



Small prey hunting technology and zooarchaeological measures of taxonomic diversity and abundance: Ethnoarchaeological evidence from Central African forest foragers

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Abstract

Archaeological analyses of faunal assemblages often rely on rationale derived from the prey choice model to explain temporal and spatial changes in taxonomic measures of diversity and/or abundances. In this paper, we present analyses of ethnoarchaeological observations and bone assemblages created by Central African Bofi and Aka forest foragers which show that different small prey hunting technologies target specific suites of prey and that hunters vary their technological choice depending on their foraging goals. Analysis of ethnoarchaeological bone assemblages produced by the Bofi and Aka shows that variability in target prey can create spatially distinct, but contemporaneous, faunal assemblages with different diversity values and abundance indices. These data reveal important variation in how individuals within a contemporary human population rank prey and challenge current assumptions about the meaning of diversity and abundances measures in archaeological contexts. We argue that the use of diversity and abundance indices can obscure important intrasite variability in prehistoric foraging effort and suggest strategies that might enhance current techniques.

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Building on a strong foundation of ethnographic research, archaeologists often use predictions derived from the prey choice model to guide interpretations of taxonomic diversity and relative abundances in zooarchaeological assemblages (Bayham, 1979; Broughton, 1994, 1997, 1999; Butler, 2000, 2001; Cannon, 2000; Grayson and Delpech, 1998; Grayson et al., 2001; Naga-

oka, 2002; Quirt-Booth and Cruz-Urbe, 1997; Schmitt and Lupo, 1995; Stiner et al., 2000; Szuter and Bayham, 1989). The prey choice model assumes that resources are ranked on a single scale of profitability, usually kilocalories obtained per unit of handling time (i.e., post-encounter return rate). Foragers attempt to maximize the rate of energy acquisition by adding resources into their diet in rank order from highest to lowest to maintain a high mean net return rate (e.g., MacArthur and Pianka, 1966; Pyke et al., 1977; Smith, 1983). The prey choice model predicts that foragers should always pursue high ranked

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resources whenever they are encountered. The inclusion of lower ranked resources in the diet depends on the chance of encountering higher ranked resources; lower ranked resources are added into the diet as a function of the abundance of high ranked resources. Ethnographic studies demonstrate that the prey choice model generally predicts overall resource selection for combined samples of adult foragers (Hawkes and O'Connell, 1982; Hill and Hawkes, 1983; Hill et al., 1987). Nevertheless, research also shows fine-grained individual variation in the diet breadth as a function of daily and seasonal variation in the profitability of some resources (Hill et al., 1984; Kaplan and Hill, 1992; Smith, 1991; Sosis, 2002) and the macronutritional content of the resource relative to the dietary needs of the forager (Hill, 1988; Hill et al., 1987). Since foraging efficiency is influenced by physical and environmental constraints and the foragers overall goal, resource choice often varies as a function of the sex, age, and composition of the task group (Bird and Bleige Bird, 1997; Hawkes et al., 1989, 1995; Hill and Hurtado, 1996; Hill et al., 1987; Hurtado et al., 1985; Lupo and Schmitt, 2002; Noss and Hewlett, 2001; Romanoff, 1983; Sosis, 2000; Weissner, 2002). Women foraging with their offspring, for example, may target resources that are easily handled by children or that can be efficiently taken in tandem (Hawkes et al., 1995). Children foraging by themselves may focus on low ranking, but easily handled resources because physical constraints limit their ability to efficiently collect and process some foods (Bird and Bleige Bird, 2000). Similarly, under certain circumstances, some men selectivity target inefficient or seemingly wasteful resource opportunities that have high social or political payoffs and/or that may signal desirable qualities (e.g., Hawkes and Bleige Bird, 2002; Lupo and Schmitt, 2004; Smith and Bleige Bird, 2000; Sosis, 2000; Weissner, 2002). The results of these studies do not diminish the overall value of the prey choice model, but show a greater range of complexity in foraging behavior than once imagined and have prompted new studies that focus on variation in foraging effort.

In an archaeological context, changes in prey taxonomic diversity or abundance indices in concert with rational derived from the prey choice model comprise powerful interpretive tools for identifying and explaining gross spatial and temporal changes in prehistoric diets. Declining abundances of high ranked prey, concurrent with an increased emphasis on low ranked prey, can signify changes in foraging efficiency resulting from resource depression, population growth, environmental change and/or technological innovations that change the costs of searching for or handling some prey (Bayham, 1979; Broughton, 1994, 1997, 1999; Broughton and Grayson, 1993; Broughton and O'Connell, 1999; Butler, 2000, 2001; Byers and Broughton, 2004; Cannon, 2000; Grayson and Delpech, 1998; Grayson et al., 2001; Janetski, 1997; Nagaoka, 2002; Quirt-Booth and Cruz-Urbe,

1997; Schmitt and Lupo, 1995; Stiner et al., 2000; Szuter and Bayham, 1989; but see Lyman, 2003). While these analyses use a variety of complex and simple measures to monitor different characteristics of zooarchaeological assemblages (Grayson and Delpech, 1998), all are based on similar underlying premises. All of these analyses assume that all foragers rank prey in an identical fashion and that prey are incorporated into the diet in a non-random fashion according to rank. Prehistoric resource rankings, however, are difficult to reconstruct and analysts must often extrapolate from a limited number of experimental and ethnographic data (also see Bettinger, 1991; Grayson and Cannon, 1999). For zooarchaeological assemblages analysts often assume that terrestrial fauna are ranked taxonomically by body-size. A corollary idea is that prey of similar body-size and overall anatomical proportions have similar relative ranks and may be considered as a group (e.g., Grayson and Cannon, 1999; Simms, 1987; but also see Jones, 2004; Smith, 1983). Larger-sized prey groups, such as artiodactyls, are higher ranked than smaller-sized groups of prey such as rabbits and hares. Empirical ethnographic and experimental studies show that when prey are acquired individually, larger-sized animals are generally higher ranked than smaller-sized prey (Hawkes and O'Connell, 1982; Kelly, 1995; Simms, 1987). Nevertheless, there are also important exceptions to this generalization. Extremely large-bodied prey such as whales or some pinnipeds often have excessive handling costs that depress their rank relative to overall body-size (Broughton, 1994, 1999; Jones, 2004; Smith, 1991). The circumstances of capture, especially the hunting technology used to acquire the prey, also influence resource profitability and relative rank (Bettinger, 1991; Grayson and Cannon, 1999). Mass collecting dense patches of some small-sized and low ranked prey, can be more profitable than might be predicted based solely on body size (Madsen and Kirkman, 1988; Madsen and Schmitt, 1998; Schmitt et al., 2004). Recognition that prey profitability varies as a function of circumstances of capture and hunting technology has lead some to suggest modifications to current methods of prey ranking (Grayson and Cannon, 1999, p. 150; Jones, 2004) and others to propose new criteria for ranking prey in archaeofaunal contexts (Stiner et al., 2000).

A second premise guiding these analyses concerns what archaeofaunal diversity and abundance indices actually measure (e.g., Cannon, 2001; Grayson, 1984; Jones, 2004; Lyman, 2003; Ugan and Bright, 2001). Archaeologists assume that there is a relationship between measures of prey abundance and diversity and some measure of prehistoric diet breadth. Problems arising from sample-size, preservational bias, excavation techniques, taphonomic and other factors that can influence measures of diversity and abundance are widely recognized (Cannon, 1999, 2001; Cruz-Urbe, 1988; Grayson, 1984; also see Lyman, 2003) and in some cases,

statistical and methodological techniques can help identify and compensate for some of these factors (Cannon, 1999, 2001; Grayson et al., 2001; Schmitt and Lupo, 1995). But considerably less attention is given to how variation in resource choice as a function of age, sex and other factors might influence measures of diversity and abundance in archaeofaunal assemblages (but see Bird and Bleige Bird, 2000).

In this paper, we present data on how variation in choice of hunting technology and target prey among contemporary Central African foragers creates bone assemblages associated with very different measures of prey diversity and abundance. Data reported here show that hunters vary their investment in different hunting technologies depending on their overall foraging goal. The range of prey taken with different technologies can produce different measures of prey diversity and abundances, which are manifest in ethnoarchaeological bone assemblages from temporary forest and residential camps. We argue that variation in choice of hunting technology as a function of age and sex is linked to tradeoffs hunters make in gaining consumptive and non-consumptive benefits derived from acquiring meat. The differences in prey diversity and abundance measures displayed by faunal assemblages created in these contexts are linked to the benefits associated with acquiring different prey, but do not involve real changes in the encounter rates with different animals or foraging efficiency.

Central African Bofi and Aka forest foragers

Data on hunting technology and prey capture were collected as part of an ethnoarchaeological study of two nomadic forest forager groups, the Bofi and Aka. These foragers occupy the villages of Grima and Ndele located in the N'gotto Forest Reserve in the southwestern Central African Republic. Data were collected by focal follows and interviews conducted over a 218 day period spanning two wet and dry seasons between 1999 and 2003.¹ Collections of bone assemblages representing individual meals and camp middens also provided information about hunting and prey exploitation patterns.

The Bofi and Aka are ethnolinguistically distinct, but related populations that use the same hunting technology, share many material traits, and have similar cultural beliefs (Lupo and Schmitt, 2002, 2004). Both groups have close social and economic ties with settled farmers that involve the exchange or sale of forest items, espe-

cially meat, for manioc and other products (Kitanishi, 1995). The relationship between foragers and farmers is believed to be very old and extend back some 2000 years to when Bantu horticulturalists arrived in the area.

The Bofi and Aka occupy permanent residential camps and a series of temporary forest camps throughout the year. Permanent residential camps are maintained next to farmer villages and may be occupied for up to 6 months or longer by segments of the forager population. The foragers also use a series of temporary forest hunting camps as bases for procuring forest resources for trade and consumption. These camps may be occupied for up to several months by a single family or larger population aggregates.

The N'gotto Forest Reserve is comprised of a complex heterogeneous mosaic of tropical microenvironments including forests, ephemeral wetlands, and so-called wet savannas (Bahuchet and Guillame, 1982). Bofi and Aka subsistence depends on wild plants, honey, invertebrates, and hunted wild animals available in these varied habitats (Kitanishi, 1995). All meat is obtained by hunting and, on rare occasions, scavenging wild prey. The most common prey are less than 10 kg in live weight and include blue duikers (*Cephalophus monticola*), giant pouched rats (*Cricetomys emini*), and brushy-tailed porcupine (*Atherurus africanus*). Medium-sized prey (>10 to <25 kg) includes Bay and Peters duikers (*Cephalophus dorsalis*, *Cephalophus callipygus*), which are uncommon in and around Grima, but are encountered more frequently near Ndele. Larger-sized prey (>25 kg) such as yellow-backed duiker (*Cephalophus silvicultor*) and river hog (*Potamochoerus porcus*) are uniformly uncommon in this area. The largest traditional prey, elephant (*Loxodonta africana*), is currently rare and protected by law.

Bofi and Aka employ a variety of communal and individual hunting techniques targeting slightly different, but not mutually exclusive, suites of prey. Communal hunts can involve men, women, and children using hand made fiber nets and are well-described in the literature (e.g., Harako, 1981; Lupo and Schmitt, 2002; Terashima, 1983). While a variety of resources are encountered and pursued during these hunts, nets target dense but randomly distributed terrestrial prey that can be easily flushed, especially blue duikers (Fig. 1).

Individual hunting can involve 1–3 people and includes the use of spears, traps, snares, crossbows, and hand capture. The most common prey taken with spears are medium and larger-sized duikers that are too large to be caught in nets and other animals that are difficult or dangerous to handle, such as forest and river hogs, porcupines, and small carnivores. The hand capture of prey can involve the use of fire, dogs, and digging implements and is aimed at animals that are fossorial, solitary and nonaggressive, such as giant pouched rats, pangolins, and tortoises. Snares include pole noose snares made from

¹ The 218 days were not consecutive. We collected dry season data for 113 days over two seasons (1999/2000 and 2001/2002). Wet season observations were made for 105 days over two seasons (2002, 2003).



Fig. 1. Net hunt in progress.

fiber or metal cable. Metal cable snares are illegal, but are widely used by settled farmers and their use among foragers is increasing despite the high cost of the cable. Noose snares are generic in form but are scaled to the size of the prey. Snares target a wide range of prey, especially those known to use habitual runways or trails (see also Noss, 1995, 1998). Small traps are uncommon and include devices designed to entrap prey via complete enclosure. The two most common traps used in this area are quite specific to prey target and include a cone-shaped trap for murid mice and rats and a fiber purse or bag trap used to procure porcupines and occasionally giant pouched rats (Figs. 2 and 3). The woven cone traps are placed along known and visible rodent runways. Rodents are driven into the traps when the surrounding tall grass is set on fire. The purse traps are set close to known prey burrows or hiding places, such as thickets. Men and dogs then frighten the fleeing animal into the trap by making noise. Traditionally crossbow hunting with poisoned darts was used to procure arboreal prey such as monkeys, bats, and birds, but it is now largely replaced in this area by the use of guns.

Meat redistribution among the Bofi and Aka is guided, in part, by cultural rules that vary depending on how the prey was acquired (Bahuchet, 1990; Hudson, 1990; Kitanishi, 1998, 2000; Lupo and Schmitt, 2002). Prey acquired with nets during communal hunts must be shared with other individuals in a specific manner depending on their participation in the kill (see Bahuchet, 1990). For example, the individual who kills or is the first to touch the animal usually receives the head. Importantly, the kill from communal net hunts is not pooled or divided among all the participants. Although the meat from net kills must be shared according to obligatory rules, many participants walk away empty handed (also see Kitanishi, 1998). In contrast, prey acquired using individual technology is redistributed according to the wishes of the hunter.



Fig. 2. A Bofi boy holds two woven cone-shaped murid rat and mice traps.

Analyses of Bofi meat sharing from the 1999 to 2000 season, showed that while obligatory sharing rules are often not followed, prey distribution generally conformed to cultural prescriptions. Prey acquired in the nets is more widely distributed than prey caught by hand (Lupo and Schmitt, 2004). The hunter and his family generally consume prey acquired by individual techniques. These data also show significant age-related



Fig. 3. A Bofi man holds a large number of woven bag traps. This man (and his brother-in-law) specialized in hunting porcupines with these traps.

differences among men in the degree to which meat is shared within their own families and unrelated conspecifics. Younger married men shared significantly more net acquired meat with unrelated conspecifics than older married men and older married men shared more meat acquired with individual techniques with their families than younger men. We argued that variation in choice of hunting technology and target prey reflected variability in the benefits derived from sharing meat as a function in men's overall goal (Lupo and Schmitt, 2004).

Variation in choice of small prey technology, profitability, and target prey

While it is theoretically possible for an individual Bofi and Aka hunter to use any available hunting technologies, there is a high degree of individual variation in choice of technology (Lupo and Schmitt, 2004). Although adults of both sexes hunt, variation in the choice of hunting technology is more marked in men because they hunt more often and use a wider variety of hunting tools than women. Most men use several different types of hunting technology throughout the year and some men may actually use two or more different hunting technologies on a single hunting trip (e.g., net, spear, and knife). The degree to which hunting effort is diversified is highly variable (Lupo and Schmitt, 2004). Some men invest more time in net hunts, while others rarely participate in net hunts and rely on individual hunting technology. Table 1 shows the frequency of use of different hunting technologies among Aka and Bofi adult men for Grima and Ndele. A higher proportion of adult men from the village of Ndele regularly participated in net hunts than the men from Grima (64% versus 42%). More men from Grima combined communal and individual techniques to procure meat than the men from Ndele. In both villages, a small proportion of men relied entirely on individual techniques to obtain meat.

Selection of hunting technology by Aka and Bofi men is unrelated to access to hunting technology. Household inventories show that most men either own or have access to most types of hunting technology, except guns and crossbows. Guns and cartridges are expensive and rarely owned by foragers. Farmers who own guns will occasionally hire foragers to hunt for them. Crossbows are quite rare and owned by only a handful of Aka and Bofi. Furthermore, men can and often do borrow hunting tools, but if a man kills an animal with borrowed technology, he must share the catch with the tool owner. For example, if a man catches a duiker in a borrowed net, he must give 1/2 the carcass to the net's owner. Selectivity in hunting technology also appears to be unrelated to the bush meat trade.² Blue duikers are most common

Table 1
Bofi and Aka men's hunting effort^a

Camp	Number of hunters ^b	Days of observation	Net-hunters ^c	Mixed ^d	Individual ^e
Grima	36	119	15 (.42)	12 (.33)	9 (.25)
Ndele	33	99	21 (.64)	8 (.24)	4 (.12)

^a Hunting effort measures the proportion of carcasses acquired by different hunting techniques in wet and dry seasons.

^b Number of adult men and teen-age boys who actively hunt. This category includes married and unmarried males between the approximate ages of 12 and 65.

^c The number and proportion (in parentheses) of men who acquired more than half of the meat they consumed/exchanged through net hunts.

^d The number and proportion (in parentheses) of men who acquired more than half of the meat they consumed/exchanged by using individual techniques. These men also participated in net hunts, which accounted for less than half of the carcasses they acquired.

^e The number and proportion (in parentheses) of men who only used individual techniques to acquire meat.

type of meat marketed in this area, but any animal acquired by hunters can be sold or exchanged for products. Prey value is scaled to body-size so that larger-sized animals command higher prices than smaller prey.

Some variation in choice of hunting tool is linked to seasonal changes in precipitation that influence the costs of net-hunting and other techniques, but not the encounter rate with different prey. There are no seasonal differences in the abundance and distribution of prey in this area (Bahuchet, 1992), but variation in precipitation does influence choice of hunting technology. In the dry season, the most common hunting technique is the communal net hunt, but nets are less often used during the wet season because excessive precipitation causes the fiber to rot and makes the nets heavier to carry (Hudson, 1990). Snares placed along known prey runways are particularly effective during the wet season when the runways are easier to locate in the wet forest soil than in the dry season. Hunting by hand and with spears and traps is practiced year round. However, rat-hunting by hand is less productive in the wet season because the rats can easily dig escape tunnels in moist forest soil.

In the wet season, men who primarily net hunt in the dry season use nets whenever it is possible. Some of these same hunters may broaden their choice of technology and rely on snares or spears while others simply hunt less during the wet season. Consequently, more men use a mixed hunting strategy during the wet season than in the dry season.

Some variation in choice of hunting technology also likely reflects differences in an individual hunter's skill, quality of hunting technology, and kin resources. For example, two Bofi hunters in the Grima sample were particularly skilled at trapping porcupine with bag traps and some men were reputed to be better with spears than others. But skill increases with practice, and men who selectively use some technologies more than others gain competency hunting with those technologies. Similarly, since net-hunting success is linked to net-size, hunters with larger-sized net invest more time in communal hunts than men with smaller-sized nets (e.g., Harako, 1981; Ichikawa, 1983). Hewlett (1991, 1996) found that men with a larger number of close male kin in residence participated in net hunts more often than men who lacked kin resources.

Profitability of different small prey hunting technology

While a variety of factors influence technological choice, rationale derived from the prey choice model predicts that hunters should selectively pursue those hunting opportunities that are most profitable as measured by post-encounter return rate. The profitability of different hunting technologies is measured here by the post-encounter return rate or kcal per handling time. Handling time includes time spent pursuing and dispatching specific prey after it is encountered³ regardless of the outcome. Handling time is summed for all of the foragers directly involved in the hunt. Thus, for communal net hunts the post-encounter return rates are determined by multiplying the handling time by the total number of people involved in the hunt. Table 2 shows the mean post-encounter return rates for the most common hunting technologies used by the Bofi and Aka. Note that of all the hunting technologies considered here (except trapping murid rats and mice), communal net hunts have the lowest return rates and are less efficient at capturing prey than most other types of technology.⁴ These results parallel the findings of other researchers in the Congo/Zaire Basin (Bailey and Auger, 1990; Kitanishi, 1995; Noss, 1995; Terashima, 1983). The hand capture of slow and docile prey, such as tortoises and pangolins, can be especially profitable because it does not involve pursuit time. Solitary spear hunting and snaring yield the highest post-encounter return rates as scaled by prey size. If men based their technological choice solely on post-encounter return rates, then many other technologies considered here should be selected over net hunting. Since medium-sized duikers are encountered less often than smaller-sized game, one might predict that hunters should concentrate on spear hunting blue duikers or porcupine. Many men who participate in net hunts also often carry spears and sometimes alternate between using nets and spears during any one net hunt. In fact, most of the spear hunts that we observed took place during net hunts.

In addition to differences among small prey hunting technologies in profitability, we have previously demon-

² Access to markets explained differences in the use of hunting technology (nets and crossbows) among the Efe and Mbuti (Bailey, 1991; Bailey and Auger, 1989, 1990; Wilkie and Curran, 1991). Access to markets does not explain the individual variation described here because there is no differential access to markets and meat vendors among individual men in the villages of Ndele and Grima.

³ As discussed in Lupo and Schmitt, 2004; net hunting handling time does not strictly fit the definition of "post-encounter." Nets are set up in the forest where prey is likely to be encountered and beaters attempt to flush animals hidden in the brush into the nets. Occasionally, animals are observed and nets quickly raised in the hopes of capturing the animal. However, for most captures, animals are not encountered or even observed before the nets are cast.

⁴ This contradicts findings reported in Lupo and Schmitt (2002). Our analysis of 1999/2000 dry season data from Grima showed that net hunting yielded 330 kcal/h. The data presented here include a larger sample of net hunts from wet and dry seasons and should supercede previously reported values.

Table 2

Post-encounter return rates and risk of failure for common Bofi and Aka prey and hunting technologies

Hunting technology	Target prey	Live weight range (kg) ^a	N ^b	Post-encounter return rate (kcal/h)	Risk of failure ^d
Nets (Grima)	Small duikers	3.5–9.0	42	106	.96
Net (Ndele)	Small duikers	3.5–9.0	43	215	.86
Spear	Peters/Bay duiker	15.0–24.0	15	6769	.39
	Blue duiker	3.5–9.0	13	3044	.39
	Brush-tailed porcupine	1.5–4.0	8	2152	.43
Snares	Various	—	18	4909	.50
Hand	Giant pouched rat	1.0–1.4	30	561	.52
Hand ^c	Various species	.025–2.7	15	352–5543	.00
Traps	Brush-tailed porcupine	1.5–4.0	10	1037	.70
Traps	Murid rats and mice	.025–.065	11	10	.00

^a Liveweights after Kingdon (1997).^b Number of observations.^c Includes all other hand captured prey, except giant pouched rats. Animals in this category include: small birds, murid rats, and mice (except those that were trapped), bats, civets, tortoises, and pangolins.^d Rate of failure per individual hunter.

strated that some hunting technologies are more reliable in outcome than others (Lupo and Schmitt, 2002, 2004; see also Ichikawa, 1983). Specifically, our analysis of the hunting data from 1999 to 2000 field season from Grima showed that communal net hunts were associated with a higher risk of failure than rat-hunts. Here we expand that analysis to include the failure rate for other types of hunting technology (Table 2). The risk of failure for most hand captures (except giant pouched rats) is negligible because once a pangolin or tortoise has been found success is virtually assured. Most hand captured prey are opportunistically acquired because foragers are always checking under trees, in dense brush and under fallen logs for any type of prey while they are foraging. We could not calculate an accurate risk of failure for trapping murid rats and mice the woven cone traps simply because we never observed any failed attempts. But it is likely that this hunting technique fails at least some of the time. The risk of failure for snares is about 50%, but success with this technology is highly variable and depends on the number of snares and level of diligence invested in monitoring the snares. Most hunters checked their snares every two to three days depending on the weather, but heavy precipitation and other time commitments often prevented hunters from monitoring snares in a timely fashion. As a result, approximately 9% of the animals obtained with snares were abandoned because the carcasses were putrefied by the time the hunter retrieved them (also see Noss, 1995, 1998). A much smaller proportion of the animals obtained with snares (<1%), escaped before the hunter could kill the animal or check the snare.

Of all the techniques considered here, net hunting is associated with the highest risk of individual failure. As we discussed elsewhere (Lupo and Schmitt, 2002), even though net hunting can return some animals nearly everyday, the number of carcasses retrieved is far lower than the number of participants. Table 2 also shows that

the risk of failure is lower at Ndele than Grima. The forested area around Ndele is more prey rich than the area surrounding Grima and this lower risk of failure and higher profitability of net hunting may explain why more hunters in Ndele than Grima prefer to net hunt.

Clearly, the consumptive payoffs for communal net hunting are lower than other available hunting technologies, so much so that one might question why hunters bother with net-hunts. Hunters invest effort in different types technologies, not so much to obtain a specific animal, but to obtain the nonconsumptive payoffs resulting from sharing meat acquired with specific technologies. Elsewhere we argued that men vary their hunting effort depending on their overall foraging goal and the trade-off's between gaining consumptive and nonconsumptive benefits (Lupo and Schmitt, 2002). Hunting with certain high risk technologies, such as nets, may potentially yield nonconsumptive benefits that can take many forms, including enhancing social relationships, forming political alliances, bonding with other hunters, attracting mates or signaling desirable qualities (e.g., Hawkes and Bleige Bird, 2002; Smith and Bleige Bird, 2000; Sosis, 2000; Weissner, 2002). Successful net hunts are witnessed by many participants and the successful hunters are known to all. Cash obtained from selling net-caught prey can be used to buy a variety of items that can also enhance social relations. Moreover, since the meat obtained in the net hunt is subject to both obligatory and demand sharing, participating in net-hunts may offer an additional incentive to individuals who are unsuccessful at acquiring prey with nets. Net-hunts are best viewed as foraging events where many different resource opportunities are potentially encountered (i.e., insects, nuts, fruit, and honey). Net hunts involve many people searching the forest for resources and it is possible that participation increases the chance of encountering food resources (Lupo and Schmitt, 2002). Some individual hunting

Table 3

Target prey obtained with different hunting technology for Grima and Ndele from 1999 to 2003 (wet and dry seasons combined)

Prey	Guns	Nets	Spear	Hand	Snare	Trap	Scavenge
Blue duikers	17	305	25	1	5	0	0
Medium duikers ^a	2	9	23	1	25	0	0
Large duiker	0	0	2	0	1	0	0
Forest hog	0	0	0	1	0	0	0
Porcupine	0	5	22	2	4	12	0
Pangolin	0	0	0	6	0	0	0
Civet/mongoose	0	1	1	3	2	0	0
Giant pouched rat	0	0	0	106	11	1	0
Marsh cane rat	0	0	0	0	1	0	0
Murid rats/mice	0	0	0	1	0	11	0
Cephus monkey	17	0	0	0	2	0	2
Bats	0	0	0	4	0	0	0
Tortoise	0	0	0	8	0	0	0
Serpent	0	0	1	0	2	0	0
Small bird	0	0	0	4	1	0	0
Horned-bill bird	0	0	0	0	1	0	0
Medium bird	0	0	1	0	1	0	0
Total	36	320	75	137	56	24	2

^a Medium duikers include Peters and Bay duikers.

endeavors are more profitable and lower-risk but tend to be more clandestinely pursued. The meat obtained from these ventures yield direct consumptive benefits for the hunter and his family (Lupo and Schmitt, 2002).

Small-prey hunting technology and target prey

Variation in choice of hunting technology structures the range of prey a hunter is likely to acquire. As discussed above, some types of hunting technology target specific suites of prey by taking advantage of certain behavioral attributes of the animal (see also Frison, 1991). In an analysis of a small sample data-set from the 1999 to 2000 field season we showed how the range of prey targeted by nets and traps and snares (combined) produced different measures of taxonomic richness and evenness (Lupo and Schmitt, 2002). Here, we expand that analysis to include a full range of hunting technologies and use a larger sample of carcasses ($N=650$) obtained between 1999 and 2003 for which the mode of capture is known (Table 3). Richness is defined as $\sum \text{TAXA}$ or the number of taxa in each assemblage. Evenness is represented by reciprocal of Simpson's index $1/\sum p_i^2$ where p_i represents the proportion of individuals in the total site aggregate that fall in species i (Cruz-Urbe, 1988; Grayson, 1984; Schmitt and Lupo, 1995). Because these data are observations of the number of acquired animals, richness, and evenness values are based on the number of individual carcasses captured with each respective technique.

Fig. 4A shows the range of richness and evenness values for the different types of hunting technology for wet and dry seasons combined. Traps and nets have low rich-

ness and evenness values because both take only a few species in any great numbers. For example, 96% of all animals taken in net hunts are blue duikers. Porcupines and murid rats/mice dominate the prey taken with small traps. Hand capture has a higher richness value than traps and nets, but the evenness value is quite comparable to that of net hunts. While many different types of animals are taken by hand, giant pouched rats comprise 81% of all hand captured prey. Spear hunting has high richness and evenness values, as does the use of snares. Of all the techniques considered here, prey obtained with noose snares have highest richness and evenness values. In this sample snares, but not traps, are more generalistic in target prey than many of the hunting techniques discussed here, especially nets.⁵ (also see Noss, 1995, 1998). Clearly, the richness and evenness values of some hunting technologies overlap. However, Fig. 4B shows that combined values for all of the individual techniques are higher than those of communal hunting.

To further investigate differences in measures of prey diversity resulting from the use of different hunting technologies, additional measures were derived from the published literature. Using ethnographic sources for different groups of Aka and forest foragers in other portions of the Congo Basin, including the Mbuti, Efe, and Bambote, we calculated prey diversity measures for net, hand and snare hunting. While there likely are some localized ecological differences throughout this larger

⁵ In 2002, we reported that traps and snares were more generalistic in prey target (Lupo and Schmitt, 2002). In that analysis, we combined the samples for traps and snares because they were small; the results reported here are derived from significantly larger samples and should supersede our previous report.

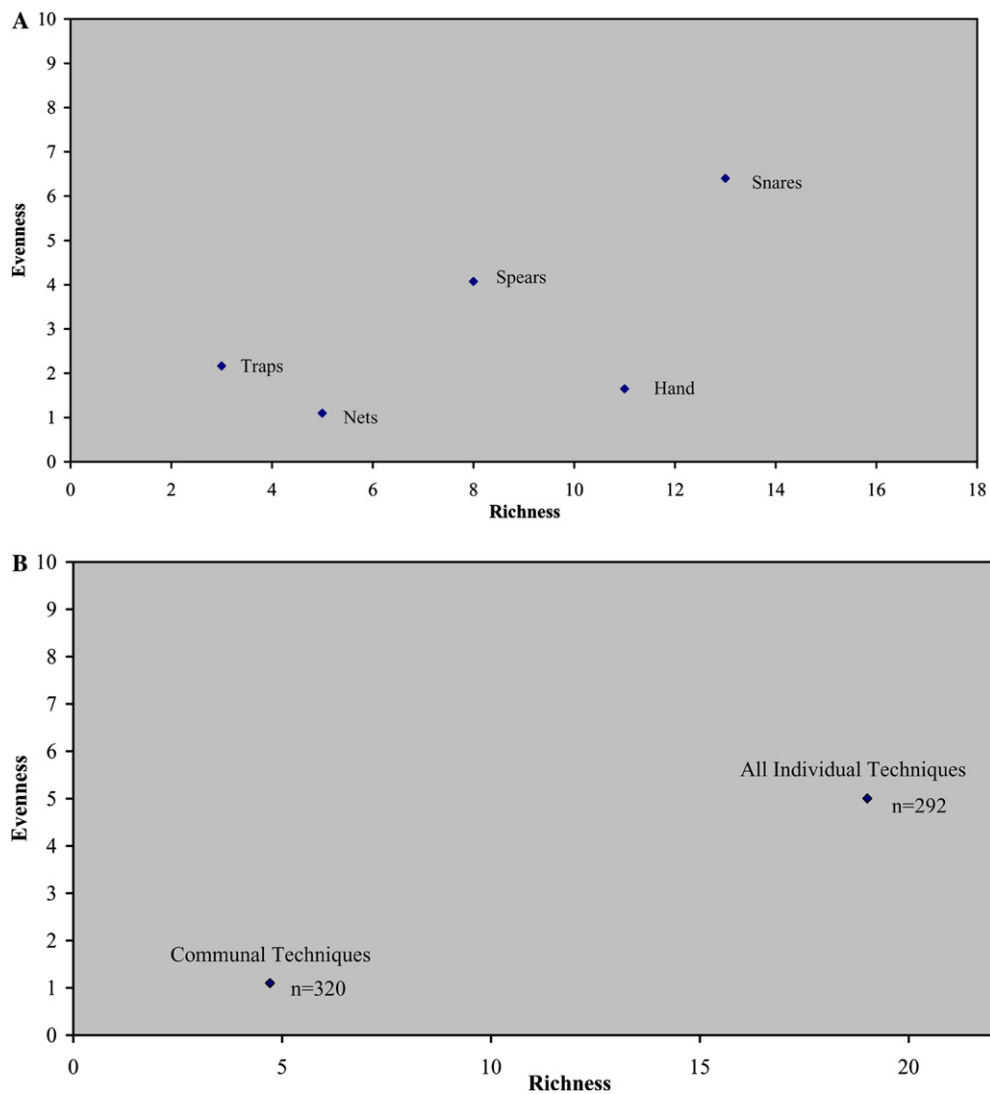


Fig. 4. (A) Hunting techniques. (B) Hunting techniques combined. Does not include prey acquired by scavenging or with guns.

region, all of these groups use some of the same hunting techniques and focus on the same small-sized prey as the Aka and Bofi. The results (Fig. 5) show that net hunting in several localities throughout the Congo Basin is associated with low richness and evenness values comparable to those in our data set. There is only one other hand capture sample and it compares favorably to ours. Several different snare datasets have values that overlap with the spear sample showing the range variation possible for this hunting technology.

Bofi and Aka ethnoarchaeological bone assemblages

During the course of our project, bone assemblages were collected from a variety of different contexts. Ani-

mal bones are discarded at both the permanent residential camps and temporary forest hunting camps and primarily represent refuse from meals. Given the small body size of the prey in this area, the discard of bones at field/butchery sites to reduce transport costs is rare.⁶ Prey carcass processing for transport in the field often involves evisceration and, in the case of medium and large carcasses, dismemberment. With very few exceptions, most carcasses are completely transported to temporary and permanent residential camps for further processing.

⁶ An exception is the forest hog, which is often consumed entirely in the forest. Foragers are reluctant to sell or share meat derived from this highly prized animal.

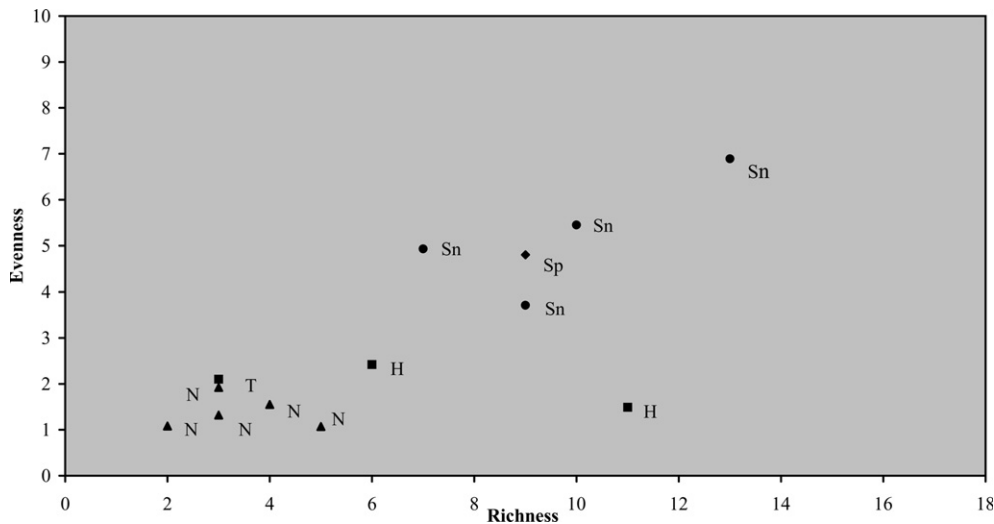


Fig. 5. Comparison data of hunting techniques: H, Hand; N, Net; T, Traps; Sp, Spear; Sn, Snare. Data derived from Harako (1981), Hudson (1991), Ichikawa (1983), Terashima (1983) and reported here.

Large bone assemblages in the form of middens accumulate at permanent residential camps. Since most structures in the permanent camp are routinely swept and the hearths cleaned, middens comprised of bones and other types of refuse accumulate behind and/or next to most residential structures. Temporary camps may manifest middens if the camp is occupied for more than a few weeks. Temporary camps occupied for shorter periods are not routinely cleaned and bones are simply tossed into the undergrowth surrounding residential structures. Camp dogs are ubiquitous and very quickly modify and deplete bone refuse deposited at all camp sites (Hudson, 1990).

Here, we report five assemblages collected from three temporary forest hunting camps and two permanent residential camps (Tables 4 and 5). We have observational data on the camp occupants, and the number and range of hunting techniques used in the formation of each assemblage, except one (Sungu). For this assemblage, we have partial observations and extensive interview data on the camp occupants and hunting activities that formed the assemblage.

The Bodenge 1 assemblage represents meals from a temporary net-hunting camp occupied for 15 days by a variable population of hunters. Camp residents changed frequently because foraging parties and meat vendors from Ndele made daily visits to the camp to participate in hunts, forage, and transport meat. A core group of nine related men camped continuously at Bodenge 1, but friends and relatives frequently joined them. Women and children visited the camp during the day but few stayed the night. Eight different net-hunts were conducted during the time that the site was occupied. Spear and hand hunts also were conducted but

were less frequent activities; most of the meat consumed at this camp was acquired by net-hunting. The site consisted of one residential structure and three large ramadas used as sleeping and eating areas spread over a 300 m² area. All of the discarded surface prey bones were collected immediately after the site was abandoned from areas inside and outside the structures and the overgrowth immediately surrounding the camp.

The Bodenge 2 assemblage consists of animal bones from two temporary spear and snare hunting camps. The assemblages are combined here because both sites were located in close proximity to one another (<500 m apart) and were occupied by five related families consisting of five men, five women, and four children. These families were neighbors in Ndele and the adult men often hunted together. Meat from animals acquired by any one of these hunters was shared among all the families. Combined, the camps contained five residential structures and one large communal ramada spread over a 50 m² area. All structures were swept and small middens were beginning to form next to some structures. The sites were synchronously occupied for approximately 8 weeks and all visible animal bones were collected from the middens and surface areas between the structures immediately after it was abandoned.

The Sungu assemblage is from a very large temporary forest camp used for hand, snare spear, and trap hunting. Because the site was occupied during the wet season, only a few net hunts were attempted at this location. The camp contains some 30 residential structures spread over a 3375 m² area that were intermittently occupied by approximately 50–60 people (men, women and children) over a three and a half-month period. Bones were

Table 4
Bofi and Aka ethnoarchaeological bone assemblages

Site	Dominant hunting activities	Occupation length (days)	Occupation season	NISP ^a
<i>Temporary hunting camp</i>				
Bodenge 1	Net	15	Late dry–early wet	589
Bodenge 2	Spear, snare	65	Late dry–early wet	126
Sungu	Hand, snare, and spear	75	Wet	229
<i>Permanent camps</i>				
Ndele 7	Net	180	Dry to early wet	195
Ndele 5	Spear and snare	730	Year round	172

^a Number of identified specimens.

Table 5
Assemblage composition of the ethnoarchaeological sites

Taxon/animal-size	Bodenge 1	Bodenge 2	Sungu	Ndele 5	Ndele 7
Blue duiker	414	5	27	56	108
Medium-sized duiker	80	105	15	68	37
Yellow-backed duiker	0	12	0	5	2
Large-sized monkey	0	0	0	2	0
Medium-sized monkey	0	0	18	7	8
Small-sized monkey	0	0	12	2	0
Giant forest hog	0	0	5	2	2
Brush-tailed porcupine	10	0	2	8	3
Civet	0	0	21	0	1
Mongoose	0	0	3	0	0
Pangolin	0	3	20	0	0
Giant pouched rat	21	1	72	4	12
Marsh cane rat	0	0	0	2	0
Undifferent squirrel	0	0	2	0	0
Serpent	0	0	2	0	4
Lizard	0	0	26	0	0
Tortoise	64	0	4	16	18
Total	589	126	229	172	195

collected from the surface areas and hearths 4 months after the site was abandoned.

The Ndele 5 and 7 assemblages are from two spatially discrete permanent residential camps associated with the Ndele village that were occupied by different families. Ndele 5 is an assemblage from a camp occupied by an extended family consisting of seven adults (two men and five women) and three children. The camp is comprised of four residential structures covering a 100 m² area. Although the adult women regularly participated in net hunts and opportunistically acquired prey by hand, the men in this family relied almost exclusively on spears and snares to obtain prey. Most, but not all, of the meat consumed at this camp was acquired by the efforts of the men. The camp was occupied intermittently by segments of the same family over a 2-year period. The bones were collected from surface areas surrounding the structures and had accumulated over an unknown period.

The Ndele 7 assemblage is from a camp occupied by an extended family consisting of six adults (three men and three women) and eight children. The camp has four

residential structures spread over a 330 m² area. Two younger men assisted by their wives and children acquired most of the meat by net-hunting and the occasional use of spears. All occupants opportunistically acquired prey by hand. One elderly man who occupied the camp occasionally hunted with porcupine traps, but was never successful during the period of our observation. This camp was newly constructed and occupied for less than 6 months when the bones were collected. The bones were collected from all of the surface areas adjacent to the features while the camp was still occupied.

Analysis of the ethnoarchaeological bone assemblages

As the previous analyses show, different hunting technologies target specific suites of prey and are associated with different diversity measures (richness and evenness). These results led us to question whether choice of hunting technology influenced measures of diversity, and by extension, the relative abundances of prey in zooarchaeological assemblages. The results of Hudson's (1991) analysis of

assemblages created by Aka foragers in the southern Central African Republic suggest a link between hunting technology and assemblage composition. Her analysis demonstrated differences in the taxonomic composition of two ethnoarchaeological faunal assemblages associated with temporary forest net hunting and trapping camps. She found higher proportions of blue duiker associated with the net hunting camp than the trapping camp, and the trapping camp assemblage contained higher proportions of rodent remains.

Nevertheless, the link between ethnographic observations and the material record is not direct because observations are made at different scales. Ethnographic observations are based on single events, while zooarchaeological assemblages may represent the sum of any number of different hunting events involving different individuals, each potentially using different hunting technology. The camp assemblages described here, for example, accumulated by the actions of different family/camp members. Even in camps where men mostly used nets to acquire meat, animals were still opportunistically acquired by hand, trap or spear by all family members. Similarly, in camps where most of the prey was taken using individual techniques, portions of animals captured in the nets were often obtained from net-hunters when the meat was shared. Furthermore, a host of taph-

onomic factors can greatly alter the expected content of ethnoarchaeological faunal assemblages in a very short period of time (Lupo, 1995, 2001).

Diversity and hunting technology

Table 6 and Fig. 6 shows the richness and evenness values for the Bofi and Aka assemblages described here. In the temporary camps, bone assemblage diversity values vary, but not entirely as predicted from the dominant hunting technology. The temporary net-hunting camp, Bodenge 1, is less rich than Sungu, but not Bodenge 2 where spears and snares were used. The evenness value for Bodenge 1 is lower than Sungu and consistent with our ethnographic observations which show that net hunting yields are usually dominated by a single taxon, in this case blue duikers (Table 5). Even though hand and spear hunting also occurred at Bodenge 1, this assemblage still has a lower richness and evenness value than Sungu. Sungu has a higher richness and evenness value than either of the Bodenge assemblages because bone specimens are more evenly distributed among the represented taxa and no single taxon dominates the assemblage (Table 5). The range of prey that occur in the Sungu assemblage such as pangolin, tortoise, giant pouched rat, lizard, and small

Table 6
Diversity indices and relative abundances for the ethnoarchaeological sites

Hunting camps	Hunting technique	Richness	Evenness	Duiker index	Interpretation
<i>Temporary forest camps</i>					
Bodenge 1	Net	5	1.90	.838	More blue duiker
Bodenge 2	Spear and snare	5	1.42	.041	Less blue duiker
Sungu	Hand, snare, and spear	14	6.74	.643	More blue duiker
<i>Permanent camps</i>					
Ndele 7	Net	10	2.79	.735	More blue duiker
Ndele 5	Spear and snare	11	3.54	.434	Less blue duiker

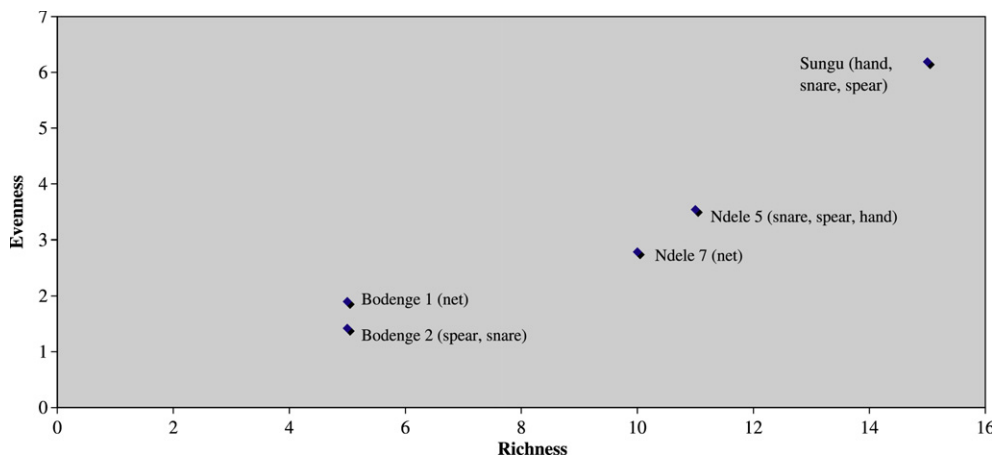


Fig. 6. Diversity values for the ethnoarchaeological assemblages.

carnivores, are those typically taken by hand or with traps and snares.

An exception to these results is Bodenge 2, the spear and snare hunting camp. While the major activity at Bodenge 2 was spear hunting, the assemblage is less rich and even than might be expected given these technologies. However, unlike all the other assemblages discussed here according to our observations and interviews, only a handful of kills (approximately 5 or 6) were made during the entire time the site was occupied and most of the bones in the assemblage came from these few kills. Despite the similarities in richness and evenness, the two Bodenge assemblages differ in one important way; unlike Bodenge 1, medium and large-sized duikers dominate Bodenge 2, a point that will be returned to below.

Interestingly, the richness and evenness values for the two permanent camps (Ndele 7 and 5) do not greatly differ. Despite the differences in the dominant mode of hunting technology used to form each of these assemblages, both are quite similar in diversity measures. Diversity measures are too insensitive to discern any appreciable differences between these assemblages. Nevertheless, and as with Bodenge 1 and 2, the assemblages do differ in the representation of different duiker species. Ndele 7 contains far more remains from prey acquired with nets (i.e., blue duiker) than Ndele 5.

These results show that the use of different hunting techniques, especially mass collecting technology, can influence measures of richness and evenness even in assemblages formed by several different hunting activities. However, the results are far less robust than might be expected if each assemblage was formed by only the use of only a single hunting technology (such as nets). Too, additional factors such as length and intensity of site occupation and season of site use might also influence measures of diversity.

Diversity measures and length and season of site occupation

All of the assemblages were formed over different lengths of time and reflect different intensities of occupation. Among the temporary camps, Sungu was occupied for the longest period of time and by the greatest number of people. Both permanent camps, Ndele 5 and 7 were occupied longer and more intensively than either of the Bodenge assemblages. Since all three of these sites have the highest richness and evenness values, it might be argued that duration and intensity of occupation more strongly influence diversity than differences in hunting technology (Table 6). While it is very likely the case that length and intensity of occupation have some influence of measures of diversity, our data do not show a one to one correlation between length and intensity of occupation and measures of diversity. If, for example, diversity varies as a function

of length of occupation, than we might expect Ndele 5 to have the richest and most even assemblage because this site was occupied far longer than any of the others described here (Table 4).

Given that variation in seasonal variation in precipitation can influence choice of hunting technology, it is also possible that season of occupation can appreciably influence diversity measures. Of all of these assemblages, Sungu was occupied during the heart of the wet season in 2001 and bone assemblages from this site likely reflect seasonal variation in choice of hunting technology. Interestingly, and importantly, some of the other camps described above were synchronously occupied during the late dry and early wet season of 2003. Different extended families that knew each other occupied Ndele 5 and 7 at the same time. The male hunters who occupied Ndele 7 were frequent overnight guests at Bodenge 1 and often participated in the net hunts, and the women from Ndele 5 visited and participated in some of the net hunts staged from Bodenge 1. Bodenge 2 was occupied at the same time that Bodenge 1 was used and operated. The men who occupied Bodenge 2 knew the occupants of Bodenge 1, but rarely participated in net-hunts and invested most of their individual efforts in hunting with spears, snares, and occasionally crossbows. Thus, differences in the taxonomic composition of these assemblages, as measured by diversity, cannot be attributed to seasonal variation in choice of hunting technology.

Abundances indices

Given the results of the previous analyses, we anticipated that hunting techniques would also influence measures of relative taxonomic abundance in the assemblages. Abundance indices are usually expressed as a ratio between 0 and 1.0 and defined as: $\sum i / (\sum i + \sum j \dots)$ where i and j are the taxonomic categories of comparison. Table 5 lists the duiker index for each assemblage because duikers are the most common prey in many of the assemblages discussed here. The duiker index is defined as: Blue duiker NISP / (Medium duiker NISP + Large duiker NISP + Blue duiker NISP). The higher the index value, the more blue duikers comprise the taxonomic classification of all duikers. Following Quirt-Booth and Cruz-Urbe (1997), any value higher than .50 indicates that blue duiker are more frequent in the assemblage than other duikers and values less than .50 indicate that blue duikers are less common relative to other types of duikers. We expected that the assemblages formed largely by net hunting will display high abundances of blue duikers exceeding .50 and those formed by other types of technologies should have abundances indices for blue duikers that are less than .50.

Relative abundance indices differ in predictable ways among the sites where net-hunting is the dominant mode of prey acquisition. In the Bodenge 1 net hunting camp,

blue duikers are more abundant than any other type of duiker (Table 6). Surprisingly, Sungu has a high duiker index indicating high relative abundances of blue duiker. But this value is misleading because duikers, in general, are poorly represented and only account for 18% of the assemblage (see Table 5). Bodenge 2 conforms to expectations and has a very low blue duiker index. The differences in abundances of blue duiker bones between the temporary net hunting assemblage and two assemblages created with individual technology are statistically significant ($\chi^2 = 231.86$, $P < .001$).

Despite the similarity in richness and evenness values displayed by Ndele 7 and 5, these assemblages show the expected differences in the duiker index given the dominant hunting technology used in each camp. Ndele 5 (spear and snare) shows a low relative abundance of blue duikers because medium and large-sized duikers are better represented and Ndele 7 (net) shows a greater abundance of blue duikers than medium and large-sized duikers. The differences in the abundances of blue duiker-to-duiker bones between Ndele 5 and 7 are statistically significant ($\chi^2 = 25.45$, $P < .001$).

In an archaeological context, variations in diversity and abundance indices in these sites could have profound implications for interpretations about subsistence. Recall that most of the sites described here, except Sungu, were occupied at the same time by foragers who occupied the same residential base camp. The residential base camp was comprised of seven spatially discrete camps all occupied at the same time; Ndele 5 and 7 are but two of those camps. Depending on which site(s) was excavated, very different interpretations about Aka and Bofi subsistence pursuits might be derived. The highly uneven and relatively narrow assemblages associated with the temporary net hunting camps might be interpreted as reflecting a more specialized diet than the more even and richer assemblages of the temporary snaring and trapping camp. The differences in the duiker abundance indices between some assemblages might be interpreted as reflecting important changes in the encounter rates with high ranked prey and declining foraging efficiency. Bodenge 2 and Ndele 5, for example, have low blue duiker indices and contain very high frequencies of medium-sized duiker bones relative to all other prey. These assemblages might be interpreted as reflecting higher encounter rates with high-ranked prey than net hunting assemblages with greater abundances of smaller-sized blue duikers relative to medium and large duikers. Although, one might argue that such temporary camp assemblages would be archaeologically obscure and are unlikely candidates for such analysis, the two base camp assemblages also showed similar significant differences in duiker abundance indices. As described here, the differences in prey abundances are linked to the hunting technology used to form each assemblage,

not any real changes in prey encounter rates or larger declines in foraging efficiency.

Implications for the archaeological record

The results of these analyses have implications for conventional assumptions about the meaning of archaeological measures of diversity and abundances and current approaches to prey ranking systems. Our results identify behavioral variation that can create circumstances where the content of faunal assemblages only reflect the foraging choices of a segment of the population, but not the entire population. Observational data on a large sample of hunted prey reported here show that different types of hunting technology often target different suites of prey. The link between prey behavioral attributes and the range of hunting technology used to procure the animal is not surprising and is well established (e.g., Frison, 1991). What is surprising is how hunters vary their foraging effort and how these foraging choices influence diversity and abundance measures in faunal accumulations. As discussed here, prey diversity and abundances in the Bofi and Aka assemblages vary partly in response to seasonal variation that limits the use of certain technologies. But hunters also selectively use certain technologies to target specific prey depending on their overall foraging goals (i.e., consumptive and/or nonconsumptive benefits). Under these circumstances, the differences in assemblage diversity and abundances are not linked to large scale changes in the diet breadth resulting from the declining availability of prey, nor are they a product of environmental change or technological innovation.

Variation in men's hunting effort

The variation in men's foraging effort described here is not unique. A variety of ethnographic studies document variation in foraging effort as a function of sex and age. Sexual variation in foraging effort is well documented (e.g., Hawkes et al., 1995, 1997; Hill et al., 1987; Hurtado et al., 1985) and researchers have recently quantified age-related variability in foraging effort. Bird and Bleige Bird (2000) describe how the foraging efforts of Meriam children on the Torres Strait target low-ranked but easily handled resources that satisfy immediate nutritional needs. Because children are more likely to transport and process resources at residential locations than adults (who may handle larger-sized and higher ranking prey items), middens may be artificially enriched by low ranking resources. Variation in men's foraging effort has also been documented by a number of researchers. Hawkes (1990, 1991, 1992, 1993; Hawkes et al., 1991) argues that East African Hadza men target big game that are associated with a high average return rate,

but a very high risk of individual failure (97% chance of failure). Although men could provide their families with more reliable sources of animal protein, such as small prey, most Hadza adult men do not pursue this option. Hawkes suggests that Hadza big game hunters derive political and social benefits by widely sharing meat with other unrelated people (Hawkes and Bleige Bird, 2002). Smith and Bleige Bird (2000; Bird and Bleige Bird, 1997) report that only 15.5% of Meriam men targeted high cost long-distance turtle hunting activities to procure meat for public feasts. They argue that providing turtles for public feasts may serve to signal qualities such as generosity, hunting skills, leadership abilities, and special knowledge. Depending on the participant's age and level of participation different social benefits can accrue, including increased social status or deferment in political and private disputes. Similarly, Sosis (2000) found that some Ifaluk men engage in high cost and inefficient torch fishing as a means of signaling their work ethic. Alvard and Nolin (2002) document variation in participation in communal whale hunts among the Lamelara islanders; many men participated in cooperative whale hunts but, a smaller proportion regularly used other (and more efficient) fishing methods. More recently, Weissner (2002) presents longitudinal data on Ju/'hoansi big game hunting. She argues that a variety of different benefits might accrue to hunters who target big game and that the value of these benefits changes during a man's lifetime. She specifically nominates political goals as an important factor shaping men's foraging effort.

As many have now pointed out, cross-cultural studies show that enhanced status can confer reproductive benefits on men and that status enhancement can be achieved by many different routes depending on local ecological, social, and historical circumstances (e.g., Borgerhoff Mulder, 1987; Cashdan, 1996; Cronk, 1991; Hill, 1984; Kaplan and Hill, 1985; Smith and Bleige Bird, 2000; Weissner, 2002). Sharing meat derived from high cost, risky, and sometimes inefficient hunting strategies seems to be one arena in which men strive to achieve social status in many foraging groups (see Weissner, 2002). While this line of research is still in its infancy, the available data suggest that these patterns are very pervasive among contemporary foraging societies, and it is very likely that similar types of variation existed in prehistoric foraging societies.

Hunting technology and prey ranking

Since variation in hunting effort linked to the use of different technologies can shape the content of ethnoarchaeological assemblages, it also has the potential to influence the content of archaeological faunal assemblages. Accordingly, analysts need to modify current techniques to be able to identify synchronic variation in hunting effort and distinguish it from apparent large

scale changes in foraging efficiency resulting from prey depletion, population pressure, climate change, and other factors. To accomplish this goal, archaeologists need to know something about how foraging effort and goals vary with respect to resource characteristics. As described here, ethnographic studies show that resources commonly exploited for nonconsumptive benefits are those that are high risk and expensive to obtain, but highly valued by many. If some types of foraging variation are linked to resource characteristics in a predictable way, it might be possible to identify the influence of different (and sometimes competing) foraging goals in prehistoric assemblages by modifying current assumptions about prey ranks and changing how diversity and abundance measures are calculated.

The conventional assumption is that prey rank is based solely on caloric profitability which often varies as a function of body-size. But given the link between capture technology and prey profitability, Grayson and Cannon (1999) argue that prey that can be acquired by mass collecting technology should be considered separately from animals that are individually acquired. Stiner et al. (2000; Stiner and Munro, 2002; Munro, 2004) argue that standard methods for calculating diversity are often insensitive barometers of dietary change and that more information on prehistoric diet breadths can be gained by considering the predator defense mechanisms that influence hunters access to prey, especially for smaller-sized fauna. Since there is a link between hunting technology and prey characteristics, as demonstrated here and elsewhere, then these approaches are calling for very compatible modifications to current analytical techniques. A consideration of prey characteristics and hunting technology, in concert with return rates (either experimentally derived or relative estimates), might illuminate potentially expensive, yet highly valued hunting strategies and important synchronic variation in foraging effort. Clearly, the identification of potentially expensive hunting strategies must consider all of the available hunting technologies, available prey and local ecological circumstances (i.e., encounter rates).

Large scale changes in foraging efficiency resulting from resource depression, population growth, ecological change and/or technological innovations should be reflected in the faunal assemblages of a number of archaeological sites, and should be supported by independent lines of material evidence such as diminution of size of certain prey (Broughton, 1997; Stiner et al., 2000), intensification of resource processing (Munro, 2004), known changes in the climatic record (Grayson et al., 2001; Schmitt et al., 2004), and changes in the types and frequencies of food acquisition tools (Byers and Broughton, 2004). Even so, analyses that identify larger scale changes in foraging efficiency might consider the wider

implications these changes have on men's foraging strategies. If, for example, a technological innovation decreases the handling costs and increases the profitability of a previously inefficient resource, the political and social benefits associated with targeting an expensive but highly valued prey might decrease as that strategy becomes available to more individuals. One expectation is that the nonconsumptive incentives for pursuing that resource will be removed and some other expensive strategy might replace it. But clearly other responses are possible depending on the circumstances (e.g., population increase or packing, climatic change) (see [Bettinger, 1999](#); [Hildebrandt and McGuire, 2002](#); but see [Broughton and Bayham, 2003](#)). A corollary question might be how external stimuli, such as trade, influence the paths used to attain political and social agendas. Moreover and by extension, how might these stimuli influence the value of pursuing expensive resources? Current understanding of how these changes might actually play out in a human population are poorly developed, but worthy of future research.

Zooarchaeological assemblages and taxonomic abundances

Because individual hunting variation can produce bone assemblages with vastly different measures of diversity and abundances, these data also imply that current analyses of taxonomic abundances and diversity may underutilize the available data. Abundance and diversity values derived from one or two sites or assemblages from within a single time period may not necessarily reflect the diet breadth for the population as a whole. Archaeological analyses based on prey diversity and relative abundances should begin by examining sites of similar age to identify the range of synchronic variation in foraging effort represented in assemblages. Analyses could combine both traditional approaches to diversity and abundances based on taxonomy or body-size and those based on prey characteristics and method of capture. The latter divisions would be especially valuable in identifying the influence of mass capture technology (see also [Lupo and Schmitt, 2002](#)). Closer attention to intrasite spatial variation in diversity or abundance indices calculated by prey characteristics and/or hunting technology within a single archaeological site might reveal important differences in foraging effort. Obviously, this approach will not be appropriate or useable for all sites, especially those that represent palimpsests, where the function and seasonality of the site may have changed over time. However, it might be applied to assemblages resulting from short term and/or redundant occupations with clear-cut spatially patterning in faunal assemblages. Small assemblages that likely formed as the result of a single occupation may also be profitably explored in this manner.

Conclusions

The prey choice model was originally formulated to be simple and have few assumptions. This stems from its historical roots as an explanatory tool in animal behavioral ecology. But more recent research on animal and human populations show that immediate energetic value does not always predict resource choice and highlights the need for models that take into account a greater range of complex decision-making ([Kelly, 1995](#); [Weissner, 2002](#)). This may be particularly true for humans who often target resources to meet a variety of foraging goals including those mitigated by social relations and cultural rules. We are not arguing that the prey choice model does not predict some dimensions of resource choice. However, fine-grained variation in forager diet breadth among different sex and age groups as documented here is prevalent among many contemporary foraging populations. In the past, analysts assumed that such fine-grained variability would be invisible or muted in archaeological assemblages. Here, we demonstrate how hunter selectivity as a function of overall foraging goals can appreciably influence the content of ethnoarchaeological faunal assemblages.

The larger challenge for archaeological analysis is twofold. First, archaeologists need to gain a greater understanding of variability in foraging effort and the circumstances that create such variation. We have documented one dimension of foraging variability that exists in a nomadic forest dwelling population and others clearly exist among contemporary foraging populations. Second, analysts need to try to develop analytical techniques to identify individual variation in foraging effort and distinguish it from larger processes, such as changes in foraging efficiency predicated by climatic degradation, prey depletion, technological innovation, and other phenomenon. While these tasks might seem daunting, we believe that recognition of the complexity of foraging decisions, especially as they relate to the acquisition of prey, can only act as a catalyst for zooarchaeological analysts to enhance and expand current analytical techniques.

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