a 2-hr period in which capuchins cracked open nuts at the site, we observed 13 bouts of cracking by four adults (two males and two females). For each of these cracking bouts, we recorded the number of strikes and the duration of the bout, and whether the monkey opened the nut. To calculate duration, we defined a cracking bout as starting when the monkey stepped onto an anvil stone, and ending with the last strike. Whenever possible, we assessed whether the monkey used the larger or the smaller stone, or both.

Physical Evidence of Nut-Cracking

The stone anvils at the blind area, which have been used heavily by monkeys from at least four groups for the past 3 years, have characteristic shallow hemispherical depressions on the surface that are the size of an uncracked palm nut or somewhat larger (>2 cm in diameter, ≥ 1 cm deep), and pieces of palm nut shells. Within a polygonal area of 20 ha, we selected 20 anvil sites away from the blind area. This was not an exhaustive sampling of anvil sites in this area, but we judged these sites to be representative of the sites where nut-cracking activities were known to have occurred. Ten sites were judged, by the color and texture of the shells present, to have been used within the last few months; nine were sandstone boulders or exposed rock, and one was a fallen log. Ten other sites, all sandstone boulders, were judged to have been unused within the past year. To evaluate the possibility that the distinctive depressions on anvil sites could be caused by means other than the pounding activity of monkeys, we examined 10 boulders that had a horizontal, flat upper surface (and thus were exposed to equivalent weathering compared to the anvil sites) but lacked palm shells.

We measured the two largest diameters of the top surface of each site, and counted the number of hemispheric depressions on the upper surface. The three classes of sites (active, inactive, and control) presented approximately equivalent horizontal surface areas (Kruskal-Wallis $H=2.74$; $df=2$, $P=0.25$) (see Table I). Depressions were noted as large (>2 cm deep) or small (<2 cm deep). We weighed (to the nearest 25 g) the loose palm nutshells on the upper surface of the anvil, and on the ground immediately next to the stone or log (within roughly 10 cm). One hundred grams of dried palm shell corresponds to about 4–15 nuts, depending on the nut species (and consequently size) and the dryness of the shells. Finally, we weighed (to the nearest 25 g) each loose stone that we judged large enough (at least 125 g) to serve as a pounding stone, and we visually assessed the stone's shape (rounded vs. planar surfaces).

RESULTS

Nut-Cracking Behavior

Males performed seven bouts, six of which resulted in the nut being opened. The males' successful bouts averaged five strikes (range = 3–8) and lasted 65 sec (range = 48–92 sec). Females performed six bouts, two of which were successful in

Table I. Features of Sites Used By Capuchin Monkeys to Crack Open Palm Nuts*

Site[a]	Size of anvil surface (m^2)	Number of pounding stones	Weight of pounding stones (g)	Weight of nut shells (g)	Number of large depressions on anvil[b]	Numbers of small depressions on anvil
Active	2.7±4.1	1.8±1.5	504.8+291.1	331.8±318.0	14.3±26.8	17.6±40.5
Inactive	3.3±3.3	0.9±0.8	433.3±262.5	130.0+188.5	6.8±8.2	2.6±3.1
Control	0.9±0.5	0.4±0.7	62.5±82.7	0.0±0.0	0.4±0.7	0.1±0.3

*The active sites sampled are not those at the blind.
[a]The presence of palm shells on the surface or near a stone or log was considered as indicative of its use as an anvil to crack open nuts. Active sites, presence of fresh nut shells (n = 10); Inactive sites, presence of weathered nut shells (n = 10); Control sites, absence of nut shells (n = 10).
[b]Large depressions were >1 cm deep and ≥2 cm in diameter; small depressions were ≤1 cm deep and ≤2 cm diameter.

four and 10 strikes, and in 81 and 119 sec, respectively. Both sexes used both pounding stones, and we noted no relation between which stone was used and the duration of a successful bout. We observed monkeys using two forms of action to crack nuts, with similar frequencies. In the less-effortful form, the monkey sat or stood bipedally, held the stone in both hands, and raised and lowered the stone with arm and shoulder movements. In the more-effortful form, the monkey stood bipedally in front of the pounding stone, using its lower extremities as well as its arms and shoulders to lift the stone (see Fig. 1A). In the most extreme version of the standing form, the monkey rose quickly to a nearly vertical posture by explosively extending the joints of its lower extremities, generating high momentum, and raising the stone to shoulder height. When the monkey pounded while standing bipedally, it sometimes placed its tail in apparent compression against the upper surface of the anvil, or in tension against a lateral surface—postures that may increase stability during strenuous action. In some cases, the monkey's feet came off the ground when the animal was fully extended, as occurs also in humans who lift heavy weights while using leg extension [Bachle, 1994]. Whether the monkey stood or sat, each strike occurred as a discrete action. Strikes were punctuated by postural adjustment, and inspection and repositioning of the nut.

Physical Evidence of Nut-Cracking

Table I summarizes the characteristics of the sample of anvil and control sites, and the loose stones on or near the sites, and Fig. 1B–D illustrate three anvils. On average, the anvils (both active and inactive) contained 1.4 loose stones, typically sandstone river pebbles (identified by their rounded shapes) (see Fig. 1C). Even anvil sites on the tops of mesas contained river pebbles. Some of the river pebbles had flat surfaces on a semi-hemisphere, showing evidence of recent planar fracturing. On some loose stones at active anvils, fibrous residue from palm nuts was visible at center positions on one side. The centered location of the residue suggests precise positioning during striking with these stones. The loose stones found on or next to the anvils weighed 494 g on average (range = 125–1,100 g).

The stone anvils at the blind area showed evidence of heavy use: several were covered with a layer of fine stone dust, and contained so many depressions that the edges between the depressions were diminished. Thirteen stone anvils in the

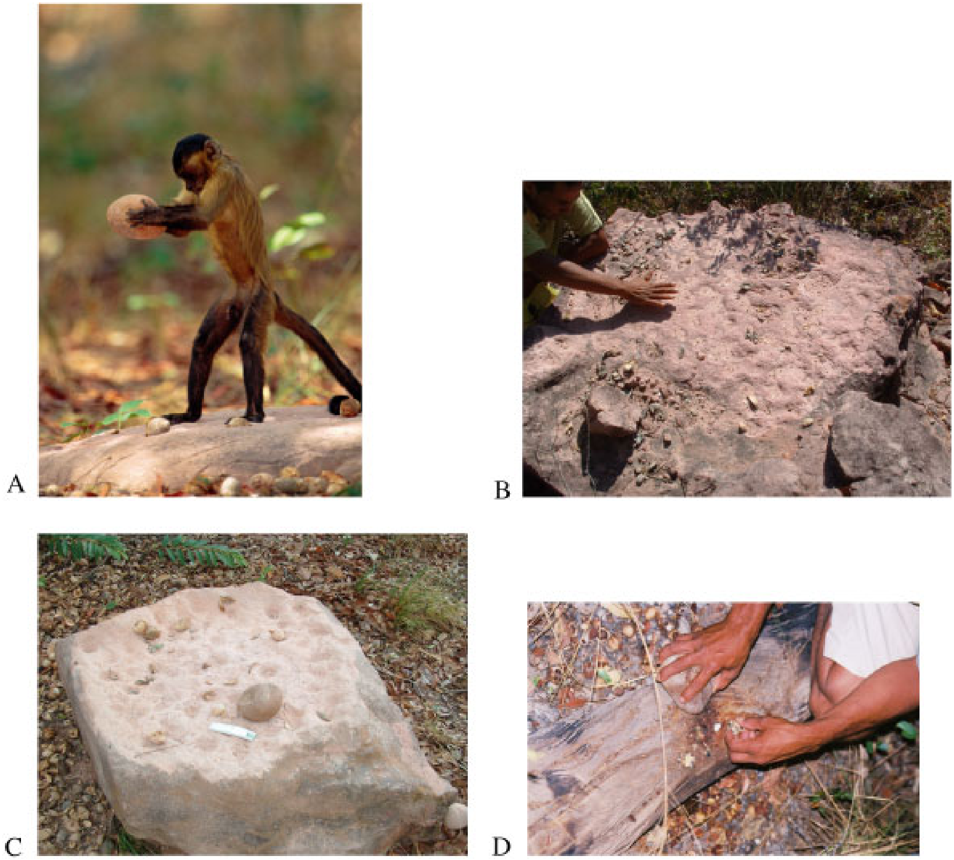

Fig. 1. **A:** Monkey pounding a palm nut with a river pebble on a stone anvil. Photo by Peter Oxford, printed with permission. **B:** Anvil stone with large pounding stone (925 g) and remains of palm shells (625 g). This anvil had 10 depressions >1 cm deep, and at least 15 depressions <1 cm deep. **C:** Anvil stone with multiple depressions and a river pebble pounding stone. Ruler $=12.5$ cm. **D:** Anvil log with large shallow depression, river pebble, and fresh remains of palm nuts.

blind area had measurable discrete depressions. These anvils had up to 64 large depressions and 50 small depressions—values at the upper range of those found in the active and abandoned anvil stones sampled away from the blind area. Both the active and the abandoned anvils had significantly more depressions than the control boulders, which averaged <0.5 depressions per stone (Dunn test, $z=4.2$ and $z=3.9$, respectively, $P<.05$ for both comparisons; see Table I). We conclude that while erosion can produce occasional shallow depressions in the local sandstone, virtually all of the depressions present on the stone anvils resulted from repeated striking of the anvil surface. Similarly, the log anvils had one or more shallow hemispheric depressions resulting from pounding actions (see Fig. 1D).

The active anvils held 25–1,000 g of palm shells (see Fig. 1B), and the inactive anvils contained 0–600 g of shells. The control boulders contained no shells. The palm shell remains at the anvil sites included the outer fibrous husk of the palm as well as the harder inner shell. Some nuts were broken cleanly into two halves, while others were cracked into many small pieces. All of the shells were characterized by a sharp edge and a fully exposed interior. Shell remains like this were not found elsewhere in the area.

DISCUSSION

We directly documented the use of anvils and stone pounding tools by four wild capuchins, and M.G.O. has informally observed wild capuchin monkeys in this area cracking nuts with stones for about 30 years (i.e., over several generations of capuchin monkeys). The characteristic depressions on the anvils, the large amount of palm shells on the anvils, and the presence of loose stones of an appropriate size and shape for pounding at anvil sites (but not elsewhere), and palm residue on these stones are clear physical by-products of nut-cracking activity. Although our documented behavioral observations at this site have just begun, those already completed (together with the physical evidence collected during our initial study) strongly suggest that wild capuchin monkeys at this site spontaneously and routinely use tools to crack open nuts, that they transport stones to anvils, that the activity occurs in many places, and that it apparently has occurred over many generations of monkeys.

This is the first direct report of such activity in wild capuchin monkeys; however, it is in line with several previous observations of capuchin monkeys in wild and captive circumstances. The activity of cracking nuts with stones on a hard surface has been well-documented in captive and in semi-free capuchin monkeys [e.g., Ottoni & Mannu, 2001], and has been suggested by indirect evidence in the wild [reviewed in Fragaszy et al., 2004; Langguth & Alonso, 1997]. The cracking activity we observed was similar to that described by Ottoni and Mannu [2001], although it appeared more strenuous, with heavier stones used to crack larger and apparently harder nuts. Fernandes [1991] observed that wild capuchins (*C. apella*) pounded a detached oyster or piece of oyster shell on other in situ oysters to crack the in situ oysters. This action does not incorporate a loose target object, as cracking a nut on an anvil stone does. Boinski et al. [2000] reported one observation of a wild capuchin monkey (also *C. apella*) striking a hard fruit with a detached section of a tree limb; however, they did not see whether the monkey opened the fruit by that action, and have not reported seeing this event again. Thus, our observations of many individuals using a tool to crack a loose object placed against an anvil surface are unique for wild capuchin monkeys.

There is no doubt that the 3-year history of provisioning nuts attracted monkeys to the area near the blind from which we observed the monkeys cracking nuts. Nevertheless, the monkeys' nut-cracking with stones predated human interest in the activity. The evidence of nut-cracking at sites well away from the blind indicate that the behavior is not restricted to the blind area. Provisioning encouraged this familiar activity in a particular place, just as Matsuzawa and colleagues [2001] and Inoue-Nakamura and Matsuzawa [1997] encouraged nut-cracking by wild chimpanzees by providing naturally-occurring nuts and stones in an area in front of a blind.

The physical demands of the actions that we observed, particularly the bipedal lifting technique, are noteworthy in two respects. First, no other activity routinely observed in wild capuchin monkeys, or any other wild nonhuman primate, requires manually lifting the same proportion of body weight that this action does. The smaller (700 g) pounding stone weighed between 19% and 25% of the monkey's body weight, conservatively estimating a weight range of 2.5–3.7 kg [Fragaszy et al., 2004]. The larger of the two stones was 37–50% of the monkeys' estimated weight. Thus the monkeys (particularly the smaller animals) lifted a proportionally very heavy weight several times to crack each nut. Second, the standing posture and bimanual grasp result in a striking action that is more difficult to control precisely than striking with a smaller stone held in one hand from a sitting position, as the chimpanzees at Bossou and Taï typically do [Inoue-Nakamura & Matsuzawa, 1997; Boesch & Boesch-Ackermann, 2000]. The seated position and the use of a smaller stone in one hand together afford more precise control of the strike force and trajectory than the standing bimanual action used by the capuchins with very heavy stones, because in the former case, fewer limb segments are coordinated during the movement, the trajectory of the stone is shorter, and the forces generated by the actor are closer to the normal range of forces exerted in daily activities—all features associated with more precise control [Bernstein, 1996]. The degree of control and the rate of success that the capuchins at Piauí achieved with their pounding are thus impressive.

Visalberghi [1987] predicted that pounding tool use would be most likely in wild capuchins in areas where a staple food is collected on the ground and requires extraction, and where anvil sites and pounding stones are available. Although these conditions are largely met at Piauí, the least supportive element in Piauí for stone-and-anvil tool use is that pounding stones are not locally abundant. Like the chimpanzees at Taï, capuchins in Piauí must bring stones that are heavy enough to crack the nuts to the anvils from a distance [Boesch & Boesch-Ackerman, 2000]. The source(s) of the river pebbles used by the monkeys, and the distance of the source(s) from the anvils remain to be determined, but from our observations of river pebbles on anvils at the tops of mesas, we predict it can routinely be at least 200 m. Continuing research on this fascinating phenomenon is under way.

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REFERENCES

Bachle T. 1994. Essentials of strength and conditioning. Champaign, IL: Human Kinetics. 549 p.

Bernstein N. 1996. On dexterity and its development. In: Latash M, Turvey M, editors. Dexterity and its development. Hillsdale: Lawrence Erlbaum. p 3–237.

Boesch C, Boesch-Achermann H. 2000. The chimpanzees of the Taï Forest. Oxford: Oxford University Press. 316 p.

Boinski S, Quatrone R, Swartz H. 2000. Substrate and tool use by brown capuchins in Suriname: ecological contexts and cognitive bases. Am Anthropol 102:741–761.

Fernandes MEB. 1991. Tool use and predation of oysters (*Crassostrea rhizophorea*) by the tufted capuchin, *Cebus apella apella*, in brackish water mangrove swamp. Primates 32:529–531.

Fragaszy D, Visalberghi E, Fedigan L. 2004. The complete capuchin. Cambridge: Cambridge University Press. 339 p.

Groves CP. 2001. Primate taxonomy. Washington, DC: Smithsonian Institution Press. 350 p.

Hill WCO. 1960. Primates. Comparative anatomy and taxonomy. IV. Cebidae. Part A. Edinburgh: University of Edinburgh Press. 523 p.

Inoue-Nakamura N, Matsuzawa T. 1997. Development of stone tool use by wild chimpanzees (*Pan troglodytes*). J Comp Psychol 111:159–173.

Langguth A, Alonso C. 1997. Capuchin monkeys in the Caatinga: tool use and food habits during drought. Neotrop Primates 5:77–78.

Matsuzawa T. 2001. Primate foundations of human intelligence: a view of tool use in nonhuman primates and fossil hominids. In: Matsuzawa T, editor. Primate origins of human cognition and behavior. Tokyo: Springer-Verlag. p 3–25.

Matsuzawa T, Biro D, Humle T, Inoue-Nakamura N, Tonooka R, Yamakoshi G. 2001. Emergence of culture in wild chimpanzees: education by master-apprenticeship. In: Matsuzawa T, editor. Primate origins of human cognition and behavior. Tokyo: Springer-Verlag. p 557–574.

Ottoni EB, Mannu M. 2001. Semi-free ranging tufted capuchin monkeys (*Cebus apella*) spontaneously use tools to crack open nuts. Int J Primatol 22:347–358.

Rylands AB, Schneider H, Mittermeier RA, Groves CP, Rodriguez-Luna E. 2000. An assessment of the diversity of New World primates. Neotrop Primates 8:61–93.

Visalberghi E. 1987. Acquisition of nut-cracking behavior by two capuchin monkeys (*Cebus apella*). Folia Primatol 49:168–181.