

**Why do foragers share and sharers forage?:
explorations of social dimensions of foraging**

May 18, 2002

Michael Gurven[†]
Department of Anthropology, University of California-Santa Barbara, Santa Barbara, CA 93106
Email: gurven@anth.ucsb.edu
chatidye@hotmail.com (after June 30, 2002)

Kim Hill[†]
Department of Anthropology, University of New Mexico, Albuquerque, NM 87131
Email: kimhill@unm.edu

Felipe Jakugi
Mbaracayu Forest Reserve, Department of Canendiyu, Paraguay

[†]To whom all correspondence should be sent

Running Title: Social dimensions of foraging

Abstract:

Inferences made about typical foraging and sharing activities are almost always based on observations of these behaviors in a naturalistic setting. We examine: 1) To what extent are foraging groups random samples from the larger population? 2) If certain groups of individuals preferentially forage together, do these same groups also preferentially share with each other at the reservation? 3) Can we understand behavior in the forest context without consideration of the reservation, and vice versa? Among the Ache of Paraguay, we show that foraging treks are not representative of the larger population, individuals vary in the kinds of treks in which they participate, and those who tend to share together at the reservation are also more likely to forage together on trek.

Key words: hunter-gatherers, food sharing, behavioral ecology, social networks

Introduction

The Ache of Paraguay came to epitomize hunter-gatherer generosity after Kaplan and Hill (1985) first showed that their food sharing patterns were highly egalitarian. The Ache ethnographic case study has been invoked to support popular and academic accounts of the origins of human altruism and cooperativeness (Cosmides and Tooby 1992; Kameda, et al. 2002; Miller 2000; Ridley 1996). Kaplan and Hill (1985) showed that roughly 90% of small and large-sized game items were given to members of other families. While non-meat items were shared less widely, an impressive 60% of foods such as palm fiber, fruits, and honey were given away, on average, to non-family members. Subsequent analyses have shown that over the course of single two-week long foraging trips, members of each family give some food to members of every other family about 97% of the time (Gurven, et al. 2001; Gurven, et al. 2002). Conversely, sharing patterns observed among Ache while resident at a horticultural colony are less egalitarian than those observed during foraging trips. While the Ache of Arroyo Bandera still give away significant portions of game and cultigens (90% and 76%, respectively), single meat and non-meat resources are given to an average of only 3 (out of a possible 23) other families (Gurven, et al. 2001). Over the duration of a four-month study, a single family shared roughly 75% of its food production with only 3 other families.

The Ache are well aware of the differences in their sharing behavior while foraging versus while resident at the reservation. Many have commented on the difficulties of receiving shares in the large reservation population, and attest to the more desirable sub-group clustering of smaller sharing networks. Consistent with these views, explanations for the different sharing patterns in both contexts include a combination of ecological and social factors (Gurven et al. 2002). First, resources consumed at Arroyo Bandera are more predictable, and do not require

substantial cooperation in their production. Second, the number of potential recipients is much greater in Arroyo Bandera than in typical foraging camps. Third, living in wooden houses spaced about 100 meters apart allows for more privacy than the typical spatial structure of foraging camps.

The sharing patterns in these two contexts have generally been described in isolation, without consideration of how prior or expected future associations with the same people in one context may influence relationships in the other. It is important to recognize that *all* observed foraging trips, during which sharing and production data are collected, are temporary excursions leaving from and returning to a permanent residential colony. The lack of independence between life in the forest and life at the reservation raises several important questions about interpretations of behavior within each context. This paper therefore reconsiders aspects of Ache grouping patterns, foraging behavior, and sharing partnerships. We ask: 1) Are foraging groups random samples of the larger population, or do certain individuals and groups of individuals “self-select” to forage together? 2) If certain groups of individuals preferentially forage together, do these same groups also preferentially share with each other at the reservation? 3) If foraging and sharing partnerships are significantly correlated, then is the commonly reported pattern of communal sharing in the forest merely a consequence of extensive cooperation among groups of families back at the reservation? Would a more random sampling of individuals during foraging trips result in a less egalitarian sharing pattern? Conversely, we could also ask whether foraging partnerships lead to preferential sharing back at the reservation. 4) If sharing at the reservation is not an important predictor of foraging partnerships, then what other factors might explain the patterns of social interactions in the forest? If foraging is at all cooperative, we might expect that kinship, spatial proximity, are important predictors. 5) Do the observed patterns of sharing or

foraging reveal any pro-social consistencies in behavior? We explore these questions involving foraging and sharing partnerships by analyzing data on the composition of foraging treks of 23 Ache men leaving from the Arroyo Bandera settlement from 1995-99, and on sharing behavior of these men and their families at Arroyo Bandera in 1998.

These five questions are not limited to the Ache, nor to interpretations of food sharing patterns; they are general questions that are relevant for all anthropologists who make inferences about cultural patterns of foragers based on observations of individual behavior. First, they recognize that inferences made about foraging-related behavior based on research among groups of individuals who are no longer full-time foragers may require special consideration. Instead of concluding that studies among foraging groups with mixed economies are at best misguided, and at worst, completely inadequate for attempting to understand foraging-based adaptations (e.g. Schrire 1984), we argue that relatively recent behavior (e.g. farming, reservation life) can provide an additional source of variation that is very useful for testing general behavioral ecological models. For example, because the Ache now live on reservations, a day spent in the forest with others is the result of a conscious decision to leave the reservation and forage with others. Thus, foraging partnerships in the modern Ache context may reveal as much, if not more, about foraging partner preferences than if the Ache were constrained to forage everyday.

Second, the relevance of population structure and the actions or strategies of other individuals within a social group have long been recognized by game theorists and foraging theory specialists as potentially significant influences on individual behavior (e.g. Jochim 1988; Maynard Smith 1982), although empirical investigations of human foraging behavior have often ignored many aspects of social context, cooperation, division of labor, and behaviors of other group members. This neglect of social context is due to the fact that simple foraging models,

which historically have been mainly applied to non-social animals, ignore these complexities. Incorporation of frequency-dependent behavior into general foraging models can add considerable complexity (Giraldeau and Caraco 2000). Nonetheless, we may not be able to explain the abundant exceptions and outliers observed when testing simple foraging models against empirical data on humans (e.g. Hill, et al. 1987) unless we explicitly consider important aspects of frequency-dependent decision-making, social cooperation, grouping patterns, and age-dependent learning.

Study population: the Ache

Much has been written about Ache foraging behavior (Hill and Hawkes 1983; Hill, et al. 1987), demography and life history (Hill and Hurtado 1996), and food sharing patterns (Gurven, et al. 2000b; 2001; 2002; Kaplan and Hill 1985). The Northern Ache were full-time hunter-gatherers until the 1970s, at which time they were peaceably settled in several permanent communities where horticulture was introduced. The post-contact reservation period has seen high population growth due to high fertility and declining infant mortality. The majority of the calories consumed in the current Ache diet are derived from cultivated crops, including sweet manioc, corn, rice, and peanuts. They domesticate small animals such as chickens, and several individuals even have cows. On average, the Ache spend up to 25% of their time in the forest on trek, where the diet still consists mostly of wild game (especially nine-banded armadillos, pacas, and brown capuchin monkeys), honey, palm fiber, and seasonal fruits. More detailed comparisons between forest and reservation contexts can be found in terms of diet and time allocation (Hawkes, et al. 1987), demography (Hill and Hurtado 1996), and food sharing (Gurven, et al. 2002).

The Arroyo Bandera settlement was founded in 1980 when a group of Ache left the Chupa Pou settlement to accept the offer of a Protestant mission to live on the edge of a Guarani Indian reservation administered by that mission (Hill and Tikuarangi 1998). It is located a short distance (6 km) from the Mbaracayu Reserve, a ~600 km² region where the Ache forage. In 1998 there were 117 permanent residents comprising 23 nuclear family-based households living in Arroyo Bandera. Families live in small wooden houses, arranged in a circular fashion around a soccer field. Food preparation and consumption occurs either in exposed kitchen areas in the front of people's houses, or more rarely, inside the house. Every adult man possesses a bow and several arrows in his house, and is therefore equipped to go foraging on any given day.

Methods

Foraging trip composition

A continuous census of foraging trips has been collected by an Arroyo Bandera resident, Felipe Jakugi, since 1995, as part of a hunting sustainability project organized by KH. A 'foraging trip' or 'trek' can be defined as any departure from Arroyo Bandera to the Reserve for the purpose of extracting food resources from the environment. For each trip, Jakugi recorded the length of the trip in days, the identity of all hunters on the trip, and all game items killed by each member on each foraging day. Identities of women and children present on these trips were not recorded. Men usually travel alone on single-man, single-day trips. Women and children are more likely to participate on foraging trips that last at least several days. The sample we used for this paper includes 753 foraging trips involving 30 men in Arroyo Bandera between September 1995 and December 1999. This sample represents 6,365 man-days of foraging over a period of 52 months, which constitutes about 14% of all days. Comparison of Jakugi's notes with those of

others present on several of those trips, and of other researchers present in Arroyo Bandera in 1998, reveals that Jakugi's data are reasonably accurate.¹

Food transfers

Settlement food sharing data were collected in Arroyo Bandera over 55 sample days between February and May 1998. A total of 380 complete (mass=1,030 kg) and 635 incomplete (mass=1,247 kg) food distributions were sampled using a combination of focal-household cluster observations (87% of all distributions), focal-resource sampling (7%), and interviews (6%). Focal-household cluster observations were 3-hour observation blocks of all food distributions, consumption, and production events of all members of two or three households. Each household was sampled in this manner for an average of 56 hours, yielding a total of 1,294 house-hours of observation for all 24 nuclear family-based households in Arroyo Bandera. For each food distribution, Gurven and W. Allen-Arave recorded the donor, the original acquirer (if different), all recipients, estimates of total resource package size, and amounts given to each recipient. Amounts were either weighed using 10-kg and 25-kg Homs spring scales or counted (as in sticks of manioc) and then converted to kilograms or calories by using unit weight measurements of counted resources. Further details on sharing methodology are provided in (Gurven, et al. 2001).

The sharing data are best analyzed at the level of the nuclear family, rather than the individual, because many foods are often shared by household members other than the acquirer. For example, hunters' wives may share portions of meat or stew, while kids may share oranges or manioc roots that their mother harvested. Food is freely shared within the household, and an exchange between two households can occur if any member in one family gives food to any member of another family.

Because the composition and quantity of sharing partnerships is of primary interest, rather than the overall levels of sharing per se, we focus attention on the percentage of food production each family gave to the nuclear family of each of the hunters. We examine the distribution of all food types pooled, cultigens, foraged foods brought back from treks, and market foods purchased from local merchants. There was not a sufficient sample of domesticated animal sharing events to warrant a separate analysis of these foods.

Analyses

We examine bivariate relationships between variables using correlations, linear regression, and multidimensional scaling (see Appendix). For multivariate analyses, we use path analysis and multiple linear regression. Path analysis is used a method for exploring the relationship between foraging and sharing partnerships. Path analysis is useful for examining the relationship between two variables that are related to each other through a causal process involving other, usually co-dependent, variables (Gurven, et al. 2000a; Loehlin 1987). We use path analysis to examine the relationship between the percentage of *A*'s foraging days spent with *B* and the percentage of *B*'s foraging days spent with *A*. The other predictor variables included in this analysis include sharing of foraged foods and cultigens (where sharing is defined above), kinship (“Wright’s coefficient of relatedness with individual *B*”) and household proximity (“distance in meters to individual *B*'s house”). Kinship and proximity may be responsible for explaining the patterning of sharing and/or foraging partnerships, and so omission of these variables from our analysis could result in a spurious correlation between foraging and sharing partnerships where none exists.

The values for each path are calculated by solving a set of simultaneous equations. Path values are expressed as standardized parameter estimates, where one standard deviation unit increase in the variable at the base of each arrow in the path diagram causes an increase in the variable at the head of each arrow equal to the parameter estimate given in standard deviation units, controlling for all other effects in the model. One can assess the overall impact of X on Y (equivalent to the correlation between X and Y) by summing the direct effect of X on Y and the indirect effects of X on Y through intervening variables in the model. The path model was computed using the PROC CALIS procedure in SAS, which employs a maximum likelihood algorithm for estimating path coefficients (Hatcher 1994).

The fact that food transfers are dyadic in the sense that any piece of food is transferred between only one donor and one recipient, while foraging treks are multi-individual activities, does not invalidate the comparison of our measures of sharing and foraging relations. Any single distribution can have $n-1$ recipients, just as any foraging trek can include $n-1$ other members. While the range of observed sharing group sizes at the reservation and foraging group sizes may differ, the means and medians are similar (2 vs. 4 men, respectively), given the availability of 23 other men in the village. It is likely that individuals are more easily excluded from sharing distributions at the reservation than from participating on foraging treks in the forest, but this only makes our investigation of co-dependence between sharing and foraging relations more conservative.

Results

Foraging Trips

There were an average of 2.6 (s.d.=2.2) men present per trip in the sample of 753 trips from 1995 to 1999, for a mean duration of 2.3 (s.d.=2.5) days². A total of 41% of all trips were solitary trips (with 98% of these trips being single-day trips), while only 20% of all trips were multi-male and longer than 3 days. Table 1 presents the frequency of trips for each combination of trip duration and number of hunters. The mean length of multi-day trips was 3.2 days (s.d.=3.0), with 3.8 men (s.d.=2.3) present. Figure 1 illustrates the tendency for larger groups of hunters to go on longer trips ($r=0.46$, $p<0.001$). Little is known about how individual Ache men decide when and for how long to go foraging. Ache will often complain about meat hunger due to the relative scarcity of meat at the reservation, and this hunger may motivate a desire to forage. However, there is no centralized decision-making institution for organizing trips. Sometimes small groups of men may loosely plan a trip, but plans often do not result in a coordinated trek. Some trips are planned somewhat secretly, by invite only, where individuals discretely leave the reservation; other trips are publicly announced and discussed openly. Ache do not act as if certain group sizes are most desirable when foraging, even on extended trips, although pursuit group size may have an important effect on foraging return rates (Hill and Hawkes 1983; McMillan 2001). On both single- and multi-day trips, a greater number of hunters present on the trip is associated with a greater total quantity of meat calories acquired ($r=0.52$, $p<0.0001$; $r=0.55$, $p<0.0001$ for daily returns on single- and multi-day trips, respectively), although there is no relationship between the number of hunters and per-capita meat production ($r=-0.02$, $p=0.86$; $r=-0.09$; $p=0.33$)³.

There is substantial variation among men in the number of participated foraging trips, total days spent foraging in the forest, the mean number of other hunters present on participated treks (and the standard deviation), and the number and proportion of all foraging trips that were

solitary excursions. Table 2 presents these data and other summary statistics for the sample of 30 men. These results show that men differ substantially in the number of days they leave the reservation to forage, and in the type of trips in which they are most likely to participate. Men spent anywhere from 9 to 357 days (2 to 114 trips) in the forest, with anywhere from 0 to 57% of the trips without other men present. However, on average, men went on trips that contained anywhere from 2.1 to 5.5 other men (2.5 to 6.4 if these means are weighted by trip duration). Figure 2 shows the mean percentage of forest trips a man spent with a given number of other men (error bars represent one standard deviation unit). Again, there is much variation within and among men in the size of foraging groups in which they participate. Men tend to vary most in their frequency of participation in solitary and single partner hunting.

Sharing

The diet at Arroyo Bandera consists of cultivated foods, foraged foods, market-derived foods, and domesticated animals. While the Ache at the reservation continue to give a large percentage of their foods to non-family members, they tend to target distributions to only a few families. Figure 3 shows the percentage of food given to each other potential recipient nuclear family, with recipients ranked from those who received the most to those who received the least. A rank of 0 refers to the percentage kept within the nuclear family of the acquirer. The sharing of cultigens, forest foods, storebought items, or all foods combined, is marked by similar, steeply decelerating curves. A truly egalitarian sharing pattern would predict a relatively flat or slowly decelerating curve. However, we find that, on average, 82% of all cultigens, 81% of all storebought foods, 68% of all forest foods, or 77% of all foods combined, are shared within the family and with only four other families. The larger standard deviations in percentages of all

food given to the first several ranked families (displayed as error bars in Figure 3) indicate that families vary most in the extent to which they preferentially favor the few families who receive the most from them.

We can best summarize the distinguishing character of foraging and sharing partnerships in Figure 4. This displays the percentage of *A*'s forest days spent with each other *B*, ranked from those who were present for the most to the fewest number of days. The curve in Figure 4 is less steep than the analogous curve for sharing in Figure 3, demonstrating that groups of individuals who forage together are larger, and have a more flexible composition over time, than those who share together at the reservation⁴. Furthermore, of all possible pairs of hunters that could be present on the same trip over the four year period, only 7.6% never occurred, while 33% of all possible sharing pairs over a four month period never occurred.

Foraging and sharing partnerships

If individuals who forage together more frequently also share together more intensively at the reservation, we should expect significant correlations between the percentage of *A*'s forest days spent with *B* and the percentage of *B*'s food production given to *A* or of *A*'s food production given to *B*. Bivariate analyses of the percentage of *A*'s forest days spent with *B* show significant correlations with the percentage of *B*'s foraged and cultivated food given to *A* ($r=0.47, p<0.0001$; $r=0.23, p<0.05$ respectively), as well as with the distance in meters between *A*'s and *B*'s house ($r=-0.19, p<0.0001$), and the percentage of *B*'s forest days spent with *A* ($r=0.21, p<0.0001$).⁵ Another method using multidimensional scaling shows a similar relationship between sharing and foraging partnerships (see Appendix). No correlation is found with the percentage of *B*'s storebought foods given to *A* (or of *A*'s given to *B*) ($r=0.11, p=0.29$; $r=0.04, p=0.69$), the

percentage of *A*'s cultivated food given to *B* ($r=-0.01, p=0.95$), nor the closest kinship relation between members of *A* and *B* ($r=0.05, p=0.31$). While the percentage of *A*'s foraged foods given to *B* is a (smaller) significant predictor of *A*'s forest days spent with *B*, it loses statistical significance when percentage of *B*'s foraged foods given to *A* is included in the model ($p=0.09$).

We combine the significant predictor variables mentioned above in a path model to tease apart the relative effects of these co-dependent variables on the percentage of *A*'s forest days spent with *B*. The path diagram of the causal model is illustrated in Figure 5. The numbers on the arrows are standardized path estimates. Overall, the model is a good fit to the data ($\chi^2=3.70, p=0.30$; Bentler's comparative-fit index (CFI)=0.995, Bentler and Bonett's normed-fit index (NFI)=0.977).

Several important results emerge from this analysis. First, geographical distance between households, the percentage of *B*'s forest days spent with *A*, and the percentage of *B*'s foraged food given to *A* each have similar significant effects on the percentage of *A*'s trip days spent with *B* (summed effect=0.19, 0.18, 0.17 respectively). Notice that only half of the distance effect is direct, while the remaining indirect effect is due to the significant path estimates via the percentage of *B*'s trip days with *A*, and the percentage of foraged food *B* shared with *A*. Second, neither kinship nor the sharing of cultigens have any significant direct or indirect effects on foraging partnerships. Third, only 10% of the variance in the percentage of *A*'s trip days spent with *B* is explained by the inclusion of all these variables in the model. Fourth, although these measures are derived from different statistical procedures, the effect of sharing forest foods on foraging partnerships derived from the path model (+0.17, Figure 6) is almost identical to the effect derived from the MDS method (+0.19).

Other predictors of foraging partnerships

Because foraging in the forest is often a cooperative endeavor (Hill 2002), other traits of potential foraging partners may also be important to consider in decisions about foraging group formation. Men may prefer hunting with men of similar ages, either because these individuals tend to be closer friends, or because of preferences to forage with men in the same age cohort. Men may also prefer to hunt with other men of similar hunting ability, or perhaps only with the best hunters. Alternatively, one might predict that men may wish to forage with poorer hunters, so that they gain signaling advantages by appearing more skilled than other men in Arroyo Bandera (Wood and Hill 2000). A multiple regression analysis incorporating the difference in men's ages, and the difference in their ranked hunting ability (ranked from 1 to 5), controlling again for kinship, spatial distance between households, sharing of cultigens and foraged foods, and the total number of days spent in the forest, showed significant positive effects for both age and hunting ability on foraging partnerships, as measured by the percentage of forest days where another individual was present.

These results are given in Table 3. The third column in Table 3 shows the standardized parameter estimates, whose magnitudes can be compared to assess the relative importance of different predictors on foraging partnerships. First, in this more complete model, the transfer of foraged foods is still a significant predictor of foraging partnerships, but is less important than the other significant predictors in the model. Second, the relative difference in age is significant, such that older men are less likely to spend their foraging time with younger men, even after controlling for differences in time spent in the forest and in ability. Third, poor hunters spend a greater percentage of their foraging days with good hunters, rather than vice versa, again controlling for differences in age and frequency of time spent in the forest. Fourth, the strongest

predictor of A 's foraging with B is B 's foraging with A , controlling for all other predictors in the completed model that could potentially confound this effect. Fifth, this more complete model explains 38% of the variance in forest-days A spent with B .

Discussion

We return to the five questions posed in the introduction.

Question 1: non-random social interaction

An important implication of this paper is that foraging groups are not random samples of the population, and that people often self-select into foraging groups based on a multitude of factors. That foraging trips are not random samples of the resident reservation group is also evident by comparing the censuses of foraging trips with those of the reservation source population. A comparison of the demographic composition of 18 foraging treks before 1986 and the Chupa Pou source population during this same time period reveals a higher proportion of men and women older than 30, and a scarcity of teenagers and small children of both sexes on the foraging treks. This natural 'sampling' bias raises important questions, including the extent to which observed levels of foraging effort, especially among teenagers, are typical of those during pre-contact times. Self-selection biases such as this one are under-explored realities that can complicate interpretations of observed foraging or sharing behavior, or any naturalistically observed behavior for that matter. Two examples illustrate our point. First, observational studies of foraging activities that are used to assess caloric return rates of foragers can lead to misleading estimates of foraging success rates and of abilities, if individuals selectively forage only during certain conditions, such as when weather is favorable, after receiving privileged information about animal locations from others, when opportunity costs are low, or when ability is sufficient.

Second, if teenagers and children only increase work effort on foraging trips when the number of dependents is relatively high, then the low work effort of teenagers and children (and their low rates of caloric return) may be more an artifact of the lower dependency characteristic of post-contact foraging trips rather than any inherent limitations on their foraging abilities.

Question 2: sharing and foraging partners

Our results show that pairs of families who tend to share foraged foods together at the reservation also tend to participate in foraging trips together. This correlation was statistically significant even when controlling for other confounding associations, although reservation sharing partnerships only explain a small proportion of the variance in foraging partnerships. This suggests that other factors are important influences on foraging group composition (see question #4 below). It is interesting to note that neither the sharing of cultigens, storebought items, nor all foods combined were significant predictors of foraging partnerships in multivariate analyses. The fact that only sharing of foraged foods predicts foraging partnerships suggests that trade or turn-taking are unlikely social arrangements for obtaining meat among the Arroyo Bandera Ache.

Question 3: foragers that share, or sharers that forage?

If post-contact foraging treks have compositions akin to ‘camping trips’ with friends, families, and age-mates, we might expect a higher level of cooperation in these trips compared with the typical mixed groups of pre-contact foraging bands. This paper first attempted to determine the extent of non-random foraging associations, and then the extent to which foraging partnerships overlap with sharing partnerships. Does the correlation between foraging and

sharing partnerships force us to re-evaluate the appropriateness of using observed foraging or sharing patterns to make inferences about typical pre-contact forest behavior? While no data on pre-contact foraging or sharing patterns are available, many older Ache commonly report that widespread sharing has always been a core feature of forest life, even if estimated band sizes were larger during pre-contact times (McMillan 2001). Personal observations of recently contacted groups by Hill in 1978 confirm this notion. Additionally, preliminary analysis of unpublished sharing data collected during several foraging trips in 1998 revealed few differences in food transfer patterns compared to the forest trips of the 1980s, and foraging groups have become even smaller during the past twenty years. Two other changes also deserve mention. First, hunters often eat portions from their own kills, contrary to the tacit cultural taboo that previously denied hunters this benefit. Second, white-lipped and collared peccaries and coatis have declined in daily contributions to the game portion of the diet. Armadillos, pacas, and capuchin monkeys are now the top three sources of animal protein (Hawkes, et al. 1982; Hill and Tikuarangi 1998) (see below).

The dependence between foraging and sharing partnerships does not force us to conclude that sharing associations at the reservation are only a reflection of foraging partnerships in the forest. The significant “contingency” correlations of giving and receiving among the same pairs of families for all food, foraged food, cultigens, and storebought foods, estimated using the percentages of food production each family gave to each other family over the duration of the sample period (Gurven, et al. 2001), remain significant and only slightly reduced in magnitude after controlling for the foraging associations among the same pairs of families in a multiple regression analysis (partial estimate=0.35, 0.08, 0.33, 0.33, respectively; $p < 0.0001$, 0.0001, 0.05, 0.0001; $df=230$). These results suggest that how much is given at the reservation depends on

how much is received at the reservation, regardless of the amount of time both parties spent in the forest together. Thus, while time spent foraging on trek together may influence (or be a partial result of) social behavior at the reservation, sharing in the forest and at the reservation seems to be strongly determined by independent social factors occurring in these separate contexts.

It is also difficult to infer from the results reported in this paper that individuals of different households maintain a marked division of labor (cf. Chicchón 1992). If *A* relies on *B* for access to meat, a large percentage of *A*'s forest days may be spent with *B* if access occurs in the forest context, whereas a low percentage of *A*'s forest days may be spent with *B* if *B* gives meat to *A* upon returning to the village. The fact that the transfer of cultigens and foraged foods from *A* to *B* were equally good predictors of the transfer of foraged foods from *B* to *A* (Gurven, et al. 2001) suggests that, on average, the same sharing partners are called upon for access to different food types.

Question 4: other predictors of foraging partnerships

Although this paper was not meant to be an exhaustive study of the determinants of foraging partnerships, we have shown that several other factors are important predictors of who forages with whom. Relative foraging ability, age, others' interest in foraging together, food sharing, and geographical proximity were all significant predictors of foraging partnerships, as was relative foraging ability and age. In our multivariate models, sharing did not explain much of the variation in foraging partnerships. Another important finding was that biological kinship displayed no effect on foraging partnerships. This result is consistent with the lack of a kinship bias in sharing patterns during foraging trips (Gurven, et al. 2001; Kaplan and Hill 1985). It is

important to note that the effects reported here are significant even though we did not explicitly incorporate variation in foraging group sizes in the analyses. As mentioned earlier, foraging preferences are not always easily recognizable given the data on the composition of foraging trips, because the composition of any foraging trip (especially large ones) may be the result of many (often competing) preferences of multiple actors.

Question 5: revealed pro-social preferences?

The majority of all Ache foraging trips during 1995-1999 were solitary one-day trips. Does each individual's decision to engage in solitary trips tell us anything about their social "preferences", or is perhaps, the abundance of solitary trips linked to the decreased necessity for cooperation during foraging trips due to the importance of more easily acquired armadillos (and decreased importance of peccaries and coatis) in the diet? Indeed, only older, and more skilled hunters participated in a higher number (but not proportion) of solitary excursions ($r=0.40$, $p=0.05$ for age; $r=0.59$, $p=0.001$ for ranked ability). Sharing behavior bears no relationship to the number or proportion of solitary trips ($p=0.33$, 0.34 , 0.11 for three resource types and number of solitary trips; $p=0.12$, 0.23 , 0.85 for three resource types and proportion of solitary trips; $df=22$).

Individuals who shared a greater proportion of cultigens, storebought foods, or foraged foods at the reservation were also no more likely to forage in larger groups than those who shared fewer of these foods ($p=0.72$, 0.31 , 0.32 respectively; $df=22$). Those who spent more time in the forest, however, were more likely to share more cultigens ($r=0.44$, $p=0.04$) and foraged foods ($r=0.46$, $p=0.03$). The only factors we found to correlate with average foraging party size were age and skill (which are themselves correlated, $r=0.53$, $p=0.03$, $df=23$). Older and more skilled hunters are more likely to participate in trips with fewer total men ($r=0.52$,

$p=0.05$ for age; $r=0.41$, $p=0.05$ for ranked hunting ability; $df=22$)⁶. These same older and skilled hunters spent the greatest total number of days in the forest on trek during the four-year sample period. The worst hunters, who tended to be the youngest men, participated primarily only on the large foraging trips. These trips tend to be the equivalent of open-invitation village parties in the forest.

It is important to mention here that any model of grouping patterns needs to consider the possibility for conflicts of interest among individuals (Smith 1985). Ache will rarely go on trek for multiple days by themselves. Any extended trip therefore requires coordinating other individuals to participate on a potential trek. At some point, member-joiner conflicts may arise, wherein group members may not wish to forage with others who wish to forage with them (ibid). For example, more skilled hunters often forage with other skilled hunters, while poor hunters also prefer to forage with skilled hunters ($p=0.04$, regression of percentage A 's forest days spent with B on the difference in ranked hunting abilities for A and B , where A is less skilled than B). Similarly, older individuals often forage with older men rather than younger men, whereas younger men show no age bias in their observed choice of foraging partners.

Conclusion

In modeling the decision for individual A to forage on any given day, one must not only consider certain frequency-independent factors such as weather conditions, time since meat was last eaten, or hunting ability, but also frequency-dependent influences such as the number of individuals who have already committed to go foraging, and whether these individuals are neighbors, age-mates, sharing partners, high or low producers, young women, etc. Given the cluster of cues, factors, and coordination involved in the decision making process regarding

foraging group formation, it may not be surprising that a gross measure such as “percentage of *A*’s foraging days spent with *B*” does not reveal very tight foraging partnerships, and that the percentage of variation in foraging partnerships explained in our models is no greater than 38%. Even if *A* participates on a trip because *B* will be present, either *A* or *B* may also decide to participate on the trip because of meat hunger, good weather, appropriate seasonal time frame, information about certain profitable areas, in addition to the identities and characteristics of others expected to participate on the trip. Furthermore, others may choose to accompany *A* and *B* because *A* and/or *B* may be experienced, skilled hunters. Given that decisions to go foraging are rarely made simultaneously, the process by which group members or subsets of group members converge upon a specific course of action is an important area that deserves serious attention (see Alvard and Nolin 2002).

Explorations of social dimensions of economic activities are a necessary companion to studies of the economic dimensions of social activities. Although grouping patterns are usually interpreted as providing useful information about individuals’ pro-social or cooperative inclinations, straightforward interpretations often ignore the processes that produce grouping in the first place. If six individuals agree to forage because of a seasonal abundance in palm fruits, the harvesting of which does not require any coordination of individual actions, then the group foraging that follows is an example of simultaneous solitary foraging, rather than cooperative foraging (Giraldeau and Caraco 2000). However, even simultaneous solitary foraging may require some additional explanations if, for example, fruit groves are dispersed, but individuals still choose to forage in the same patches.

During the five-year period when all foraging groups were recorded, the Ache did not leave the village to forage preferentially with kin. This means that the composition of foraging

groups was not as groups of closely related individuals, as described in many portrayals of typical hunter-gatherer foraging parties. Whether or not Ache foraging groups were more kin-based in the 1980s, when many of the foraging economics studies were conducted, is currently being investigated. Nonetheless, the fact that the Ache still share extensively in forest camps (and that kinship has no effect on sharing patterns in the forest – Kaplan and Hill 1985; Gurven et al. 2002) supports the notion that close kinship is not a prerequisite of effective cooperation. This reasoning is consistent with recent studies showing that even among chimpanzees, for whom it has often been assumed that kinship is the most important predictor of social affiliations, kinship plays only a secondary role in the development of grooming and spatial proximity, alliance formation, meat sharing, and boundary patrols (Mitani, et al. 2000). However, we cannot rule out the possibility that some individuals may opt out of the forest-sharing network by choosing to hunt by themselves during single-day excursions, whereupon the foods they acquire are brought back to the village, shared more restrictively, with an evident kin bias in meat distribution.

Additional research is needed to explore the ways in which individuals form foraging parties, especially when most extant foragers and forager-agriculturalists are central-place foragers that leave their larger, more permanent residential base to engage in subsistence foraging. Decisions about group composition may interact in important ways with the kinds of activities and work effort decisions of those individuals while foraging. We have already mentioned many factors that may influence an individual's decision to forage and with whom to forage. Additional research is also needed to better understand how our evolved pro-social psychology influences actual social behavior, given the ways that the dynamic socioecological context of an individual's local environment can structure the costs and benefits of cooperative

behavior. For example, this paper reports that those who share food more generously do not forage in larger groups. Similarly, Hill and Gurven (n.d.) found that those who share generously did not behave any differently than less generous individuals in several economics games designed to measure individual cooperativeness. Understanding the multifaceted goals of individuals in specific situations, and how those goals trade-off in the context of limited time and resources, may provide important insight into explaining variability in social preferences and behaviors.

Acknowledgements

This work was made possible with the financial support of a Leakey Foundation grant to Gurven, and NSF Grant BNS 9727656 to Hill and A.M. Hurtado. Many thanks to the Ache of Arroyo Bandera for their generous cooperation and hospitality. Helpful comments were kindly offered by Rich Sosis.

Appendix

Multidimensional scaling analysis of foraging and sharing partnerships

The degree of association between individuals was also estimated using multidimensional scaling analysis (MDS), in addition to the path analysis described in the text. MDS analysis is a method commonly used to provide a representation of the strength of associations among a set of objects or individuals. The set of Ache men may be visualized as points in n -dimensional space, where the Euclidean distances between points correspond in a functional way to raw associations from an input matrix, and where the degree of fit is estimated by a stress criterion. The computed Euclidean distance between any two individuals is a measure of the strength of association between those individuals. Greater distances suggest weaker associations. The associations we consider in this paper include those related to foraging and sharing. The input matrix for foraging partnerships is the variable “percentage of all A ’s foraging days where individual B was present on the trip”, computed for all A and B . Similarly, the input matrix for sharing partnerships is the “percentage of all B ’s (foraged) food given to the family of A ”. The MDS methodology therefore allows us to examine the relationships between pairs of individuals as a function of the derived Euclidean distances separating them, rather than from the raw input matrix data. MDS analyses were performed using PROC MDS in SAS V8.1.

Figure A1 shows the results of the MDS procedure. The Euclidean distances that describe foraging preferences among all pairs of men are plotted against the distances describing sharing preferences among the same pairs. These distances are standardized to the maximum distances on each axis. We used seven dimensions for each of the MDS analyses to satisfy the criterion that the stress factor be below 0.1 (Borgatti 1992). A regression through these points reveals a positive, but weak, relationship between sharing of all food and foraging partnerships

(estimate=0.17, $r=0.14$, $p=0.003$, $n=461$). A similar relationship exists when considering the sharing of only forest-derived foods (estimate=0.19, $r=0.16$, $p<0.001$, $n=461$). As described in the text, these results are similar to those obtained with regression and with the path model.

REFERENCES

- Alvard, Michael, and David Nolin
2002 Rousseau's whale hunt? Coordination among big game hunters. *Current Anthropology*.
- Borgatti, Steven
1992 ANTHROPAC 4.0 Methods Guide. Columbia: Analytic Technologies.
- Chicchón, Avecita
1992 Chimane resource use and market involvement in the Beni Biosphere Reserve, Bolivia, University of Florida.
- Cosmides, Leda, and John Tooby
1992 Cognitive adaptations for social exchange. *In* *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*. J. Barkow, L. Cosmides, and J. Tooby, eds. Pp. 163-228. New York: Oxford University Press.
- Giraldeau, Luc, and Thomas Caraco
2000 *Social Foraging Theory*. Princeton: Princeton University Press.
- Gurven, Michael, et al.
2000b 'It's a Wonderful Life': signaling generosity among the Ache of Paraguay. *Evolution and Human Behavior* 21:263-282.
- 2001 Reservation food sharing among the Ache of Paraguay. *Human Nature* 12(4):273-98.
- Gurven, Michael, Kim Hill, and Hillard Kaplan
2002 From forest to reservation: transitions in food sharing behavior among the Ache of Paraguay. *Journal of Anthropological Research* 58(1):93-120.
- Gurven, Michael, et al.
2000a Food transfers among Hiwi foragers of Venezuela: tests of reciprocity. *Human Ecology* 28:171-218.
- Hatcher, Larry
1994 *A Step-by-Step Approach to Using the SAS System for Factor Analysis and Structural Equation Modeling*: SAS Institute.
- Hawkes, Kristen, Kim Hill, and James F. O'Connell
1982 Why hunters gather: optimal foraging and the Ache of Eastern Paraguay. *American Ethnologist* 9:379-98.
- Hawkes, Kristen, et al.
1987 Ache at the settlement: contrasts between farming and foraging. *Human Ecology* 15:133-161.
- Hill, Kim
2002 Cooperative food acquisition by Ache foragers. *Human Nature*.
- Hill, Kim, and Michael Gurven
n.d. Economic experiments to examine fairness and cooperation among the Ache Indians of Paraguay. *In* *Reciprocity and Punishment in 15 Small-Scale Societies*. R. Boyd, J. Henrich, S. Bowles, and H. Gintis, eds.
- Hill, Kim, and Kristen Hawkes

- 1983 Neotropical hunting among the Ache of Eastern Paraguay. *In Adaptive Responses of Native Amazonians*. R. Hames and W. Vickers, eds. Pp. 139-188. New York: Academic Press.
- Hill, Kim, et al.
1987 Foraging decisions among Ache hunter-gatherers: new data and implications for optimal foraging models. *Ethology and Sociobiology* 8:1-36.
- Hill, Kim, and Magdalena Hurtado
1996 *Ache Life History: the ecology and demography of a foraging people*. New York: Aldine de Gruyter.
- Hill, Kim, and Tito Tikuarangi
1998 The Mbaracayu Reserve and the Ache of Paraguay. *In Traditional Peoples and Biodiversity Conservation in Large Tropical Landscapes*. K.H. Redford and J.A. Mansour, eds. Arlington: America Verde Publications.
- Jochim, Michael
1988 Optimal Foraging and the Division of Labor. *American Anthropologist* 90:130-36.
- Kameda, Tatsuya, et al.
2002 Social sharing and risk reduction; Exploring a computational algorithm for the psychology of windfall gains. *Evolution and Human Behavior* 23:11-33.
- Kaplan, Hillard, and Kim Hill
1985 Food sharing among Ache foragers: tests of explanatory hypotheses. *Current Anthropology* 26:223-245.
- Loehlin, John C.
1987 *Latent variable models: an introduction to factor, path, and structural analysis*. Hillsdale, NJ: L. Erlbaum Associates.
- Maynard Smith, John
1982 *Evolution and the Theory of Games*. Cambridge: Cambridge University Press.
- McMillan, Garnett
2001 *Ache Residential Grouping and Social Foraging*: University of New Mexico.
- Miller, Geoffrey
2000 *The Mating Mind*. New York: Anchor Books.
- Mitani, John C., D. Andrew Merriwether, and C. Zhang
2000 Male affiliation, cooperation, and kinship in wild chimpanzees. *Animal Behaviour* 59:885-93.
- Ridley, Matt
1996 *The Origins of Virtue: Human Instincts and the Evolution of Cooperation*. New York: Viking.
- Schrire, Carmel
1984 *Past and Present in Hunter-Gatherer Studies*. New York: Academic Press.
- Smith, Eric A.
1985 Inuit foraging groups: some simple models incorporating conflicts of interest, relatedness, and central-place sharing. *Ethology and Sociobiology* 6:27-47.
- Wood, Brian, and Kim Hill
2000 A test of the "showing off" hypothesis. *Current Anthropology* 41:124-25.

	# days																			%	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	23		
1	312	6																		318	42.2
2	101	21	3	8	7	1	4	3				1								149	19.8
3	48	14	16	8	11	6	2	3	1	1	1	1	1			1			1	114	15.1
4	18	6	12	10	6	8	1	1			2	1	1			1				67	8.9
5	12	3	1	8	5	2	4													35	4.6
6	3	1	6	3	4		1	1	2	1	3									25	3.3
7	4		5	1	3			1				1								15	2.0
8	1	2	4	1	4	1														13	1.7
# men	9	1	1				1				1									4	0.5
	10	1		1																2	0.3
	11	1	1	1	1													1		5	0.7
	12		1			1														2	0.3
	13				1															1	0.1
	14											1								1	0.1
	15			1			1													2	0.3
	16			1																1	0.1
	502	54	50	43	41	19	14	9	3	2	7	5	1	0	0	2	0	1	1	753	
%	66.7	7.2	6.6	5.7	5.4	2.5	1.9	1.2	0.4	0.3	0.9	0.7	0.1	0.0	0.0	0.3	0.0	0.1	0.1		

TABLE 1. Frequency of trips by number of hunters and trip length in days (n=753, Sept 1995 to Dec 1999)

ID	total # trips	total # forest days	mean trip duration (days)	mean # men present	stdev of mean # men	wtd # men per trip	# solitary trips	fraction solitary
16	114	247	2.17	3.70	2.99	5.45	22	19.3
2	105	376	3.58	4.50	2.92	5.32	8	7.6
6	105	357	3.40	4.70	3.10	5.45	7	6.7
19	103	267	2.59	3.75	2.99	5.25	20	19.4
10	92	265	2.88	4.39	3.13	5.58	13	14.1
15	90	205	2.28	4.09	2.98	5.41	16	17.8
9	89	206	2.31	3.28	2.84	4.28	28	31.5
1	73	221	3.03	4.68	3.46	5.63	17	23.3
5	73	297	4.07	4.19	3.07	4.95	9	12.3
13	70	138	1.97	3.80	3.16	5.77	13	18.6
4	69	204	2.96	3.59	2.91	4.09	19	27.5
11	61	158	2.59	4.38	2.99	5.94	7	11.5
7	60	181	3.02	3.27	2.94	4.26	18	30.0
20	46	118	2.57	4.54	3.43	6.32	5	10.9
18	45	78	1.73	3.13	2.74	4.59	18	40.0
12	42	183	4.36	5.38	3.44	6.50	2	4.8
8	38	185	4.87	3.18	1.52	3.51	2	5.3
28	30	133	4.43	5.33	3.99	6.10	3	10.0
24	29	83	2.86	5.03	2.88	5.76	1	3.4
22	23	33	1.43	3.30	3.48	4.82	13	56.5
3	22	89	4.05	4.36	2.13	4.87	1	4.5
21	19	42	2.21	4.05	3.29	5.76	4	21.1
23	18	35	1.94	4.89	3.08	5.80	4	22.2
17	15	56	3.73	4.47	3.68	6.29	4	26.7
27	15	48	3.20	6.47	3.80	7.35	1	6.7
25	12	39	3.25	4.75	3.89	5.49	1	8.3
26	7	19	2.71	4.43	3.55	4.95	1	14.3
14	6	11	1.83	6.33	4.46	6.64	1	16.7
30	3	9	3.00	5.33	1.15	5.33	0	0.0
29	2	12	6.00	4.50	3.54	6.58	0	0.0
MAX	114	376	6.00	6.47	4.46	7.35	28	56.5
MIN	2	9	1.43	3.13	1.15	3.51	0	0.0
MEAN	49	143	3.03	4.39	3.12	5.47	9	16.4
MEDIAN	43.5	135.5	2.92	4.41	3.09	5.47	6	14.2
STD	35.5	106.4	1.02	0.84	0.66	0.84	8	12.4

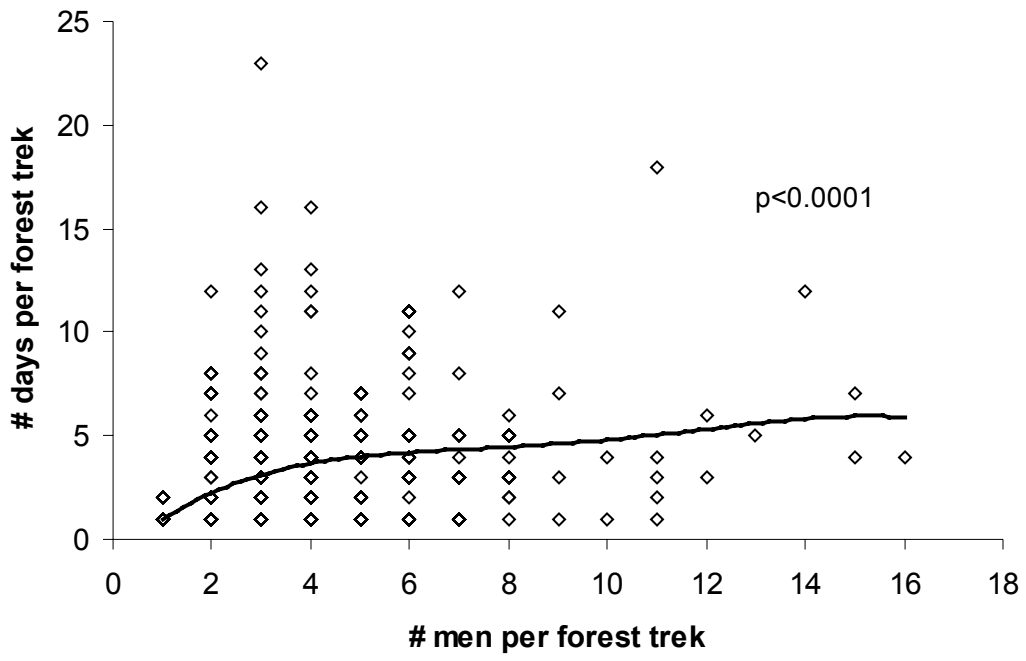
TABLE 2. Individual foraging group patterns for 30 men. Each ID refers to a different hunter, ranked from those who participated in the most to the least number of trips.

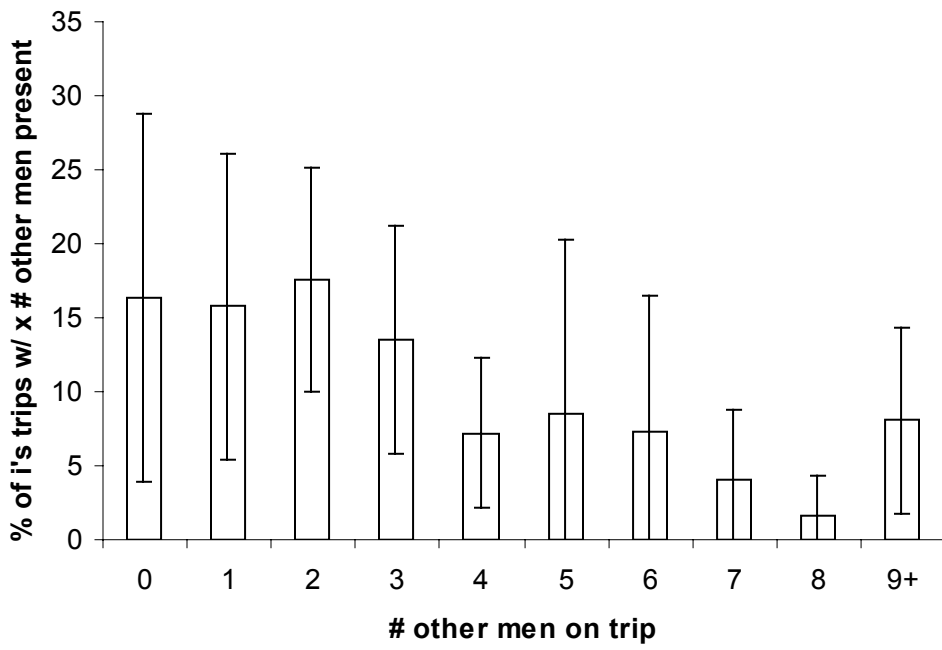
<i>Predictor variable</i>	<i>partial estimate</i>	<i>partial std est.</i>
1)% <i>B</i> 's foraged food given to <i>A</i>	-0.05	-0.02
2)% <i>B</i> 's cultivated food given to <i>A</i>	0.28**	0.13**
3)closest kinship between <i>A</i> and <i>B</i>	-1.5	-0.01
4)distance in meters from <i>A</i> to <i>B</i>	-0.02*	-0.08*
5)% <i>B</i> 's forest days spent with <i>A</i>	0.52***	0.52***
6)age <i>A</i> - age <i>B</i>	-0.29***	-0.34***
7)hunter ability <i>A</i> - hunter ability <i>B</i>	2.33***	0.31***
8)total days <i>A</i> spent in forest	-0.02***	-0.18***

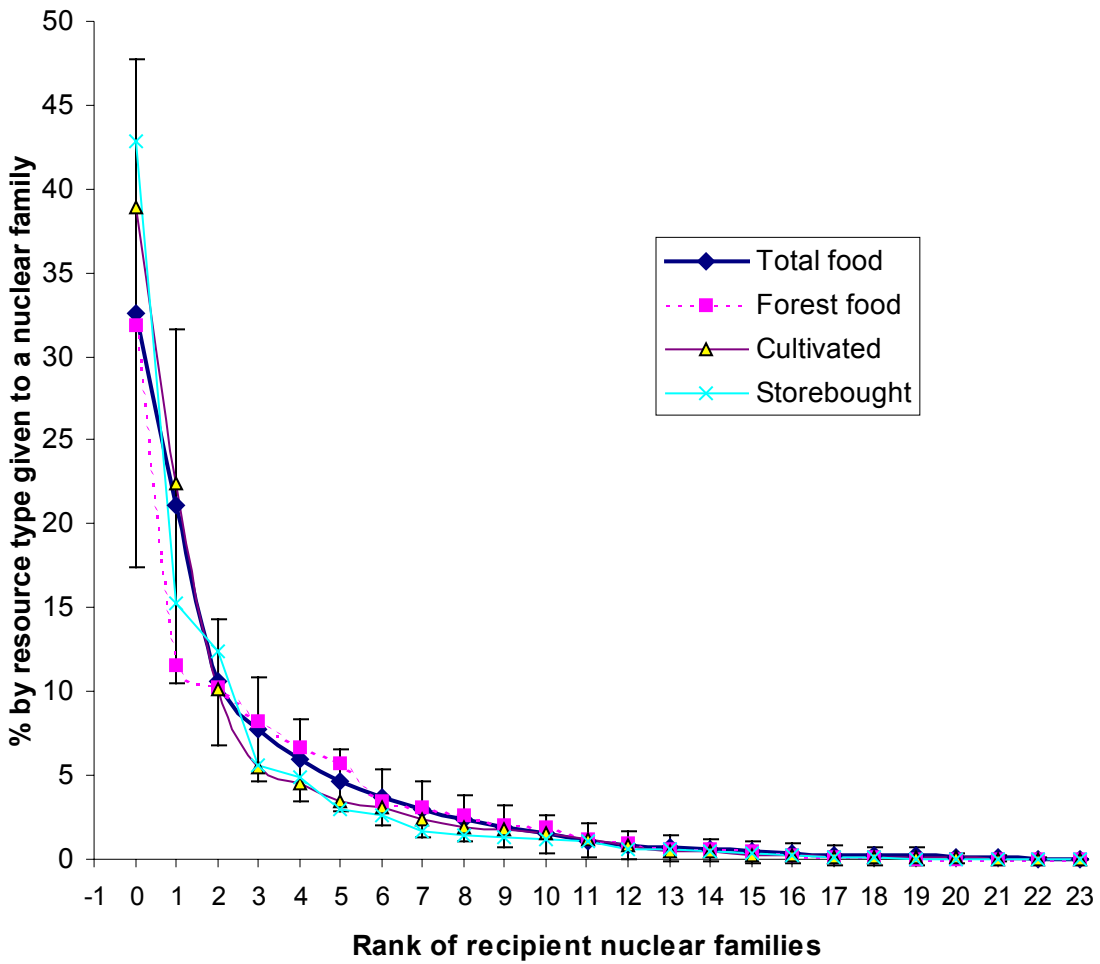
F-value=34.43, *p*<0.0001; *R*²=0.38, df=454
*** *p*-value < 0.0001 ** *p*-value < 0.001 * *p*-value < 0.05

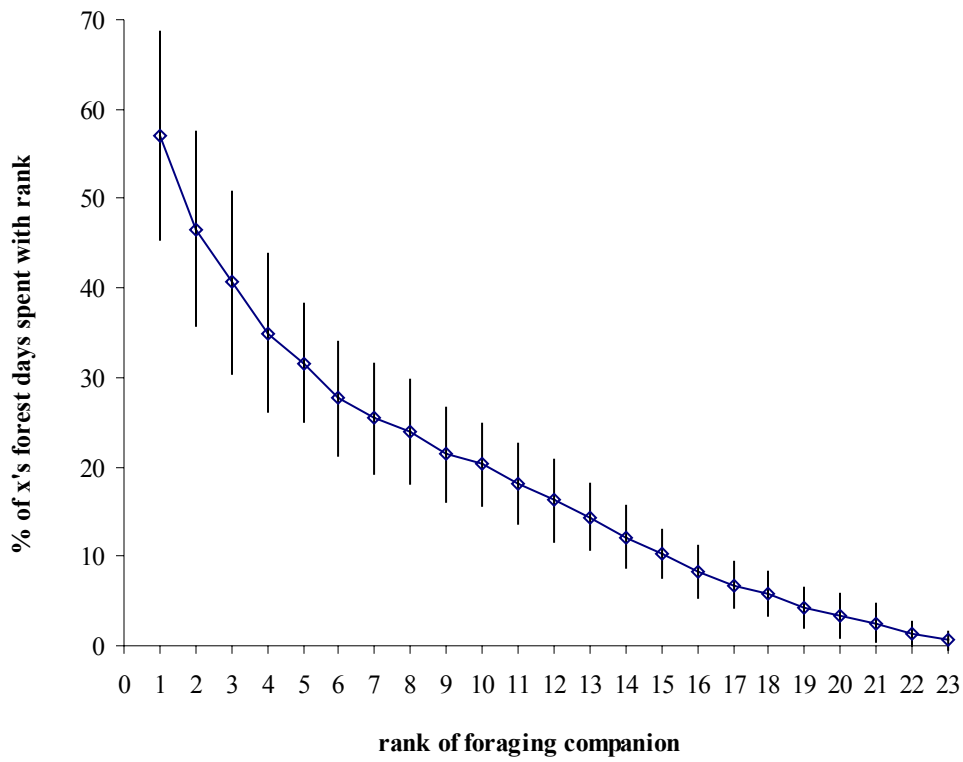
TABLE 3. What influences the total % of *A*'s forest days spent with *B*?

1995-1999 all trips (n=753)









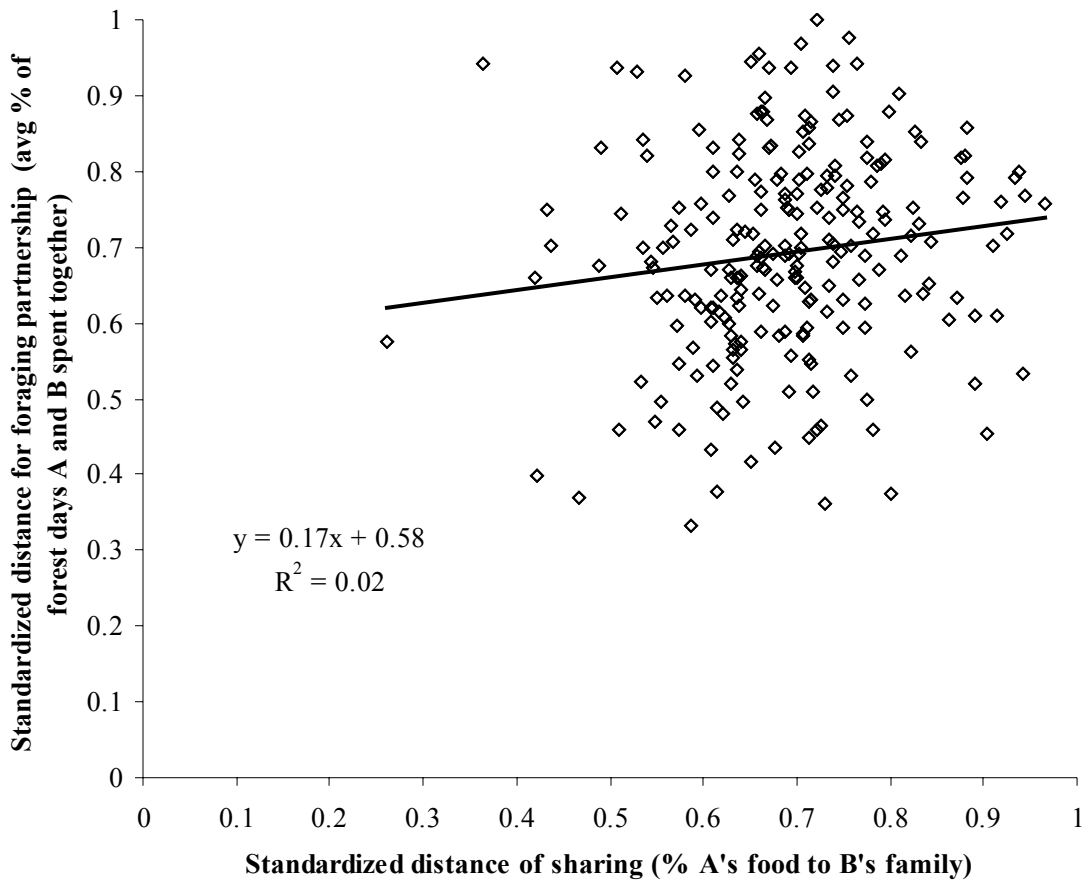


Figure 5. Path model of foraging and sharing partnerships

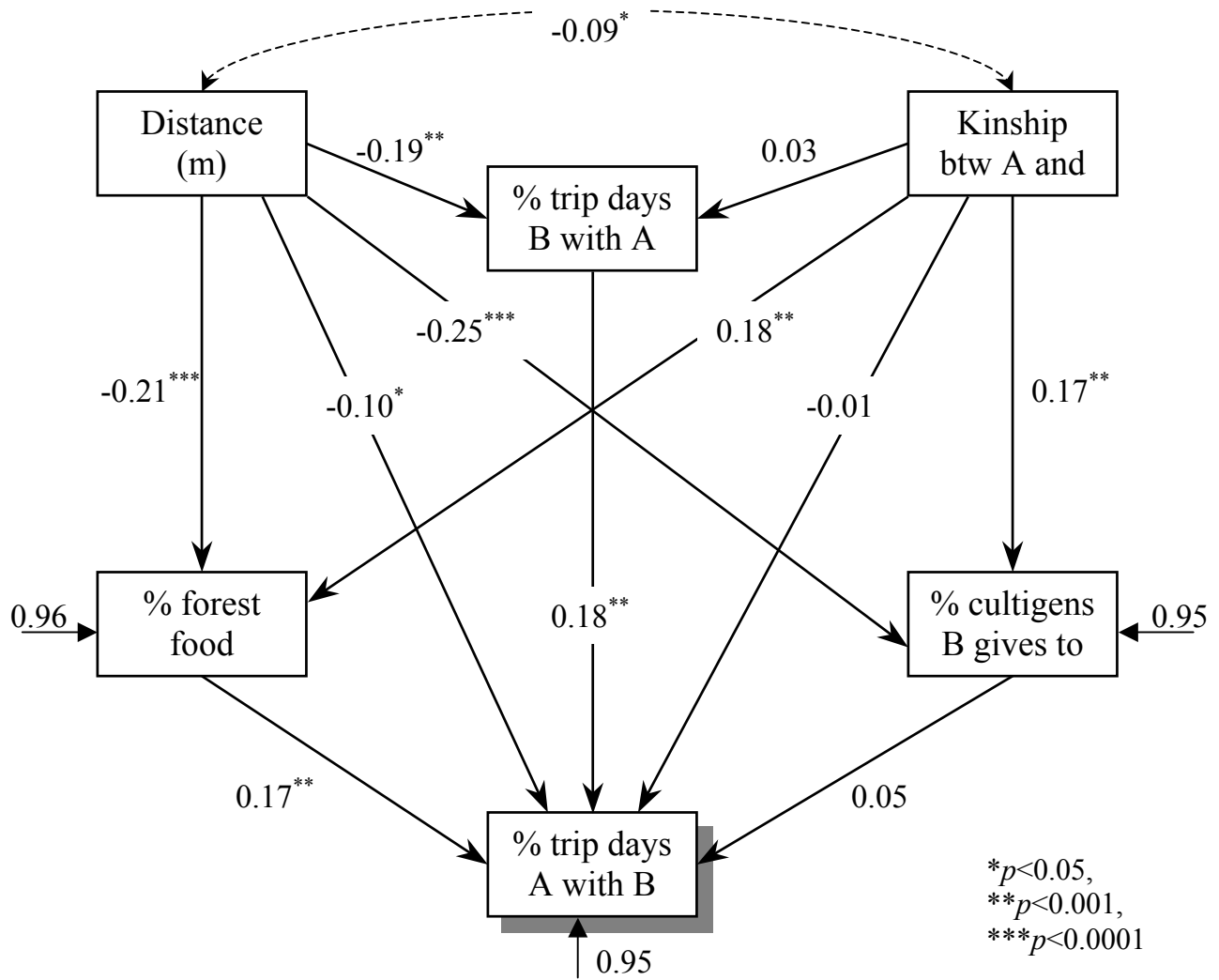


Figure Legends

FIGURE 1. Number of hunters present per foraging trek and trek duration. The length of the trek in days is plotted as a function of the number of men present on the trek. Curve is plotted as a fourth-order polynomial regression.

FIGURE 2. Observed hunting group size variation from perspective of an individual hunter. The percentage of hunter i 's foraging treks where x other men were present on the trek. Error bars signify a single standard deviation unit.

FIGURE 3. Average percentage of a focal family's food production given to each other family, where recipient families are ranked from those who received the most to the least amount of all food, foraged foods, cultigens, and storebought foods. A rank of 0 refers to the percentage kept within the nuclear family of the acquirer. Error bars signify a single standard deviation unit.

FIGURE 4. Average percentage of a focal man's days in the forest spent with each other man, ranked from those with whom was spent the most to least number of days. Error bars signify a standard deviation unit.

FIGURE 5. Path analysis of the percentage of A 's forest days spent with B as a function of the percentage of B 's foraged and cultivated foods given to A , the percentage of B 's forest days spent with A , the physical distance between the houses of A and B , and coefficient of relatedness (kinship) between A and B .

FIGURE A1. Plot of sharing partnerships (percentage of family of x 's food given to family of y) and foraging partnerships (percentage of all days x spent in the forest with y). Each point represents a standardized Euclidean distance between two men based on the strength of their foraging or sharing partnerships, as derived from the multidimensional scaling analysis described in the text.

¹ For a sample of foraging trips in 1997-98, Jakugi underestimates the length of long trips, and missed several multi-day trips composed of older men (G. McMillan personal communication).

² If we weight this mean by the duration of each trip in days, we get an average of 3.8 men.

³ Correlations consider the number of individuals present on a trip, and this number squared, to consider a quadratic relationship between number of hunters and productivity. The quadratic terms were not statistically significant ($p > 0.3$ in all cases).

⁴ The slope of $\ln(\% \text{ A's days spent with B})$ is -0.17 , and the slope of $\ln(\% \text{ A's forest food given to B})$ is -0.29 . These slopes are the shape parameter in an exponential regression.

⁵ It may be argued that while “percentage of A’s forest days spent with B” is a useful variable for comparing foraging partnerships across men, the large variation among men in time spent foraging can be misleading. We added the variable “number of days A spent in the forest” to control for variation in the denominators used in the calculation of the percentages. Controlling for time spent in the forest did not significantly change the magnitude nor significance of the correlations of % A’s forest days spent with B and % all food B gave to A ($r=0.33$, $p=0.02$), % B’s foraged food given to A ($r=0.47$, $p<0.0001$), % B’s cultivated food given to A ($r=0.20$, $p=0.07$), and distance in meters between households ($r=-0.20$, $p<0.0001$). The correlation between % A’s forest days spent with B and % B’s forest days spent with A actually increased, after controlling for the number of days A spent in the forest ($r=0.53$, $p<0.0001$).

⁶ Correlations of age and average preferred foraging group size were taken from quadratic regressions.