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Decaying wood is a sodium source for mountain gorillas

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Like several other non-human primates, mountain gorillas (*Gorilla beringei beringei*) in Bwindi Impenetrable National Park, Uganda consume decaying wood, an interesting but puzzling behaviour. This wood has little obvious nutritional value; it is low in protein and sugar, and high in lignin compared to other foods. We collected pieces of wood eaten and avoided by gorillas, and other foods consumed by gorillas, and measured their sodium content. Wood was substantially higher in sodium than other dietary items, and wood pieces from stumps eaten contained more sodium than those that were avoided. Wood represented only 3.9% of the wet weight food intake of gorillas, but contributed over 95% of dietary sodium, leading us to conclude that decaying wood is an important sodium source for Bwindi gorillas. Because sodium has been leached from the weathered soils characteristic of the subhumid and humid tropics, and because terrestrial plants generally do not require sodium, tropical herbivores, including gorillas, often encounter problems locating the sodium essential for their well-being. Decaying wood is an unexpected sodium source.

Keywords: wood; salt; sodium; gorilla

1. INTRODUCTION

Dietary recommendations for humans typically encourage a low sodium diet to avoid high blood pressure and other health problems, but many other primates must exhaustively seek sodium sources to meet their sodium requirements. Normally, only halophytic plants concentrate sodium, so the diets of herbivorous primates living in forested habitats are often sodium deficient. The National Research Council suggests a diet of at least 0.2% sodium for healthy captive primates (National Research Council 2003), but sodium levels in the staple foods of wild primates are often much lower (Calvert 1985; Silver *et al.* 2000; Rode *et al.* 2003). Consequently, herbivorous primates must supplement their diets with other foods or use innovative strategies to satisfy their sodium appetite (Denton 1984). Lowland gorillas (*Gorilla gorilla gorilla*) in western Africa congregate in swampy forest clearings with other herbivores to eat sodium-rich plants (Magliocca & Gautier-Hion 2002), and colobus monkeys (*Colobus guereza* and *Philiocolobus tephrosceles*) complement their diet with *Eucalyptus* leaves and bark (Rode *et al.* 2003). In deficient environments, sodium concentrations influence the distribution of herbivores across ecosystems (Weir 1972; McNaughton 1988), and regulate population size (Botkin *et al.* 1973). Elephants and ungulates travel to underground caves to exploit salty deposits (Denton 1984), and moose (*Alces alces*) feast on aquatic species that contain 300 times more sodium than plants commonly included in their terrestrial diet (Belovsky & Jordan 1981). Because tropical soils (Van Wambeke 1992) and most terrestrial plants contain low levels of sodium, it is in short supply and tropical herbivores are particularly susceptible to a deficiency.

Along with their vegetarian diet of leaves, stems, bark and fruit, gorillas in Bwindi Impenetrable National Park, Uganda (BINP) routinely eat wood from decaying tree stumps and logs (Stanford & Nkurunungi 2003). The reasons for wood eating are not readily apparent: its nutritional value is poor with lower levels of protein and sugar and more lignin than other diet items (Rothman *et al.* in press). Moreover, Bwindi gorillas are not alone in their predilection for wood. Gorillas in other areas also consume wood (Fossey & Harcourt 1977; Yamagiwa *et al.* 2005). Howler monkeys (*Alouatta* spp.) and spider monkeys (*Ateles* spp.) gather to consume decaying wood from the same wood hollow (Pinto & Setz 2004). In fact, many primates inhabiting tropical forests ingest or lick decaying wood, including chimpanzees (*Pan troglodytes*; Huffman & Wrangham 1994), ring-tailed lemurs (*Lemur catta*; Yamashita 2002) and mountain monkeys (*Cercopithecus l'hoesti*; Kaplin & Moermond 2000). The reason for this puzzling behaviour is unclear, but it has been proposed that wood may have a medicinal effect (Huffman & Wrangham 1994; Huffman 1997).

Based on observations of wood eating during a larger project on the nutritional ecology of the Bwindi gorillas, we hypothesized that wood was an important food for two reasons. In most observations, the dominant of two silverbacks and females fed on wood first, displacing juveniles and the subordinate silverback. Second, gorillas frequently returned to the same stump to feed on consecutive days, and spent many hours surrounding the stump as individuals took turns feeding.

Our hypothesis that wood might be a sodium source resulted from the unusual feeding behaviours associated with wood consumption. Sodium deficiency elicits a specific appetite and drive for sodium acquisition (Robbins 1993). As sodium is soluble, when herbivores are deficient, they may lick or chew items with high sodium levels. Besides ingesting wood, the gorillas sucked on wood for several minutes and then spat it out. Sometimes, gorillas licked the bases of tree stumps and the interiors of decaying logs. Often, the gorillas' gums bled from extensive wood chewing. The gorillas frequently broke off pieces of wood to carry and eat later on. To test our prediction that wood might be a source of sodium for Bwindi gorillas, we observed gorillas during wood eating and collected samples of wood consumed, wood avoided and other diet items, and analysed them for their sodium content.

2. MATERIAL AND METHODS

Approximately half of the world's remaining 740 mountain gorillas (*Gorilla beringei beringei*) live in BINP (0°53′–1°08′ S, 29°35′–29°50′ E), and there is one group habituated to humans,

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where observational data collection is permitted by the Uganda Wildlife Authority (UWA). During our study, the group consisted of two silverbacks, six females, four juveniles and three infants, and was observed for at least 4 hours daily by J. M. Rothman and assistants. We could not follow the gorillas for longer time periods because of regulations of UWA.

We collected pieces of wood ($n=15$) from the same tree stumps or logs from which the gorillas were feeding, and other foods ($n=85$) eaten on 319 days during 2002–2003. The amount of wood eaten by gorillas during a feeding session was estimated during focal animal sampling to establish the amount of wood removed from the tree stump, and by weighing representative pieces of similar size. To calculate the amounts of sodium contributed by foods ingested, we used weight-based estimates of food intake (Watts 1984).

During three feeding sessions, wood from nearby decaying stumps or logs (up to 2 m from chosen stumps) was not eaten. Because space constrained all group members from feeding on the same stump simultaneously, individuals not feeding on a particular log or stump could have fed on these nearby stumps, but they did not. Instead they fed on vegetation or rested until others finished feeding and provided access to the preferred wood. We considered these unused stumps and logs 'avoided', and collected samples ($n=4$) and compared them with wood eaten.

Mineral content (Na, Ca, P, Mg, K, Fe, Zn, Cu, Mn, Mo) was determined using a Thermo Jarrell Ash IRIS Advantage Inductively Coupled Plasma Radial Spectrometer. The dry matter, crude protein and acid detergent lignin content of wood pieces eaten and avoided were analysed as per our previous study (Rothman *et al.* in press).

Data were not normally distributed and had unequal variance; the variance of the sodium values (mg kg^{-1}) of wood pieces was greater than that of other diet items. Because the variance in the sodium content of wood pieces was higher than that of plant parts of different species, we considered wood pieces to be independent even though they may have been from the same species. Non-parametric tests were used and multiple comparisons were based on Dwass, Steel and Critchlow–Fligner pairwise rankings (Hollander & Wolfe 1999). Means are presented as mean$\pm$s.d.

3. RESULTS AND DISCUSSION

Wood eating by a group of Bwindi gorillas was observed on 35 of 319 days from August 2002 to July 2003 (figure 1*a*,*b*), during at least one day of all months of the year. Wood pieces consumed were significantly higher in sodium than were other diet items (Kruskal–Wallis, $p<0.001$; table 1). On a wet-weight basis, pieces of wood from the same stump where wood was consumed contained 92–1382 mg kg^{-1} Na (mean 537.0 mg kg^{-1}, median 334.0 mg kg^{-1}), while other diet items contained 0–61 mg kg^{-1} (mean 19.3 mg kg^{-1}, median 18.0 mg kg^{-1}). On a dry-weight basis (DM), the pieces of wood contained 100–1920 mg kg^{-1} Na (mean 810.7 mg kg^{-1}, median 690.0 mg kg^{-1}), while other diet items contained 0–720 mg kg^{-1} (mean 90.4 mg kg^{-1}, median 70.0 mg kg^{-1}). With respect to other minerals, on a DM basis, wood was significantly lower in Ca, P, Mg, K, Zn, Cu, Mn and Mo compared to other plant parts (Mann–Whitney *U*, $p\leq0.03$), and similar in Fe content ($p=0.44$). Our previous study demonstrated that wood was lower in protein and sugar and higher in lignin than other foods (Rothman *et al.* in press), suggesting that with the exception of its impressive sodium content the nutritional quality of wood is poor.

During three feeding sessions when wood was avidly consumed, nearby stumps, up to 2 m from the selected stumps were avoided. The avoided pieces ($n=4$) had much less sodium than those that were consumed (mean 75.7 mg kg^{-1} wet weight, 107.5 mg kg^{-1} DM; median 80.1 mg kg^{-1} wet weight, median 105.0 mg kg^{-1} DM; Mann–Whitney *U*, $p<0.01$). Wood pieces from the avoided stumps contained similar amounts of protein (Mann–Whitney *U*, $p=0.88$) and lignin (Mann–Whitney *U*, $p=0.29$) compared to pieces of wood from stumps consumed. Except for sodium, wood pieces avoided also contained similar amounts of all minerals compared to wood eaten ($p>0.05$), suggesting that gorillas may be choosing wood because it contains sodium.

Figure 1. Gorillas feeding on decaying wood from (*a*) stumps and (*b*) logs.

Sodium deficiency can result in poor growth, weakness and incoordination, softening of bones, impaired use of dietary energy and protein and/or reproductive failure (Robbins 1993). The sodium requirement of gorillas is not known, but moderately active humans can survive on 50–150 mg sodium d^{-1} (0.7–2.1 mg kg^{-1} body weight d^{-1}; Dahl 1958). Gorillas ate 223$\pm$181 mg sodium per feeding session, indicating that wood can provide a significant portion of their daily need. Owing to logistical constraints, we could not observe the gorillas for the entire day, so gorillas may eat more wood than we observed. During our observations, of all foods consumed, wood contributed the most sodium to the diet. Wood comprised only 3.9% of the mean wet weight intake of gorillas during our observations, yet it contributed 95.6$\pm$2.5% of dietary sodium, greatly surpassing the sodium contributions of other diet items.

Wood is not the only sodium source for Bwindi gorillas. Some frequently eaten foods, namely the piths of some herbs and thistle leaves, which grow in swampy areas of the forest, also contain appreciable amounts of sodium. However, these foods are 91–96% water, whereas wood is relatively dry (approx. 35% moisture). Therefore, large amounts of pith or thistle than wood would be needed to provide similar amounts of sodium. Bwindi gorillas that range

Table 1. Sodium content of foods (mg kg^{-1}) eaten by Bwindi gorillas. (Different superscripts indicate significance at $p \le 0.03$ between grouped plant parts.)

		dry weight		wet weight	
plant part	*n*	mean	median	mean	median
leaves	47	75.7±95.1	60.0[a]	18.5±15.1	14.3[a,b]
fruit	15	54.7±30.4	50.0[a]	14.8±9.5	11.5[a]
pith/stem	8	253.8±241.2	160.0[a]	30.0±16.8	35.8[b]
bark	15	75.3±25.0	70.0[a]	23.9±16.0	20.8[a,b]
wood	15	810.7±466.9	690.0[b]	537.0±411.5	334.0[c]

near park boundaries indulge in exotic *Eucalyptus* spp. bark (J. M. Rothman 2003, personal observation), which is commonly found in the forest edges and surrounding public land. Like decaying wood, *Eucalyptus* bark is low in protein, high in lignin and other polyphenolics, and low in sugar, but high in sodium (J. M. Rothman 2004, unpublished data), and *Eucalyptus* is the primary sodium source for primates in a neighbouring forest (Rode *et al.* 2003). In the nearby Virungas, mountain gorillas practice geophagy, which may provide needed sodium (Mahaney *et al.* 1990). We observed geophagy only twice during our study, when an individual ingested a single handful of soil. Since this behaviour is rare and the sodium content of Bwindi soils is low (Mwima & McNeilage 2003), geophagy does not appear to play an important role in providing sodium for Bwindi gorillas.

How endangered primates meet their mineral requirements is essential to assessing habitat suitability and generating conservation plans, because unusual foods may be important in providing micronutrients necessary for health (Oates 1978; Magliocca & Gautier-Hion 2002; Rode *et al.* 2003). Decaying wood is an unexpected sodium source and its value should not be overlooked. Further studies to explore whether our findings are generalizable to other habitats and species are needed.

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