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Chimpanzees Using Stones to Crack Open Oil Palm Nuts in Liberia

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ABSTRACT. The use of stone-tools to open palm nuts (*Elaeis guineensis*) was studied in a group of 16 chimpanzees (*Pan troglodytes*) released from captivity to a natural island setting in Liberia. The behaviour was started by one female of the group; it then spread to 12 others over periods varying from a few seconds to a few weeks. Nut-cracking soon spread to three other sites, both spontaneously and with human encouragement. Both nuts and tools were carried distances of several hundred meters. Social interaction at cracking sites was rich and varied, ranging from fights over possession of tools to unsolicited sharing of nuts. Nut-crackers showed selectivity in choosing "good" nuts and varied their methods according to the qualities of the nuts. Individual differences in technique emerged. These are the first detailed behavioural data on palm-nut-cracking, and they show many parallels with nut-cracking of other species by chimpanzees of the Tai Forest, Ivory Coast. This is another example of hammer-stone use from a limited region of West Africa: southeastern Guinea, eastern Liberia, and western Ivory Coast. This suggests limited cultural diffusion of the custom.

Key Words: Chimpanzee; Tool-use; Oil palm; Lithic technology.

INTRODUCTION

Evidence of wild chimpanzees (*Pan troglodytes*) using tools to open hard-shelled nuts comes from several locations in West Africa. In Liberia, BEATTY (1951) saw an ape cracking palm nuts (*Elaeis guineensis*) on a rock anvil, using a stone as a hammer. Further evidence from Liberia was reported by ANDERSON et al. (1983), who found signs of chimpanzees opening four species of nuts (*Coula edulis*, *Panda oleosa*, *Parinari excelsa*, and *Sacoglottis gabonensis*) on roots or surface rocks using hammer-stones. STRUHSAKER and HUNKELER (1971) and RAHM (1972) found evidence of this type of tool-use in Tai Forest, Ivory Coast, where *Panda oleosa* and *Coula edulis* nuts were opened on surface roots with stone and wooden hammers. Direct observations of chimpanzees at Tai were made later by the BOESCHES (BOESCH, 1978; BOESCH & BOESCH, 1981, 1983, 1984a, b, c) who reported five species of nuts (*Coula edulis*, *Panda oleosa*, *Parinari excelsa*, *Sacoglottis gabonensis*, and *Detarium senegalense*) to be eaten, with stones or wooden clubs used as hammers on anvils of rocks, surface roots, or tree-branches.

Wild chimpanzees in Guinea (SUGIYAMA & KOMAN, 1979; SUGIYAMA, 1981) and in Sierra Leone (WHITESIDES, 1985) also use nut-cracking tools. SUGIYAMA and KOMAN saw chimpanzees using hammer-stones and anvils to open palm nuts (*Elaeis guineensis*). WHITESIDES found evidence of probable tool-use for cracking *Detarium senegalense*, which was later confirmed when an ape was seen cracking these nuts on a surface root, using a stone as a hammer.

Stone tool-use for nut-cracking was also studied in two groups of chimpanzees who have spent much of their lives in captivity. SUMITA et al. (1985) first elicited tool-use for cracking

walnuts (*Juglans* sp.) from chimpanzees caged alone. Then, they put three individuals who had acquired this tool-use habit together with 11 others in a setting with rocks and walnuts, in order to see if the technique would spread. The infants of the group showed interest, and one infant female who had closely watched walnuts being cracked with rocks later tried it. After some trial-and-error she was able to open walnuts in this way. SUMITA et al. believed that the adults of the group were not interested in the behaviour of the nut-cracking individuals, and that this explained why they did not acquire it.

BREWER (1982) reported another example of chimpanzees using stone tools, in a group released from captivity and being rehabilitated to living in a natural environment. Younger members of the group learned to open pods of *Afzelia africana* and fruits of *Oncoba spinosa* using stones, although they rarely succeeded in opening *Afzelia* pods, which had to be positioned just right. The two older members of the group, one male and one female, opened the pods with their canine teeth. The latter also hit the fruit of *Adansonia digitata* (baobab) against a branch or a stone without being shown how to do it, and the younger apes were then shown how to do this by BREWER.

This paper reports the spread of stone tool-use to crack open palm nuts in a group of 16 semi-captive chimpanzees living on a natural island in Liberia in a release programme of the New York Blood Center (PRINCE et al., in press). Apes were released onto an island from June 7 to August 13, 1985. Nut-cracking was first observed on July 20, when a female released on that day exhibited the behaviour. Nut-cracking was then acquired by others, including six juveniles who had already been on the island for six weeks and two adolescents who had been on the island for four weeks. These eight individuals had shown no interest in palm nuts or signs of tool-use before the release of the innovative female. Later, all acquired this skill, suggesting that they had learned the technique from her. Another adult female released on July 20 and three adolescent males released later also acquired the technique of nut-cracking, so that in the eventual group of 16, 13 were successful nut-crackers.

The senior author spent four months studying these chimpanzees in the laboratory before release and so knew all individuals. She was able to go onto the island with them and to record behavioural details as part of an overall study of captive apes adapting to life in a natural environment.

METHODS

SUBJECTS

The subjects were 16 chimpanzees, six males and ten females, ranging from 5 to over 20 years of age. All were wild-born in Liberia, and ten had been pets who were later given to Vilab II, the laboratory of The New York Blood Center in Liberia. At Vilab all chimpanzees lived in groups in outdoor enclosures. Information about the subjects is listed in Table 1.

SETTING

The chimpanzees were released onto a 9.7-ha island (island A) in a river near Robertsfield, Liberia (06°15′N, 10°22′W). The island was surrounded by a mangrove swamp which allowed access to another island (island B), 17.4 ha in area. Chimpanzees travelled to island B by

Table 1. List of subjects and details of nut-cracking.

Name	Sex	Age at capture	Age at release	Date released	Date first seen cracking nuts	% of days seen cracking nuts since: (a)	% of days seen cracking nuts since: (b)	Skill rating	Comments
Meryn	m	2 months	5	7/6/85	24/7/85	7.3	7.8	++	Made many mistakes on first day seen trying to crack nuts
Blamah	f	2 years	7.5	7/6/85	10/8/85	20.0	30.0	++	
Maria	f	1.5 years	6.5	7/6/85	18/9/85	2.9	9.1	++	Ate kernels of nuts *Helen* opened before trying to crack nuts
Helen	f	1 year	5.5	7/6/85	12/8/85	19.1	27.1	++	First subject seen climbing palm trees for nuts
Hermaphrodite	m	9 months	6	7/6/85	12/8/85	8.8	12.5	++	
Knut	m	2 years	6.5	7/6/85	—	0	0	0	Often eats kernels opened by others, but does not open nuts
Popeye	f	?	6.5	7/6/85	20/7/85	7.3	7.3	++	Opened nuts immediately after watching *Samantha*
Carolla	f	2.5 years	9.5	22/6/85	—	0	0	0	Does not seem interested in palm kernels (has tasted them)
Goldilocks	f	2.5 years	7	22/6/85	20/7/85	20.6	20.6	++	Opened nuts immediately after watching *Samantha*
Houdina	f	3 years	9.5	22/6/85	24/7/85	2.9	3.1	++	Stopped cracking nuts
Samantha	f	1 year	9.5	20/7/85	20/7/85	13.2	13.2	++	First subject seen cracking nuts
Grace	f	?	>20	20/7/85	12/8/85	10.3	14.6	++	Had many unsuccessful attempts to crack nuts
Maki	f	7 months	9.5	20/7/85	—	0	0	0	At first stole kernels from others, then lost interest
Daniel	m	6 months	10.5	13/8/85	13/9/85	12.7	24.0	+	Not as proficient as others—holds stone too loosely
Sokomodo	m	2 years	9.5	13/8/85	17/9/85	19.2	39.1	++	
Brutus	m	1 year	8.5	13/8/85	22/9/85	4.2	11.1	++	

Subjects listed in order of date released. (a) Date of first nut-cracking observation (20/7/85), or release date, if later; (b) date individual concerned was first seen cracking nuts. ++: Proficient; +: unskilled.

crossing at least 200 m of mangroves at the shortest distance between the islands. Chimpanzees were sometimes found on island B, particularly consorting pairs who temporarily left the group on island A. Both islands were completely forested, with dense vegetation in many areas. Paths were cut on both islands to allow human access. The chimpanzees used these paths as well as other smaller ones that they made. HENTSCHEL (1983) surveyed the trees on the islands using strip-transects to estimate numbers. The number of oil palms was estimated to be 97 on island A and 164 on island B. Two other species of tree, *Sacoglottis gabonensis* and *Parinari excelsa*, the nuts of which are cracked elsewhere (see above) were also found on these islands. The estimated numbers of each were 5 and 9 on island A, and 53 and 33 on island B. There were very few stones on the islands which could be used as tools.

During the rainy season the chimpanzees drank the water around the island, but in the dry season this water was too salty. Thus, a delivery system was made of a metal drum on a stand in the river (which collected rain or was filled with water from the laboratory) linked to a tap on the island. The chimpanzees were always fed at the same site, which was an area at the edge of the river cleared of vegetation, 18 m^2 at high tide and 30 m^2 at low tide. This was where the water tap was set. There was also a cage at the feeding-site, in which chimpanzees were kept before being released onto the island or before being returned to the laboratory (if for example, they were ill). This cage was 3 m long, 2 m wide, and 1 m high, and was made of wire mesh with a wooden floor and roof.

DATA COLLECTION

Data were collected on an *ad libitum* basis during time spent on the island (271 hrs). Observability was excellent, as subjects could be approached to within 1 m and could be followed around the island.

HUMAN INFLUENCE

Human intervention first took place four days after the first nut-cracking was seen. Four stones (two hammers and two anvils) were taken to the island. Stones were again taken to the island two weeks later and ten weeks later. Two other chimpanzees had begun cracking nuts before the first stones were taken to the island and two more cracked nuts on that day. Further interventions were: collecting palm nuts, showing chimpanzees the sources of this collection (three times), carrying nuts to cracking sites (three times), giving nuts to the apes to open (four times), and, in two cases, opening nuts and allowing chimpanzees who had not yet been observed opening them to eat the kernel (once each for *Meryn* and *Hermaphrodite*). Apart from this, the observer merely watched but did not teach the chimpanzees. The results below specify cases in which the observer's intervention could have influenced the subjects' actions.

RESULTS

ORIGIN OF NUT-CRACKING

On July 20, 1985 at 1000 hours three females were added to the group of ten chimpanzees already living on island A. Later that day, at 1600 hours, one of these females, *Samantha*,

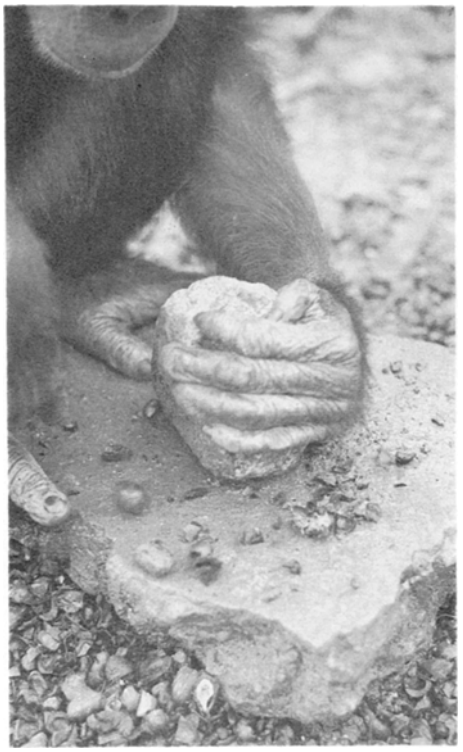

Fig. 1. *Goldilocks* holds a hammer-stone in her left hand. Remains of shells are on and around anvil.

was seen cracking palm nuts and eating the kernels. (There were many dried palm nuts lying naturally on the ground about the feeding-area.) After collecting several nuts, she placed them, one at a time, on the small concrete stand supporting the water tap in the feeding area. She then hit these nuts with a concrete block held in one hand. It weighed 1.6 kg, and measured $11 \times 13 \times 4$ cm. She did this skillfully, without prompting.

Spread of Nut-cracking Through the Group

Samantha's nut-cracking at the feeding site immediately attracted the attention of other chimpanzees, in particular *Goldilocks*. *Goldilocks* watched *Samantha* very closely, then picked up the hammer as soon as *Samantha* put it down and began to hit nuts on the concrete stand in the same way. *Goldilocks* succeeded in opening nuts, although she was more clumsy than *Samantha*, and tended to hit nuts too hard, breaking the kernel into many small pieces (Fig. 1). Another younger female, *Popeye*, also opened nuts, and a fourth female, *Grace*, tried to open nuts but was unsuccessful. She put the nuts on the ground to hit them, so they got pounded into the ground and were not opened. At this point there were ten females and three males on the island, with the three remaining older males yet to be released.

On the following two days *Grace* again tried to crack nuts, this time on the wooden floor of the cage at the feeding area. She still failed, apparently because she was not hitting the nuts hard enough. Apart from this, no other nut-cracking was seen in 12 hrs of observation over the three days following *Samantha*'s first nut-cracking.

The observer then took two stones (each weighing 1.5 kg) and two large concrete slabs

Fig. 2. *Blamah* watches *Goldilocks* cracking nuts at the feeding site, using a hammer-stone and concrete slab as an anvil.

(weighing about 15 kg each) to the island, intending the stones to be used as hammers and the concrete slabs as anvils. This was the first human intervention in the nut-cracking. The stones and slabs were placed at the feeding area. The first individual to use one of these stones was *Samantha*, who cracked nuts on the concrete tap stand. *Goldilocks* then used the other stone to crack nuts on a concrete slab. *Meryn* then tried to crack nuts. He made many mistakes, such as hitting an empty piece of shell, missing the nut, or holding a nut in his hand and hitting it against the concrete slab, but he persisted until he managed to open nuts and eat the kernels. *Houdina* also opened some nuts, quite skillfully, the first time she was observed to do so. *Grace* again tried but failed to crack nuts on the wooden floor of the cage.

On August 7 *Samantha* had a baby and showed less interest in nut-cracking for the next few weeks. However, four other individuals were now using stones to crack nuts, and the habit continued to spread through the group. For example, three weeks after the first nut-cracking observation, *Goldilocks* arrived at the feeding site with a handful of nuts, which she began to open. *Blamah* watched her very closely (Fig. 2), and then she too opened some nuts. Although this was the first time she had been observed to do so, she was quite skillful.

Within a month of the first nut-cracking observation, 9 of the 13 chimpanzees in the group cracked palm nuts using stones. Of the four remaining subjects, three still did not acquire this ability in the following three months. Of these three, *Knut* showed interest and sometimes he managed to eat kernels of nuts opened by *Hermaphrodite*, his close companion, but he never was seen to try to crack nuts. The other two, *Maki* and *Corolla*, seemed uninterested.

The three older males (*Daniel*, *Sokomodo*, and *Brutus*) released 25 days after the first nut-cracking observation all acquired the skill. For the first two weeks that these three males were on the island, the observer stayed at the feeding site, unless one of them was missing, in which case the observer searched the island. During this fortnight of more limited observations, *Goldilocks*, *Blamah*, and *Helen* brought nuts a few times to the feeding site to open, but the three males had not yet been seen cracking nuts (although there were two other cracking sites which the observer did not visit during this fortnight). The observer then gave some nuts to *Daniel* when he was sitting next to some stones at the feeding site. He took the nuts and opened them with the stones, although his method was a little clumsy. Four days later, when the observer was walking around the island, *Sokomodo* was observed cracking nuts at a site in the interior of island A, and five days later *Brutus* was also observed cracking nuts.

Geographical Spread

Three weeks after the first nut-cracking was seen, the observer took four stones (two hammers and two anvils) to another part of the island. These were put next to a palm tree with many nuts below it and not far from other palm trees with nuts around them. The group of chimpanzees followed and as soon as the stones were put down, *Samantha* and *Grace*, the two top-ranking females, collected handfuls of nuts and sat breaking these, not allowing any of the others who were gathered around to eat the kernels or use the hammer-stones. Each time *Samantha* ran out of nuts, she collected more in one hand, while keeping the hammer-stone in the other. When *Grace* ran out of nuts she collected more from 2–3 m away, leaving the hammer stone on the anvil and collecting nuts in both hands. Some of the others sat next to the hammer-stone and anvil, but they did not attempt to use them while *Grace* was collecting more nuts. *Samantha* and *Grace* continued opening nuts, then *Popeye* took over the hammer-stone *Grace* had been using while she was again collecting nuts. *Popeye* carried this stone to a fallen tree trunk 3 m away which she used as an anvil. *Grace* returned with nuts and searched around the anvil for the hammer-stone which she had been using. *Popeye* was within sight but *Grace* did not attempt to take back the hammer-stone from her. (She might well have done so if *Popeye* had been using the hammer-stone at the same place where *Grace* had

Fig. 3. Chimpanzees cluster around a cracking site on island A. One chimpanzee climbs up the palm tree to collect nuts. The palm tree is atypical in having a tree-trunk wedged against it. This had been placed there earlier by local people to collect palm nuts, but other palm trees on the island are climbed without such help.

left it.) Instead, *Grace* took her nuts and sat next to *Samantha* until she got a chance to take over *Samantha*'s stone, then she cracked her nuts.

The second nut-cracking site became well used (Fig. 3). When the chimpanzees were going round the island they often stopped to use the stones to crack nuts, which they often started to collect when the stones were not in sight.

Ten weeks after the first nut-cracking was seen, the observer took another four stones (two hammers and two anvils) to a third site on the island. The chimpanzees followed, and seemed to expect that these stones would be put down for them to crack nuts with, because each time the observer passed an area with many palm nuts, they became excited and watched her closely. When a suitable area (i.e., with nuts around and a small, level clearing) was found the stones were put down, and *Samantha* and *Grace* immediately began cracking nuts, not allowing the others to use the stones. (*Grace* attacked *Sokomodo* for using a hammer-stone while she was collecting more nuts—see below.) Eventually *Grace* and *Samantha* left the stones and the others got a chance to crack nuts. The third site was not in an area often used by the chimpanzees but it became so. They remembered where the stones were and often went there to crack nuts.

A further cracking site was found by the observer on island B, while looking for *Brutus* who had just been released and had disappeared. A large rock with a stone on top and nut shells all around was found 3 m from a palm tree. The large rock was partially sunk in the ground and the stone had been sitting 1 m from the rock, as could be seen from a hole left in the ground when it was moved. This site was not used as much as the other nut-cracking sites because the chimpanzees did not often go to island B. Another time when the observer went to look at this site there was a second hammer-stone and some more nut shells around the rock.

SOCIAL INTERACTIONS

At nut-cracking sites, many social interactions between individuals were recorded, both aggressive, such as fighting over the use of hammer-stones, and affiliative, such as the sharing of nuts (Fig. 4).

One example of aggression at a nut-cracking site occurred when *Sokomodo* took over a

Fig. 4. *Brutus* (right) reaches for the kernel of a nut that *Sokomodo* (left) has just cracked. *Brutus* grimaces and appears fearful about taking the kernel.

hammer-stone which *Grace* had just been using, while she was 2–3 m away with her back to him. *Grace*, on returning to see *Sokomodo* using the stone, screamed and jumped at him, then slapped him. *Sokomodo* immediately dropped the stone and moved away. When *Grace* went to collect nuts for a second time, *Sokomodo* again used the stone she had just put down. This time when *Grace* returned, she seemed even more upset than before, and she attacked *Sokomodo*, who ran off screaming. *Grace* pursued him for over 30 m until they were both out of sight, before she returned to crack nuts again. *Sokomodo* returned after a short time but did not try to crack nuts until the others had left the nut-cracking site.

There were also many cases of sharing and stealing of nuts at cracking sites. For example, *Helen* always allowed *Maria*, her close companion, to eat kernels of nuts that she had just opened. Once when *Helen* was cracking nuts, watched by *Maria* and *Meryn*, *Helen* continually allowed *Maria* to take kernels from the anvil, but each time *Meryn* reached toward the anvil, she slapped his hand. *Meryn* became more upset each time this happened and eventually left.

When one individual tried to take nuts from another who had just collected them, the reaction varied according to the individuals concerned and to their rank in the group. Responses varied from handing over all of the nuts just collected, to giving over some nuts then moving to another stone, to turning away and ignoring the individual trying to take nuts. The following incident involved both attempted stealing of nuts and then sharing of nuts. *Hermaphrodite* arrived at the feeding site with a handful of nuts and sat down at some stones to crack them. However, *Sokomodo*, who had been watching him from about 4 m away, then approached, presumably to take *Hermaphrodite*'s nuts, which he often did. *Hermaphrodite*, however, on seeing *Sokomodo* approach quickly went to *Goldilocks* (a frequent companion), who had just finished cracking nuts with some stones nearby. *Hermaphrodite* held out his handful of nuts to her. *Goldilocks* took these and began to open them, allowing *Hermaphrodite* to eat some kernels. *Sokomodo* watched them from about 2 m away, but did not approach or try to take the nuts.

Transport of Nuts and Hammer-stones

As the chimpanzees used up the nuts that were lying on the ground around the feeding site they began to bring nuts from other areas on the island, carrying them in the mouth, in their hands, or both. The observer collected nuts on July 24, 1985. These nuts were about 150 m from the feeding site which was out of sight. *Samantha* and *Goldilocks* both watched the observer collecting these nuts and then they collected nuts in their hands and took them to the feeding site where they opened them to eat. This was the first observation of nut-carrying. Following this, the chimpanzees were observed carrying nuts many times. Distances nuts were carried were not always verified, but at least once, *Goldilocks* carried nuts a distance of 265 m, passing an alternative nut-cracking site on the way and taking them to the feeding site to open. It was more common, however, for subjects to carry nuts to the cracking site nearest the collecting point. Sometimes subjects made successive trips around the island to collect nuts which they brought to the feeding site to open. For example, *Helen* once made five nut-collecting trips within 1 hr, and *Hermaphrodite* once made eight nut-collecting trips within 2 hrs. The chimpanzees also began to climb palm trees to collect nuts as well as collecting nuts which had already fallen.

Nuts were usually carried in one hand, but also in the mouth, the mouth and both hands,

the mouth and one hand, or least often, in both hands only. The type of carrying varied with the distance being travelled. A subject sometimes started by carrying nuts in the mouth, then transferred them to one hand. This often happened when the subject stopped to eat leaves on the way to the cracking site, thus the mouth was freed. *Blamah* once stopped, moved nuts from her mouth to her hand, ate some leaves, put the nuts back into her mouth, then moved on. Usually, however, once nuts were taken from the mouth they were then carried in one hand. When subjects carried nuts in their hands', this did not affect locomotion, unless nuts were being collected from palm trees, in which case hands had to be free for climbing and so nuts were carried in the mouth. Up to about six nuts could be carried in one hand, and the same in the mouth, with the exception of *Grace*, who filled her mouth with eight or nine nuts. *Grace* carried nuts more often in her mouth than in her hands.

As well as carrying nuts around the island, it became apparent that the chimpanzees were also moving hammer-stones from one area to another. Some "new" hammer-stones were found at cracking sites, i.e., ones which the chimpanzees had found and taken there, or marked hammer-stones which had been left in one area by the observer were moved to another area. The heaviest hammer-stone moved weighed 2.6 kg and was carried a distance of at least 175 m.

CHOICE OF NUTS AND METHODS OF OPENING

At first the chimpanzees collected any dry oil palm nuts that were lying below palm trees, but some of these had been lying on the ground for a long time and were empty. (Presumably, the kernel had been eaten by insects.) To begin with, the chimpanzees were often seen cracking the empty nuts, but this soon stopped and then they only collected and cracked nuts with a kernel. Many old and empty nuts remained, but the chimpanzees ignored the "bad" ones and collected only "good" nuts. The chimpanzees seemed to have learned quickly the good places to collect nuts, and, in places with many nuts on the ground, they sorted through these nuts, discarding some as soon as they had been picked up and keeping others in the hand. Thus, it seemed that the chimpanzees were using relative weight to decide which nuts were empty. (To test this, the observer collected two handfuls of about eight nuts each, deciding which were good and which were empty by weight alone; in all cases the nuts were classified correctly.)

Of the nuts cracked, some were drier than others. When a palm nut is completely dried out, the kernel shrinks and becomes detached from the surrounding shell. Less effort is needed to get kernels from these nuts because the nut only has to be hit once or twice to break the shell before the whole kernel can be lifted out of the remains of shell. When the kernel stays attached to the shell, however, and the nut is hit, parts of the shell break off but often a lot of the kernel sticks to the shell and is inaccessible. When cracking nuts with attached kernels, the chimpanzees did one of two things: Sometimes they hit the nut until some kernel was exposed, picked up the nut and ate the exposed kernel, put the rest of the nut with enclosed kernel back on the anvil, hit it again to expose more or all of the remaining kernel, which they then ate. This was repeated as many times as was necessary to obtain all of the kernel. Other times, the chimpanzees hit the nut and if the kernel remained attached they kept on hitting, breaking both shell and kernel, sometimes into four or five pieces. This yielded about five pieces of shell, each with an attached piece of kernel, and sometimes other small pieces of kernel. The chimpanzee then picked up each piece of shell in turn and bit off and ate the

adhering kernel, as well as any small pieces of kernel remaining on the anvil. This was when tolerated scrounging sometimes happened: Another chimpanzee would pick up a piece of kernel from the anvil while the nut-cracking chimpanzee was already eating a piece of kernel. In cases where the nut-crackers would not let others take pieces of kernel, they would put one hand in front of or over the pieces of kernel on the anvil, to keep possession. Most nuts cracked still had attached kernels, perhaps because these were more available than completely dried out nuts.

When collecting nuts directly from palm trees the chimpanzees sometimes found fresh palm nuts, i.e., ones which still had a fleshy outer husk. All the chimpanzees (including those who did not crack nuts) ate the outer husk of these nuts, but only *Goldilocks* was seen cracking a palm nut immediately after eating the outer husk from it. The shell of a de-husked, fresh palm nut is moist and pliable and is harder to break than a dried nut which has a brittle shell. (When the observer tested this, more hits of greater force were needed to open a nut with a moist shell, and dents appeared in the shell rather than cracks if the nut was not hit hard enough.) *Goldilocks* seemed to find it more difficult to crack fresh palm nuts than dry ones, but on the same day she was observed doing so, *Grace* was seen breaking open a fresh palm nut using her molar teeth, something which she had previously attempted with dry palm nuts without success. This suggests that although fresh palm nuts appear to be more difficult to open using stone tools, this is not because their shell is harder than dried nuts. Only *Grace* was seen opening a fresh palm nut with her teeth, the others discarded fresh palm nuts after eating the outer husk. *Goldilocks* was twice seen cracking fresh palm nuts with a hammer-stone, and two other times evidence was found of fresh palm nuts being cracked: Fresh palm nuts have a red-orange coating from the oily outer husk, so when they are cracked a red-orange stain stays on the anvil and hammer used. As only one of the 13 chimpanzees who cracked nuts was observed cracking fresh nuts, it seems that they prefer to crack the drier ones.

In all but one case, nuts cracked were palm nuts. *Maria* once cracked a different species of nut (*Sacoglottis gabonensis*), but the nut was empty and she did not find any others to open.

Individual Differences in Technique

On the whole, styles of nut-cracking varied little over the group, but small differences were seen in the techniques of *Daniel*, *Popeye*, and *Hermaphrodite*.

Daniel's nut-cracking did not improve like the others'. He did not grip the hammer-stone tightly, and so seemed to have less control over it. He also did not seem to exert any force, but merely let the stone drop from the height to which he had lifted it. As a result, he often had to hit nuts many times before they broke.

Popeye's manner of hitting nuts did not differ from the others, but she seemed to prefer using a fallen tree trunk as an anvil rather than a stone (Fig. 5). There was a fallen tree-trunk at the feeding site and at the second nut-cracking site, and *Popeye* often carried a hammer-stone and some nuts to them. She always used the same spot on the tree trunk at the second site, and this repeated use produced a dent in the tree, into which she set the nuts before cracking them. Before this dent appeared, nuts she placed on the tree trunk often rolled off. *Popeye* also was the only chimpanzee seen trying to use a wooden hammer, although the observer may have influenced her. The observer was hitting some nuts on the fallen tree trunk at site 2, using a stick (length 31 cm, diameter 7 cm) that was lying next to the tree trunk,

Fig. 5. *Popeye* positions a nut on a tree-trunk before hitting it with a hammer-stone.

to see if it was possible to break open nuts with it. The first stick used was too damp and soft, so a second, drier and harder stick (length 33 cm, diameter 8 cm) was then tried. More force was needed than with a stone hammer, but the observer succeeded in opening a nut with the second stick. *Popeye*, who had been watching, then picked up the softer stick and tried to crack some nuts with it. After about ten unsuccessful hits with this stick, *Popeye* put it down and picked up the stone she had used before. She was not observed to use a wooden hammer at any other time.

Hermaphrodite's technique differed slightly from the others, probably because of a deformity in his right hand: Only the thumb was normal in length, while the fingers were short, squint stumps, the longest being 4 cm long. *Hermaphrodite* always used his left hand to hold a hammer-stone, then put it down and used his left hand to pick up pieces of kernel, while other chimpanzees often kept the hammer-stone in one hand and used the other to pick up kernels. He did, however, use his right hand to keep others from taking his nut kernels.

DISCUSSION

These are the first extended observational data on palm-nut-cracking by chimpanzees, either in the wild or in captivity. (Previous studies of wild chimpanzees, e.g., SUGIYAMA, 1981, provided mainly indirect evidence, and no studies of captive chimpanzees and oil palm nuts seem to have been done.) As such, they can be compared with the BOESCHES' results on the cracking of other species by wild chimpanzees in the Ivory Coast.

The chimpanzees at the laboratory are frequently fed palm fruits, so that all chimpanzees in the group were familiar with palm nuts before arrival on the island. Some cages at Vilab

have concrete floors; other large enclosures have only sand floors, but these have shelters with concrete bases. The chimpanzees thus have a firm base upon which to crack palm nuts, but they do not have any hard objects which could serve as hammers and so they have not been seen cracking nuts. Eight of the ten chimpanzees living on the island before *Samantha*'s release showed no interest in palm nuts and never tried to open them until she did. Nor did these eight resident apes climb palm trees to collect palm fruits in order to eat the outer husk. After *Samantha*'s demonstration, the eight began cracking palm nuts. This sequence of events suggests that they acquired the nut-cracking technique by observation, or at the very least, had their memories prompted by her actions. Some individuals who took many trials and showed many errors seemed to show gradual learning. However, these data do not allow us to distinguish between observational learning and individual trial-and-error learning.

SUMITA et al. (1985) tried to follow the spread of tool-use in a captive group of chimpanzees by putting three subjects, who could crack open walnuts with rocks, together with 11 others. Of the 11, however, only one 3-yr-old female acquired the ability. SUMITA et al. believed that the five adults of the group did not acquire the behaviour for lack of interest in the behaviour of successful individuals. SUMITA et al. did not say if all of the chimpanzees liked to eat walnuts. On the island, *all* chimpanzees at first showed some interest; later, after all had eaten palm kernels, some lost interest. Two subjects who lost interest were *Maki*, who was not seen to crack nuts, but initially stole kernels from others, and *Houdina*, who cracked nuts a few times then stopped. Motivation thus seems to be important for the development of tool-use. Of the 13 subjects who acquired tool-use, some were seen cracking nuts more often than others (Table 1), which may also be related to motivation.

The tools used on the island can be compared with those used by wild chimpanzees. A stone hammer and anvil were used by a chimpanzee in BEATTY's (1951) report. ANDERSON et al. (1983) found stone hammers being used on rock anvils or surface roots. In contrast, most of the anvils and hammers used in the Tai Forest were wooden (BOESCH & BOESCH, 1983). (However, when scarcity of stone versus abundance of wood was taken into account, this showed a bias in favour of stone tools.) The BOESCHes also found that the material of the anvil and hammer used was significantly related to the kind of nut being broken. They found palm nuts could be broken with wooden clubs although more blows were needed than with a stone hammer. Thus, it seems to make sense for chimpanzees to use stone rather than wooden tools when these are available. The chimpanzees of Bossou (SUGIYAMA & KOMAN, 1979; SUGIYAMA, 1981) were observed using only stone tools, and there seemed to be plenty of suitable rocks and stones available. The hammer-stones of Bossou tended to be lighter than those of the island. (Of course, the range of stones was largely set by the observer, who supplied most of them, but there was still a tendency to use heavier ones.) For example, one stone of 7.1 kg which was taken to the island for use as an anvil was often used as a hammer (Fig. 6), even when there was at least one lighter hammer-stone available. At Bossou, however, the heaviest hammer-stone used weighed only 1.5 kg. The Tai chimpanzees often used stones of more than 7 kg to crack *Panda* nuts, which are harder to open than palm nuts, and one hammer-stone weighed 18 kg (BOESCH & BOESCH, 1984a). However, for *Coula* nuts, which are harder than palm nuts, the stones used usually weighed less than 2 kg (BOESCH & BOESCH, 1983).

Carrying of nuts to a cracking site was seen by BEATTY (1951), who watched a chimpanzee take "an armful of palm nuts" to some rocks to crack them. The distance carried was not known. BOESCH and BOESCH (1983) also observed nut-carrying, usually to an anvil

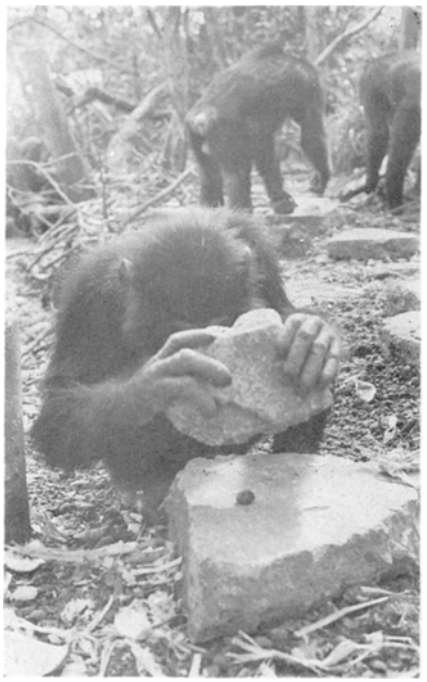

Fig. 6. *Meryn* cracks a nut on a concrete block at the feeding-site. The hammer is another concrete block weighing 7.1 kg.

in sight of the source of nuts. This may have been because there were many root anvils available, and so nuts did not have to be carried long distances. The Tai chimpanzees usually carried nuts in the mouth, but also in one hand, in the mouth and one hand, or least often, in the mouth and both hands. All of these methods of carrying were seen on the island, as well as using both hands only. Nuts were carried most often in one hand, which differs from Tai, where nuts were carried most often in the mouth. This difference may be related to the distance of nut transport. The island chimpanzees usually carried nuts short distances in the mouth, then transferred them to one hand. Sometimes only the latter stage of nut transport was observed, and so chimpanzees were observed most often carrying nuts in one hand, although they may have first been carried in the mouth.

BOESCH and BOESCH (1984a) reported cases of hammer-stones being moved from one cracking-site to another. This also occurred on the island: Marked stones left by the observer at one site were later found at another site or "new" stones found by the chimpanzees were taken to existing cracking-sites. The chimpanzees never set up a new cracking-site, i.e., they did not take both a hammer and an anvil to a nut source. There were no surface roots on the island suitable as anvils. In contrast, at Tai the chimpanzees could carry a hammer-stone and always find a surface root for an anvil. The island chimpanzees, however, did use opportunities as found, such as the two stones on island B which were used to crack nuts.

That the chimpanzees tended to use dried palm nuts for cracking agrees with other reports (BEATTY, 1951; SUGIYAMA & KOMAN, 1979; SUGIYAMA, 1981). Even the technique for getting at pieces of attached kernel seems similar: SUGIYAMA and KOMAN reported that little kernel attached to shells was found at cracking sites, but when they tried to crack palm nuts, much kernel remained in the shell which could not be easily detached. At least two possibilities might explain these findings: Either the Bossou chimpanzees only cracked nuts with detached

kernels (which seems unlikely, as such nuts are difficult to distinguish from dried nuts with kernels still attached) or they removed pieces of kernel from the broken shells, like the chimpanzees on the island. SUGIYAMA and KOMAN did not see this, as they could only watch three cases of nut-cracking from a distance.

The Tai chimpanzees used tools to crack five species of nut, but they did *not* crack the palm nuts available there (BOESCH & BOESCH, 1983). MCGREW (in press) in discussing this omission, found other cases of palm nuts being present, but ignored by chimpanzees. He hypothesized that these are cultural differences across populations. All known cases of chimpanzees using hammer-stones to crack nuts come from a small part of the wide ranges of both predator and prey species: southeastern Guinea, eastern Liberia, and western Ivory Coast. This suggests limited cultural diffusion in West Africa, perhaps from a single innovation. The findings reported here conform to this pattern, by adding another case from this region.

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REFERENCES

ANDERSON, J. R., E. A. WILLIAMSON, & J. CARTER, 1983. Chimpanzees of Sapo Forest, Liberia: Density, nests, tools, and meat-eating. *Primates*, 24: 594–601.

BEATTY, H., 1951. A note on the behavior of the chimpanzee. *J. Mammal.*, 32: 118.

BOESCH, C., 1978. Nouvelles observations sur les chimpanzés de la forêt de Tai (Côte-d'Ivoire). *La Terre et la Vie*, 32: 195–201.

———— & H. BOESCH, 1981. Sex differences in the use of natural hammers by wild chimpanzees: A preliminary report. *J. Human Evol.*, 10: 585–593.

———— & ————, 1983. Optimisation of nut-cracking with natural hammers by wild chimpanzees. *Behaviour*, 83: 265–286.

———— & ————, 1984a. Mental maps in wild chimpanzees: An analysis of hammer transports for nut-cracking. *Primates*, 25: 160–170.

———— & ————, 1984b. Possible causes of sex differences in the use of natural hammers by wild chimpanzees. *J. Human Evol.*, 13: 415–440.

———— & ————, 1984c. The nut-cracking behaviour and its nutritional importance in wild chimpanzees in the Tai National Park, Ivory Coast. *Int. J. Primatol.*, 5: 323.

BREWER, S., 1982. Essai de rehabilitation de chimpanzés au Niokola-Koba de chimpanzés auparavant en captivité. *Memoires de l'Institut Fondamental d'Afrique Noire*, Recherches Scientifiques dans les Parcs Nationaux du Sénégal, 92: 341–362. IFAN-Dakar.

HENTSCHEL, K., 1983. Report on tree survey. Unpublished manuscript.

MCGREW, W. C., in press. The chimpanzee and the oil palm: Patterns of culture? *Soc. Biol. Human Affairs.*

PRINCE, A. M., B. BROTMAN, A. C. HANNAH, M. DONNELLY, K. HENTSCHEL, & H. ROTH, in press. Rehabilitation and release to the wild of chimpanzees used in medical research. 1. Release to islands. *Primate Conservation.*

RAHM, U., 1972. L'emploi d'outils par les chimpanzés de l'ouest de la Côte-d'Ivoire. *La Terre et la Vie*, 25: 506–509.

STRUHSAKER, T. T. & P. HUNKELER, 1971. Evidence of tool-using by chimpanzees in the Ivory Coast. *Folia Primatol.*, 15: 212–219.

SUGIYAMA, Y., 1981. Observations on the population dynamics and behavior of wild chimpanzees at Bossou, Guinea, in 1979–1980. *Primates*, 22: 435–444.

———— & J. KOMAN, 1979. Tool-using and -making behavior in wild chimpanzees at Bossou, Guinea. *Primates*, 20: 513–524.

SUMITA, K., J. KITAHARA-FRISCH, & K. NORIKOSHI, 1985. The acquisition of stone-tool use in captive chimpanzees. *Primates*, 26: 168–181.
WHITESIDES, G. H., 1985. Nut cracking by wild chimpanzees in Sierra Leone, West Africa. *Primates*, 26: 91–94.

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