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Food Transfers Among Hiwi Foragers of Venezuela: Tests of Reciprocity

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Although food sharing has been observed in many traditional societies, we still do not have a deep understanding of how various ecological conditions produce variation in who gives and who receives specific resources. To understand better the behavioral ecology of food sharing, we present data collected with the Hiwi of Venezuela and focus on two questions: (a) How do characteristics of food resources and acquirers determine how much is transfered to others? (b) How do characteristics of nuclear families A and B influence how much is transferred between A and B? We use path modeling in an attempt to tease apart the relative contribution of biological kinship, geographical proximity between households, family size, and quantities family B gave to family A on the expected quantities that family A gives to family B. Reciprocal altruism is shown to be an important link in the chain of factors, but not in the tit-for-tat form common in theoretical treatments of reciprocity.

KEY WORDS: food sharing; hunter-gatherers; reciprocal altruism; evolutionary ecology; bargaining theory; Venezuela.

INTRODUCTION

Food sharing is one of the most widely cited characteristics of human social groups in traditional ethnographies (Mauss, 1925; Levi-Strauss, 1969; Service, 1966). Its importance has been emphasized by researchers in all

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domains of anthropology, being linked at times to the evolution of sociality, the sexual division of labor (Isaac, 1978), the transition from hominoids to hominids (Kurland and Beckerman, 1985), and morality (Kurland, 1995). It has even been referred to as a prime mover in the transition between protohominids and modern humans (Isaac, 1978). Widespread food sharing has often been viewed as a given among humans, but it is a behavior rarely displayed among nonhuman animals. For this reason, biologists marvel at the few instances of voluntary food transfers among unrelated individuals [e.g., Wilkinson, 1988 (bats); Stanford, 1995; de Waal, 1997b (chimpanzees); de Waal, 1997a (capuchin monkeys)].

Despite enormous interest in food sharing, very few quantitative data describing such food sharing actually exist. Many traditional ethnographic accounts contribute to the widespread ‘‘truth’’ of food sharing, especially in hunter-gatherer societies—namely, that sharing is ubiquitous and that forager social exchange is dominated by some sharing ethic (Mauss, 1925). This is captured by Sahlins’ notion of ‘‘generalized reciprocity’’ (Sahlins, 1972; Levi-Strauss, 1969). Perhaps an easy explanation for the lack of good data is a previous lack of good theory to explain the patterning of food sharing in a variety of ecological contexts. To meet this need, anthropologists have borrowed models from evolutionary biology and economics that allow for testable predictions regarding the possible mechanisms that favor various patterns of sharing (see next section).

The application of such models to data on human populations is still in its infancy [see Winterhalder (1997) for a recent review]. Therefore the principal goal of this paper is to present data collected on food sharing with the Hiwi of Venezuela. This will add to the small but slowly increasing sample of traditional populations for which we have quantitative data. Although it is important to study patterns of food sharing among villagers, peasants, and even modern peoples, there are three good reasons for studying food sharing among contemporary hunter-gatherers. First, high levels of sharing are believed to characterize most small-scale foraging groups. This should allow investigations of the factors which lead to frequent sharing. Second, among foragers, food exchanges mostly occur in the open, making it easier for an observer to measure amounts given and received. Finally, the study of food sharing within the context of a hunter-gatherer lifestyle may help us better understand the evolution of cooperation and sociality among our hominid ancestors.

The Hiwi sharing data allow us to resolve some issues in the current debate between two popular competing models of food sharing in behavioral ecology—tolerated theft and reciprocal altruism (for discussions see Blurton Jones, 1987; Hawkes, 1991, 1993; Hill and Kaplan, 1993). Both models address an apparent paradox familiar to behavioral ecologists: Why should individuals acting in their own genetic self-interest give potential fitness-enhancing resources to other individuals (kin and/or nonkin) who pay little to none of the cost of acquisition?[3] In this paper, we explicitly recognize that either reciprocal altruism or tolerated theft may explain some of the food transfers observed. We allow for multivariate causation of a sample of food transfers by examining the relative effects of biological kinship, geographical proximity, family size, and contingency on amounts exchanged between pairs of nuclear families (NFs). We provide evidence that contingency between giving and receiving is an important element of food sharing. We begin with a discussion of alternative theoretical explanations of food sharing and then test some of these with the Hiwi data.

To avoid confusion, we refer to any exchange of food between individuals as a *food transfer* (Hawkes, personal communication; Winterhalder, 1996). We reserve the more precise term ‘‘sharing’’ for instances of intentional giving, when an acquirer has some control over the distribution of his or her acquired resources and there is anticipation of some positive reward. Stolen food or food given away due to coercion should be considered transferred and not shared.[4]

THEORY

Various theories have been proposed to address the issue of why human foragers give up acquired food resources to other individuals. Three important theories include kin selection (KS), tolerated theft (TT), and reciprocal altruism (RA). All deal specifically with interactions between pairs of individuals but can be modified to examine transfers between nuclear families (NFs). Importantly, we include bargaining theory in the section on RA because it leads to very different expectations than earlier tit-for-tat models of reciprocity.

Kin Selection (KS)

Under some conditions, individual acquirers can maximize their inclusive fitness if they direct resources to biological kin who share a proportion

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[3] Although we recognize that cooperative acquisition may be important to consider in any general model of food sharing, we exclude discussion of cooperative acquisition simply because it does not pertain to the Hiwi data collected during the study period. Although Hiwi men do occasionally cooperatively hunt in pairs, we do not have data for these trips but recognize that cooperative acquisition could have some influence on overall sharing patterns.

[4] Any given food transfer could conceivably fall into the category of shared and ‘‘transferred.’’ Consider the anecdote of the carrot and the stick—namely, A gives food to B because A expects to receive a carrot from B *and* because if A refuses to give, B will beat A with a stick.

of their genes with the acquirer. Hamilton (1964) gives a simple conceptual formula relating costs to the acquirer (*C*) and benefits to the receiver (*R*): $B/C > 1/r$, where *r* is the coefficient of relatedness. This implies that the fitness value of exchanged food must be higher to the recipient than to the giver because *r* is almost always <1. An asynchrony exists for example, when the recipient is an adult who has not acquired anything, or the recipient is a dependent juvenile who in general produces very little, and when there is a diminishing return in food value with each additional amount consumed. Rogers (1993) has extended Hamilton's inequality to account for differences in reproductive value (RV) of individuals whose survivorship is increased by kin-biased altruism. If giving food is intended to improve survival, the most likely form of kin selection would be between parents and dependent offspring (Kaplan and Hill, 1985). For example, if a hunter can give a share of a kill to his 50-year-old brother or to his 12-year-old son, both of whom have the same genetic relatedness (neglecting paternity uncertainty), the hunter should choose to give the meat to his son since the food has a higher value to the child who is less able to acquire the food himself and because the son has a higher RV. Exchanges between closely related individuals are therefore likely to be asymmetric, even over a long time period. From this view, one prediction is that the degree of asymmetry in balance exchanges should vary positively with both relatedness and age difference between acquirer and recipient (Hames, 1987; Kaplan and Hill, 1985).

If kin selection were the main force favoring food transfers, we might expect for transferred foods to be distributed as a monotonic positive function of *r* and RV between recipients and acquirers, holding all else constant. However, it is important to recognize that a positive slope between genetic relatedness and some measure of food transfer does not necessarily imply that kin selection is motivating food transfers. For example, kin may tend to live in residences close to those of the acquirer. If proximity increases the likelihood of RA or TT, then the kinship effect is confounded and may be spurious.

Tolerated Theft (TT)

When resources exhibit a diminishing returns curve such that each additional unit consumed is less valuable to a consumer than the preceding unit, and when the marginal value of a resource determines the outcome of any "contest" over a resource, we have the necessary conditions for what Blurton Jones (1987) called "tolerated theft." To avoid the costs associated with any conflict over resource division, an acquirer cedes shares to hungry foragers, who possess higher marginal values for the resource and who would therefore be more likely to ‘‘fight’’ harder for the resource, all else such as resource holding potential being equal between contestants. An acquirer transfers food then because the costs of not transferring food outweigh the benefits of keeping portions for oneself, or hoarding. It is important to note that TT is unlikely if unconsumed resources can be stored or traded for future resources or other goods and services because then resources may not exhibit diminishing returns. But if TT conditions are met, differences in the initial states and resource holdings of hungry foragers should determine the relative amounts necessary to meet some saturation value (Winterhalder, 1996). For example, a forager with a large family that has not eaten recently is expected to display a high marginal value for food and a high saturation value.

The kinds of resources that exhibit high diminishing returns are those that come in large- or intermediate-sized packets, much larger than can be consumed by a single individual (Blurton Jones, 1987; Winterhalder, 1996). When acquisition of large-sized resources is asynchronous across individuals who forage separately, food sharing by TT results in variance reduction in consumption for all foragers who take turns assuming the roles of acquirer and recipient.

This scenario has been shown to be vulnerable to ‘‘scrounging,’’ or reaping the benefits of others’ acquisition efforts without ever ‘‘producing.’’ Blurton Jones (1987) argued that a large group size makes scrounging more prevalent, thereby decreasing the mean per capita consumption, and that scroungers will try to convince other foragers to become producers (through gifts or prestige bestowal). A formal model pitting scroungers, producers, and opportunists together revealed that all three strategists can coexist, with the number of scroungers increasing with smaller producer priority (the amount a producer can consume before scroungers arrive), larger group sizes, and decreased efficiency of opportunists (Vickery *et al.,* 1991).

Hawkes (1991, 1992, 1993) suggests that if TT dominates the sharing pattern of large resources (particularly large game), then large game becomes a public good. Men who target large game in such a situation are not interested solely in family provisioning; instead they may be seeking social attention from the scroungers who benefit most from their production. According to Hawkes, this social attention translates into a larger pool of potential mates and allies; however, deciding which of the scroungers should give return benefits introduces a second-order collective action problem (Hill and Kaplan, 1993; Winterhalder, 1997). Other models such as handicap display (Zahavi and Zahavi, 1998), where hunting ability honestly signals genetic ‘‘quality,’’ can also explain why men might hunt large game even with no control over its distribution. A critical component of Hawkes’ proposal is that individual acquirers should have little or no control over the distribution of large food they acquire. Thus, contingent reciprocation is not expected.

Reciprocal Altruism (RA)

Despite the abundant theoretical evidence for the success of various RA strategies, testing for the existence of these strategies in the ‘‘field’’ has been difficult. The potential for widespread cheating and the time discounting of delayed returns are two reasons typically given for the relative scarcity of RA. Only a handful of studies seem to give empirical evidence for RA among nonhuman animals [bats (Wilkinson, 1988), chimpanzees (Stanford, 1995; de Wall, 1997b), hermaphroditic fish (Dugatkin and Mesterton-Gibbons, 1996), sticklebacks (Milinski, 1987), capuchin monkeys (de Waal, 1997a)]. Among humans, the only empirical evidence to our knowledge is that found for reciprocal garden labor exchange and food sharing among the Yanomamo (Hames, 1987, 1998).[5]

Tit-for-Tat

The same conditions which favor TT also favor various forms of RA—the risky capture of large resource packets and asynchrony in acquisition of these packets across individuals (Kaplan and Hill, 1985). The idea of RA was originally proposed by Trivers (1971) and later formalized in its most popular form as the tit-for-tat (TFT) strategy. In games where players can all do better if they cooperate but some individuals can do better if they fail to cooperate with those who have cooperated with them (the classic prisoner’s dilemma; PD), TFT is a winning strategy when repeated interactions take place over time (Axelrod and Hamilton, 1981). The basic TFT strategy is to cooperate on the first move and then to mimic the previous moves of opponents on future pairwise interactions with those opponents. Since the early 1980s, many forms of TFT have been described, under such names as tit-for-two-tats (TTFT) (Axelrod and Dion, 1988), generous TFT (Nowak and Sigmund, 1992), and Pavlov (Nowak and Sigmund, 1993). Although most games involving TFT-like strategies involve only pairwise interactions, discrete strategies (cooperate or defect), and simultaneous decisions within pairs, more recent investigations have shown that some forms of TFT are robust in *n*-player games (see review by Axelrod

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[5] Indirect experimental evidence in the form of cheater detection modules also support the pervasiveness of reciprocal altruism among humans (Cosmides and Tooby, 1992).

and Dion, 1988), employing continuous strategies [e.g., cooperate or defect with certain probabilities (Frean, 1996)] and with turn-taking or time delays in interactions (Frean, 1996).

Part of the difficulty in demonstrating the existence of TFT is that what might appear to be RA could be some other form of cooperation, such as by-product mutualism that is maintained by a payoff structure different from that required for a PD (Brown, 1983; Mesterton-Gibbons and Dugatkin, 1992). Connor (1995) argues that some species such as impala and black hamlets can evade a PD payoff matrix by ‘‘parceling’’ benefits into small packages. This way, the temptation to defect is lessened by ‘‘teasing’’ interactants into future cooperation. Another complication is determining the time scale over which a return benefit counts as ‘‘reciprocation.’’ The time scale may vary across pairs of individuals and even across sequential interactions within the same pairs, making any population-level measure of reciprocation resemble white noise and difficult to interpret.

Other researchers have also stressed the ecological limitations of PD-based cooperation. Nöe (1990) argues that the PD model is limited since it focuses only on the decision to cooperate or defect among randomly interacting individuals. It does not address how individuals choose collaborating partners or how any yields of collaboration are to be divided among cooperators. The PD also does not allow communication between players to affect any outcome since signaling can be misleading without any enforceable contracts (Nöe, 1990; Nöe *et al.,* 1991).

Bargaining

Realization of the above ecological limitations has led to the incorporation of bargaining economics on cooperation (Hill and Kaplan, 1993; Sosis *et al.,* 1997). Within the context of food sharing, individuals can be viewed as negotiating resource share sizes and expected future share sizes. A ‘‘bargain’’ is struck only if both players agree (unless an acquirer has no control over distribution, in which case ‘‘unfair’’ bargains can result). Utility gain to both parties must then be compared to the gain in the event of no bargain, to see how motivated each will be to negotiate a bargain. Whereas in a PD, the payoff matrices are fixed given the strategies of each contender, here we can envision payoff matrices that can change according to the end result of a bargaining process. The set of all possible payoff matrices which give payoffs higher than those associated with no bargain to both contenders is called the ‘‘bargaining zone.’’ The bargain is then how much of an individual's production is given to another in exchange for a certain expected amount of the other's future production.

Various factors are influential in defining the relative bargaining power of players during food distributions, most of which link ‘‘need,’’ or an individual’s marginal value for a contested resource, to that individual’s ability to extract an appropriate share. Given moderate levels of control over distribution, acquirers must know or at least infer the preferences of potential recipients to bargain successfully the ‘‘price’’ of a resource transfer that may be provided. As a general rule, the higher the marginal value an individual has for a resource, the less bargaining power that individual has in extracting a fair share. Certain extrinsic characteristics such as number of dependent offspring and foraging ability are ‘‘honest’’ signals of utility for food resources, while forms of communication such as pleading, begging, promising, and playing a ‘‘poker face’’ can potentially deceive acquirers into doling out larger shares than expected given actual marginal valuation. However, if for example, certain acquirers consistently score higher hunting yields than other individuals, these acquirers might produce a ‘‘market effect,’’ whereby their essential skills lead to power asymmetry in interindividual relations. ‘‘Powerful’’ individuals can then increase their demands by playing competitors against each other and choose to collaborate with those who offer the best ‘‘deal.’’ This effect has been introduced into the biological literature with respect to cooperative breeding in birds and coalition behavior among baboons (Nöe, 1990) but might apply to forager food sharing if efficient acquirers have sufficient control over their distribution.[6]

From this perspective, there is no reason to expect equal quantities of a single resource to be exchanged between interested parties. Indeed, equal sharing in terms of calories or kilograms of food as envisioned in TFT would be likely only if the bargaining power of all players were identical.[7] Instead, unequal amounts related to marginal value of the negotiated product and price should be exchanged. Given differences in production abilities and availability of other economic options across individuals, a bargain or ‘‘cooperation’’ event can still occur even if the terms of an agreement favor one party. All that is necessary for a bargain to occur is for the benefits to both parties resulting from the bargain to be greater than those received by no bargain. If individuals have at least *some* control over the distribution of acquired resources, there is always the possibility that *no* bargain will be struck at all if conditions are not acceptable or ‘‘fair’’ to all parties

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[6] If good acquirers on average have a lower marginal value for exchanged foods than less skilled acquirers, then individuals with a higher marginal value for food (i.e., those with low bargaining power) can still receive larger portions. The bargain or negotiation is then likely to be a transfer within different fitness currencies.

[7] Similarly, Boyd (1992) shows that when costs and benefits to cooperation vary across individual players, unbalanced reciprocity is a possible outcome.

involved in a food transfer. This is contrasted with TT, where food is transferred automatically as a function of the sizes of resources acquired and the asymmetry in marginal values of the food between the haves and the have-nots.[8]

Variance Reduction

RA as discussed in the food-sharing literature has often been referred to as risk-reduction or variance-reduction reciprocity. This concept is consistent with either TFT or bargaining RA. A forager who subsists only from his own efforts is subject to daily fluctuations in food available for consumption, especially large game. Thus, pooling resources among individual foragers increases the average valve of food consumed and reduces the chance that any one forager will fall below some critical starvation threshold on any given day. Likewise, variance in food intake will be reduced if returns of several producers are pooled. The benefits from sharing would be highest when the returns for separate foragers are uncorrelated and when individual daily return rates fluctuate (Kaplan and Hill, 1985; Winterhalder, 1986). Production systems that result in highly correlated returns across individuals are poor candidates for the emergence of food sharing motivated by variance reduction. The best empirical case for variance reduction in food intake due to sharing has been demonstrated among the Ache of Paraguay during temporary foraging trips (Kaplan, 1983; Kaplan and Hill, 1985). However, variance reduction need not imply a TFT relation, and among the Ache, good hunters consistently give more than they receive (Kaplan, 1983; Kaplan and Hill, 1985).

TT Versus RA: Predictions

TT and RA make several very similar predictions. Both theories predict that large, asynchronously acquired foods will be transferred more often than small, predictable foods. Also, neither theory particularly demands complete exchange balancing. Furthermore, if hunters do not vary much in acquisition skills and each individual spends a similar time hunting, both mechanisms of food distribution lead to risk and daily intake variance reduction.

The critical issue in distinguishing between the two models is contin-

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[8] It could be argued that tolerated theft represents a bargain where the price paid is in a currency of coercion and threat rather than a positive utility. In this sense, tolerated theft and reciprocal altruism can be modeled in an identical fashion, but with a different price.

gency (Hill and Kaplan, 1993). We define contingency, in a general sense, as giving that is conditional upon receiving. The impact of this conditional transfer of food is the "contingency effect." If the amount forager A gives to another forager, B, depends on how much B has given A; this suggests that RA is a likely explanation for at least some of the food transfers. However, it is not clear what time period is critical for measuring contingency. If the observation period is too short, reciprocation might not be observed. Given discounting over time, however, it has been suggested that the time delay between exchanges should be relatively short for RA to be maintained between individuals (Hawkes, 1992). In many situations, individuals are more willing to receive a small share in the immediate future rather than a larger share at some later time, as might be expected if the probability of repeated interactions or trust is low. However, several psychological studies have revealed a preference reversal when the expected time delay is far into the future (Kirby and Herrnstein, 1995; Kacelnik, 1997). In this case, an individual is more likely to desire a larger share at a more distant time than a smaller share after a shorter delay. This is also the expectation if probability of repeated interactions is high.

Although our intention is to test separately for the existence of kin bias, TT, and RA, we must be aware of the possibility that all three might be operating simultaneously. It is not difficult to show that TT and RA can coexist (Gurven, 2000), and it is possible that kinship is important in encouraging future cooperation. Our focus then is not simply to demonstrate the existence of any or all of these processes but, rather, to explain why we might expect a combination of these models to explain much of the observed food transfers.

Explicit Inquiries

As a response to some of the issues raised above, we address two general questions: (a) How do different characteristics of a given resource and/or age and sex of the acquirer determine how much of that resource will remain within the NF on any particular distribution event? and (b) How do characteristics relating pairs of NFs determine how much food will be transferred between them over an observation period? A main goal is identifying outcomes that are consistent with one model and inconsistent with the other, such as contingency. The following questions are more specific inquiries derived from the above two questions.

- How do different resources vary in the extent to which they are transferred outside the NF?

- What is the smallest portion size of a resource that will be transferred outside the NF?
- How does overall size of a resource predict the extent to which it is transferred outside the NF?
- Do men transfer acquired resources more than women? For resources that both men and women acquire, which sex transfers more outside the NF?
- How well does the age of the acquirer for men and women predict the extent to which a resource will be transferred outside the NF?
- Do kin have a higher probability of receiving transferred resources than nonkin?
- How do men and women vary in the extent to which resources are transferred to kin?
- Does the size of the recipient NF affect the amount transferred to that NF over time?
- Does the amount received from an acquirer vary with the proximity of the recipient to the acquirer?
- Is the amount given from NF A to NF B partially contingent upon the amount given by NF B to NF A?

Ultimately, we hope to combine the information gathered from answering the above questions into one or two models that recognize dependencies among the above factors. This is important not just for teasing apart the relative effects of all factors pertinent to answering the two general questions separately, but also for relating the two questions in an attempt to gain a more comprehensive understanding of the complex interactions that govern food transfers.

THE HIWI: BACKGROUND

Prior publications examine diet, seasonality, sexual division of labor, demography, fertility, and child care among the current study population (Hurtado and Hill, 1986, 1987, 1991; Hurtado *et al.,* 1992), while the ethnography of both Venezuelan and Colombian Hiwi populations has been described by earlier ethnographers (Coppens, 1975; Fonval, 1976, Arcand, 1976).

History

Guajibo-speaking people (including the Hiwi) are centered around the Meta River, which forms the border of Colombia and Venezuela. Agricultural groups of Guajibo are found south of the Meta and west of the Orinoco. Hunting and gathering band are found in the headwaters of the Meta and tributaries north of the Meta to the Arauca River, in an area of very poor soils and poor drainage.

The Venezuelan Hiwi were first peacefully contacted in 1959, when cattle ranchers began to encroach on their home range. Bands of Hiwi from the Capanaparo and Sinaruco river drainages were settled at Carabali on the right bank of the Capanaparo River. Carabali later split into three settlements, with old hostilities reemerging. The upstream village was named San Esteban. Relations between the settled bands since at least 1974 have been hostile, often resulting in overt warfare (Hurtado and Hill, 1991). In 1986, the San Esteban band relocated farther upstream because of raids by enemy Hiwi. The new village, called Mahenemuthu, was the site of data collection in 1987–1988.

Some 21,000 ha was set aside for the two Hiwi groups by the Venezuelan government in the early 1970s, but a much larger range is exploited in the yearly round of subsistence. A Catholic priest had some short-term success in introducing subsistence agriculture to the Hiwi but was ousted in the mid-1970s by the Direction de Asuntos Indigenas (DAI) of the Venezuelan government. Governmental assistance since then has been sparse and has had little impact on the traditional Hiwi foraging economy (Hurtado and Hill, 1987).

Ecology and Economy

The Hiwi live in the *llanos,* or neotropical savanna, of southwestern Venezuela. The Ilanos are characterized by extensive grasslands and gallery forests along the river banks. Savanna soils tend to be infertile and poorly drained, with frequent flooding regulating the overall levels of plant and animal productivity, whereas alluvial soils in the gallery forests are rich, supporting a dense animal and plant biomass. There is little seasonality in temperature but high seasonal variation in rainfall (Hurtado and Hill, 1991). Roughly 90% of the annual precipitation (approximately 1665 mm) occurs during the wet-season months from April to October or November, with very limited rainfall in the intervening dry-season months (Hurtado and Hill, 1987). The observed rainfall and temperature patterns during the study period were not in any way unusual compared with long-term reports for the region.

In the 1980s, roughly 95% of the Hiwi diet consisted of wild foods, making the Hiwi full-time hunter-gatherers during the time of study (Hurtado and Hill, 1991). Meat accounted for roughly 60% of the diet by weight and 68%

of the total calories consumed, whereas plant resources accounted for roughly 35% of the diet by weight and 27% of the total calories consumed. The most commonly acquired meat products were feral domestic cattle, capybara, fish, turtles, and caimain, whereas the most commonly acquired gathered foods were roots—*hero, oyo,* and *hewyna,* an arboreal legume (chiga), and mangoes (mostly not planted by the Hiwi). Other important but less common foods were peccary, deer, iguana, palm nuts, honey, and turtle eggs. Storage is uncommon, although roots are sometimes stored for a couple days and meat is sometimes stored for a maximum of 2 days.

The generalized pattern of men hunting and women gathering seems to describe the Hiwi division of labor, although men also gather mangoes during the late dry season. The quantity of meat consumed across seasons is relatively stable, while plant food consumption tends to be very seasonal. Roots and chiga seeds are available primarily during the late wet months from September to December and are acquired by women along gallery forests. However, hunting occurs all year round. Thus, it seems that the Hiwi are carbohydrate-limited during much of the year (Hurtado and Hill, 1991).

Men hunt solitarily all year-round and also in pairs when traveling by canoe to hunting sites. Women walk to foraging areas mainly in and along gallery forests that are close to the permanent settlement. Men and women also forage together in husband–wife pairs 19% of the time during the root season and 56% of the time otherwise (Hurtado and Hill, 1992). These foraging events usually involve canoe travel, where women help navigate canoes and spot game.

Per capita consumption is low compared to that of other foraging groups for which detailed quantitative data exist (2043 cal/person/day). This low consumption corresponds with the small stature and body weight of men and women. Mean body weights for men and women are roughly 56 and 48 kg, respectively, while average heights for men and women are 1.54 and 1.45 m, respectively (Hurtado and Hill, 1987). Also, Hiwi men and women spend less than 3 hr/day foraging for food. The question why the Hiwi work so little given their constant complaints of *jainpa,* or hunger, and their low overall levels of consumption is an unanswered problem that demands future attention. Some possible explanations focus on the high levels of helminthic parasites and anemia, seasonal fluctuations in body weight, and heat stress—all of which could make extra foraging effort not worthwhile (Hurtado and Hill, 1991).

Settlement and Demographic Characteristics

The study population is a group of 106 Hiwi foragers organized into 37 NFs in 14 dwellings spaced about 100 m apart along a levee of the

Table I. Sampling Information

Month/year	Days	Total sharing events observed
Dec. 87	15, 16, 18, 20	14
Jan. 88	13, 16, 18, 19, 20, 21, 27, 29, 30, 31	35
Feb. 88	2, 3, 4, 19, 25	25
Apr. 88	4, 9, 10, 11, 13, 16, 17, 18	38
May 88	4, 5, 8, 10, 11, 12, 13, 14, 15, 16	29
Total		141

Capanaparo River (Table II). It should be emphasized that although the Hiwi diet consists almost entirely of wild foods, they still live in a large permanent settlement much of the year. On about 85% of all person-days monitored, the Hiwi slept in the main village, whereas they slept in temporary camps on only 8% of all person-days (Hurtado and Hill, 1991). Remaining sample days were dedicated to visiting other settlements.

The Hiwi form fairly stable monogamous unions for the most part, although a few stable polygynous unions exist (Hurtado *et al.,* 1992). Sterility rates are quite high, with women having an average total fertility rate (TFR) of 5.13 (Hurtado and Hill, 1987). This, along with the male-biased sex ratio (40 men to 28 women; Table II) and high juvenile mortality (52% of all offspring born who would have reached age 15 by the study period died before reaching maturity), contributes to the current condition of low population growth.

Table II. Description of Data

	Primary	Secondary
No. events	112	29
No. transfers (0 kg) (to other NF)	3656	1000
No. transfers (>0 kg) (to other NF)	315	65
kg acquired	1190.30	92.23
kg transferred (to other NF)	784.55	44.90
No. households	14	
No. NF	37	
No. individuals		
Men	40	
Women	28	
Male child (≤15)	22	
Female child (≤15)	16	
Total	106	

Food Distributions

Resources acquired by Hiwi foragers were transferred in four ways prior to consumption. These patterns appeared to be the same regardless of whether the Hiwi were residing in a large permanent camp or out on a multiday foraging trek with only a few families. First, some resources were divided at the acquisition site. This was observed primarily after cooperative capybara hunts.[9] When individuals of different households hunted in the same canoe, (some men paddling and others shooting arrows), the kill was always divided immediately. Also, nearby individuals who had cooperated in the pursuit of a single animal (e.g., driving it, spotting, etc.) often received a portion at the kill site. Division at the kill site was also observed after several members of different households shared a canoe to obtain a large amount of fish. This form of sharing was rarely seen in any other context.

The second form of food transfers is typical for game, fish, and some fruits. When an acquirer arrived at the residential camp after a foraging episode, individuals were called to his/her household to receive a share before the food had been processed in any way. Game was divided into several pieces and individuals who were called would wait about 5 m from the butchering site until called again to step up and take a share. A few pieces were sent by the divider via a woman or child to a more distant household. Some individuals also occasionally arrived to the butchering site without being called by the divider and some of those individuals occasionally were given a share as well. At most division events, the majority of NFs in the residential camp did not approach the division site and were not given a share. Roots were also shared in a similar fashion but were always cooked before division. On a few occasions several of the authors saw two women who had gathered roots together each cook them separately and then use the same pot to send cooked roots to each other. The amount of roots exchanged in these cases was almost identical.

The third form of food transfers was the redistribution from a recipient in the above sharing types (including the acquirer who might keep more in the initial division than he/she intended to be consumed within the household) to another party. This generally happened only after processing and cooking. Plates of cooked meat or fish, grated roots, root starch pudding, mashed fruits, etc., were given to nearby families and households.

The fourth form of food transfers took place within NFs and determined how much was consumed by individual members of a family unit. Most family members ate out of the same pot or were given smaller portions of any cooked item such as a piece of game. Family members faced each

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[9] Capybaras are large-bodied rodents which weigh about 45 kg.

other but turned their backs to nonfamily members while eating. Men were often served first, but fathers (and mothers) generally went without eating on days when little food was obtained. Children often cried and whined for more at any meal until all edible portions were gone. Intrafamily sharing was very difficult to observe and was not the focus of data collection or analysis in this paper.

METHODS

Data Collection

Data were collected with Hiwi foragers at the Mahenemuthu settlement in Venezuela by A. M. Hurtado and K. Hill. All data were collected during the 1987–1988 field season from December to February and in parts of the wet season from April to May (37 sample days; Table I). Because of strong seasonal changes in the Hiwi diet (Hurtado and Hill, 1991), the distribution patterns of some important resources were not well sampled.

On sample days, data were collected on every fifth resource brought back to camp among a group of families, which, due to time constraints, was biased toward sampling acquires that lived relatively close to the anthropologists. The resource type, original package size, acquirer, weights of all pieces, and names of all recipients were recorded. Most weights were measured to the nearest 0.1 kg with either a 10-kg or a 20-kg spring scale, although some weights such as a group of mangoes were estimated by visual inspection. Each observation of all people who received a share of a particular resource item is called an event. The first distribution of a focal resource was called a primary sharing event. This distribution precedes any consumption or cooking. The data include 112 primary sharing events that represent 1190.3 kg of food acquisition. We recorded 415 food exchanges during those events, comprising 784.6 kg of the food transferred to other NFs (Table II). When individuals redistribute a portion received from a primary distribution to still other recipients, this represents a secondary sharing event. Secondary sharing events were sampled only occasionally and represent only 29 of the total 141 recorded sharing events (Table II). These data are used only to provide an estimate of what proportion of a share received in a primary event is ultimately consumed by the NF of the person receiving the share.

Data Analysis

An initial database was constructed for each event, including information on the acquirer, resource type and weight, potential recipients, kinship of recipient to acquirer, distance of acquirer's household to recipient's household in meters, and amount exchanged. We coded relatedness between NFs by choosing the biological kinship relationship of the two closest related individuals from any given pair of NFs. Every individual present in camp on the day of the sharing event was recorded as a potential recipient. Additional information such as the sex and age of acquirers and the NF membership of both acquirers and recipients is also given. NFs were defined as married adult and their dependent offspring. By our definition, older adults and their adult offspring constitute separate NFs. Some NFs contained adopted children.

Most potential food transfers were analyzed as interactions between NFs rather than individuals. Data were coded in this way because tracking the movement of food shares to every individual mouth was nearly impossible. In all primary distributions and many secondary distributions, food transferred provided only a rough estimate of who actually consumed the food, and intrafamily sharing of all resources was ubiquitous.

A database was constructed for some of the later regression analyses that lists the total amount of food transferred between all pairs of NFs over all events during the sample period, as well as the above characteristics that define relationships between NFs. Each pair of families represents one data point in this database.

All statistical analyses were conducted in SAS and MS Excel. We use linear regression for many of the univariate analyses and path analysis for the multivariate analyses. Path coefficients were estimated by maximum likelihood, using the PROC CALIS protocol in SAS.

RESULTS

Extent of Food Sharing

All Resources

Roughly a third of all food acquired was kept by the NF of the acquirer during primary sharing events, while a little more than half of that food was kept within the NF during the monitored secondary events (Table III). This suggests that about 17% of all food acquired is ultimately consumed by the NF of the acquirer. More food is kept within the household (26% in our sample), which typically consisted of two or more NFs.

Among the Hiwi, being present in camp at distribution time does not guarantee receipt of a share. If food distribution were strictly egalitarian, then each of the other 36 NFs should receive on average 1.8% of any

Table III. Overall Extent of Food Sharing

Level	Primary sharing (total = 1190.3 kg)	Secondary sharing (total = 92.3 kg)
	% kept	
Nuclear family (NF)	34.1	51.3
Household	40.0	66.6
	% given	
To each other NF present	1.8	1.3
To each NF that received a share	23.4	21.7
To each other house present	4.6	2.6
To each house that received share	22.4	24.7

resource item, while in actuality, NFs that obtain a share receive an average of 23.4% from each primary event. This suggests that on average, acquirers are initially sharing with about 3 other NFs among the pool of 36 other families. The average number of sharing partners was slightly lower in secondary sharing events (2.2 NFs and 1.4 households). Thus, most Hiwi families receive nothing when a food resource is brought into the village.

By Resource Type

Table IV shows how much of each resource (meat, fish, roots, fruits, and other collected goods) is kept in the NF and how much is given to other NFs. Meat includes game such as peccary, caiman, wild pig, iguana, armadillo, deer, anteater, and turtle, and ‘‘other’’ includes nuts, palm hearts, honey, eggs, and plantains.

In our sample, meat was transferred in the greatest proportions and most widely. Only 20.7% of the game acquired was kept in the NF during primary distributions, with an average of 4.8 partners each receiving about

Table IV. Primary Sharing by Resource Type

	Percentage			
	Meat (total = 464.7 kg)	Fish (total = 276.8 kg)	Roots (total = 64.9 kg)	Other (total = 352.9 kg)
% kept by NF acquirer	20.7	45.2	83.7	36.9
% to each other NF present	2.2	1.5	0.5	1.8
% to each NF that received a share	16.5	27.4	16.3	15.8
Avg. no. sharing partners	4.8	2.0	1.0	4.0

16.5%. More fish is kept within the NF (45.2%) than game, even though both are high protein–lipid sources. Roots and other goods are often kept in the NF (83.7 and 65.9%, respectively), with an average of only 1.0 and 2.9 other NF recipients per focal event. Also, the mean percentages kept within the NF *per event* (i.e., not controlling for differences in amounts acquired per event) for meat, fish, roots, and other goods are 40.8% (SD = 33.7%; n = 36), 58.2% (SD = 33.0%; n = 51), 77.2% (SD = 30.0%; n = 12), and 43.7% (SD = 33.8%; n = 36), respectively. Although the sample size of roots is large enough to warrant inclusion in this study, the data were not collected during the peak of the root season when roots were the main food staple. Fruits appear to be transferred more widely than all other categories except meat, with only 32.1% kept within the NF and the rest transferred to an average of 4.8 other NFs.

Characteristics of Resources

Share Size

Figure 1 shows the frequency distribution for the percentage of a resource item that is kept by the NF of the acquirer or given to other NFs. For shares given to other NFs, most pieces are less than a quarter of the whole package. Whole packages are almost never given away. Conversely, pieces NFs kept for themselves constituted all to none of the resource acquired by one of their members. Small foods are consumed completely by the acquirer and his or her NF, while only larger foods tend to be transferred.

We also examined the absolute sizes of pieces shared. This may allow us to determine the size of a biologically significant piece from which significant utility can be obtained (Fig. 2). Food kept within the NF is biased more toward larger-sized pieces, with shares usually exceeding 0.5 kg. Importantly, other NFs rarely obtain a piece smaller than 0.5 kg. This suggests that most packages, which are generally smaller than 10 kg (see below), will be transferred to only a few other families.

Package Size

Figure 3 gives the percentage of a food resource kept within the NF, and the average percentage of that resource that was given to a recipient NF, as a continuous function of resource package size. For meat, fish, and other foods, the percentage kept within the NF and the percentage given

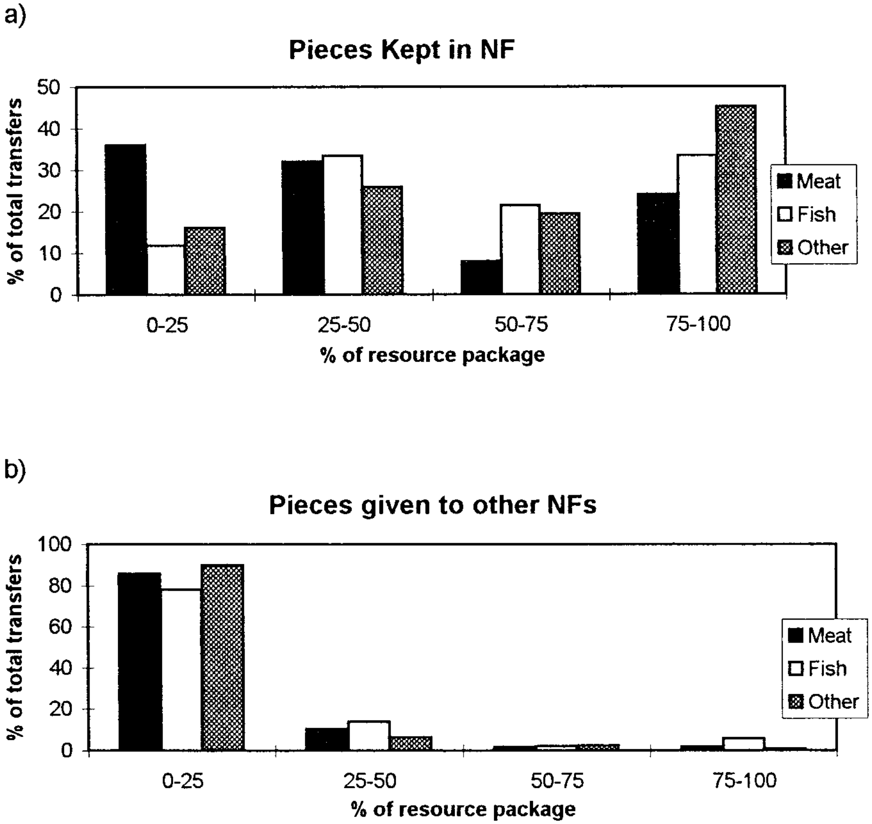

Fig. 1. Relative share size attributes. For all transfers of meat, fish, and collected goods: (a) the frequency distribution of the proportions of original packages kept within the NF; (b) the frequency distribution of the proportions of original packages that are given away to other NFs.

to other NFs is a decreasing function of package size. The graphs clearly illustrate that each recipient NF received smaller portions of fish, collected goods, and meat items under 5 kg than the acquirer's NF. For game items larger than about 5 kg, however, each recipient NF was given roughly the same size portion as that kept within the acquirer's NF.

Figure 4 shows that the number of NFs that received a share in each meat, fish, and other collected food distribution is an increasing function of resource package size. The shape of this function is similar across all three resource types, rising steeply from the origin to about six NF recipients for packages of about 10 kg, then reaching an asymptote of about six or seven NF recipients for the largest packages.

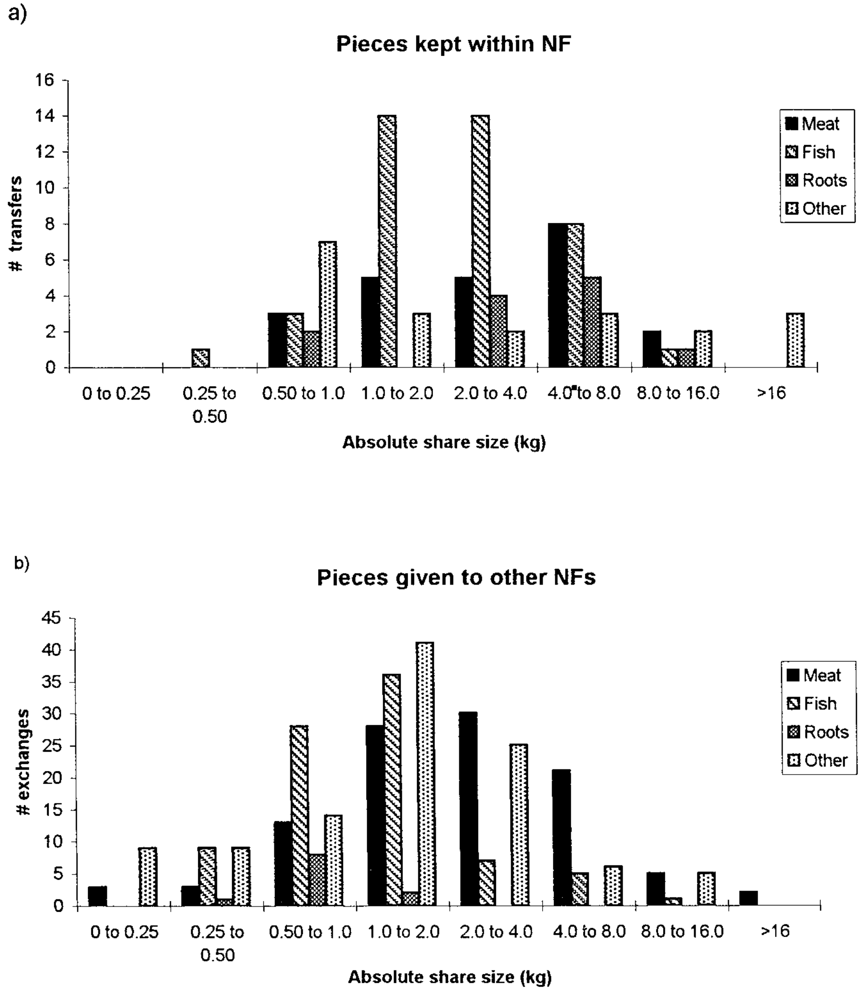

Fig. 2. Absolute share size attributes. Frequency distributions of absolute share size (kg) given for (a) shares kept within the NF and (b) shares given to other NFs. Results are stratified by resource type: meat, fish, and collected goods.

Who Gives and Who Receives?

Age Effect

Age is expected to be associated with resource transfers because the costs and benefits of food transfers for individuals are affected by factors

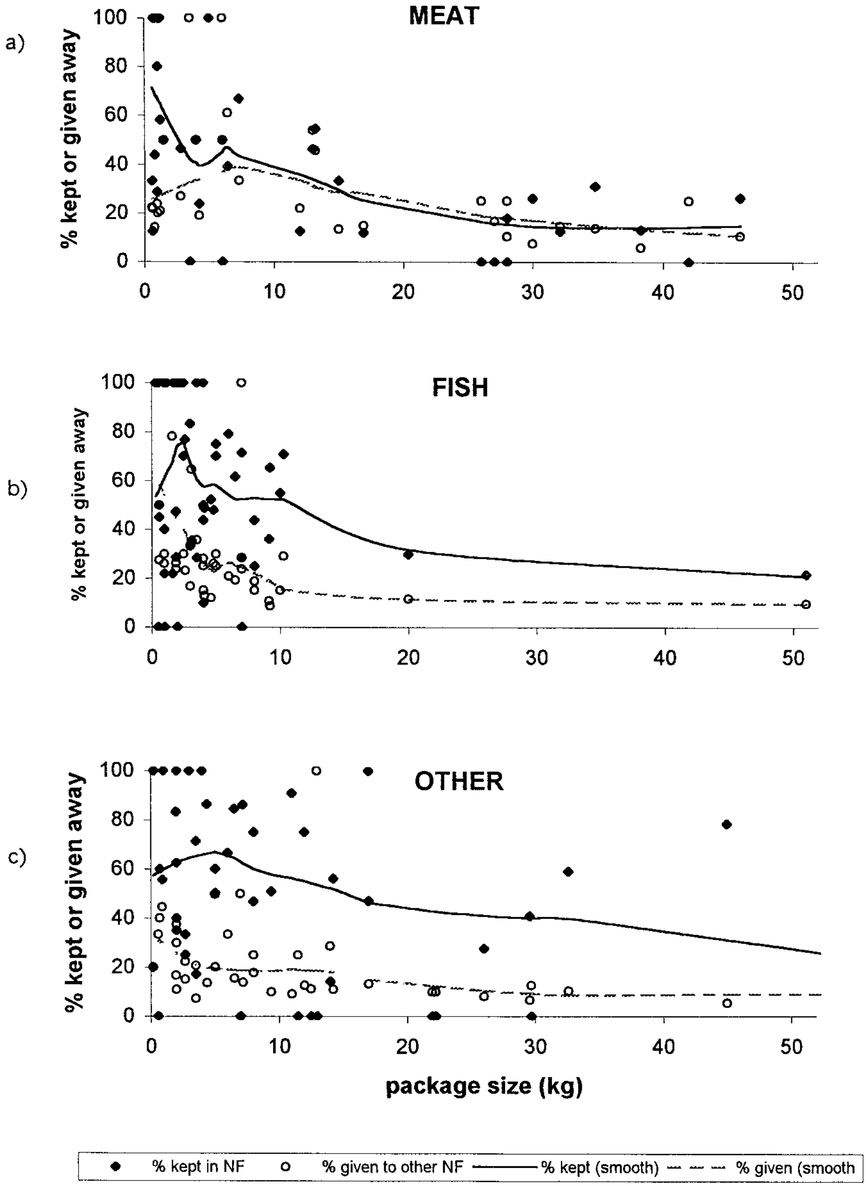

Fig. 3. Package size and sharing depth. Percentage of a resource kept in the nuclear family (filled circles and solid line) and average percentage of the same resource given to each nuclear family that received a portion (open circles and dashed line), as a function of package size of the resource (kg). Graphs are shown for (a) meat, (b) fish, and (c) other collected foods. Fits to data are lowess smooth curves.

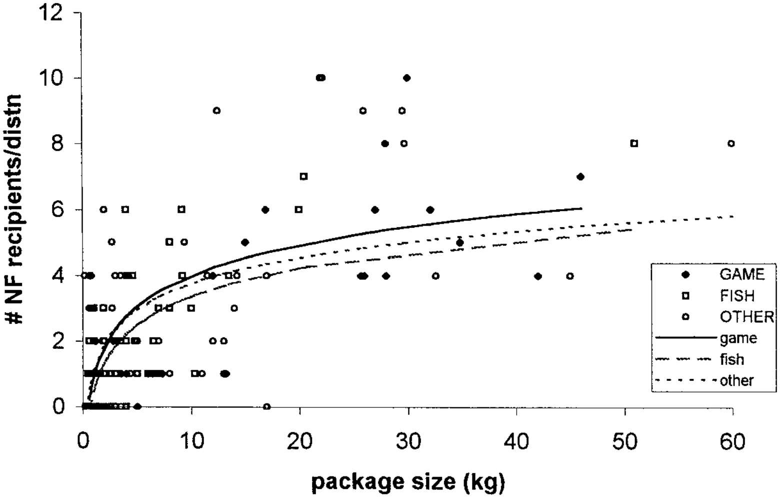

Fig. 4. Package size and sharing breadth. Number of nuclear family recipients per distribution as a function of package size (kg) for meat, fish, and other collected foods. Fits to data are logarithmic curves.

that covary with age (e.g., reproductive value, food production rates, political power, etc.).

However, in our sample, there appears to be no effect of age of acquirer among males on percentage of meat (Fig. 5a; $p = 0.545$, $R^2 = 0.04$) or fish (Fig. 5b; $p = 0.576$, $R^2 = 0.02$) kept in the NF. There were not enough sampled events of men acquiring collected goods to justify an analysis. However, there is an age effect for female acquirers (Fig. 5c; $p = 0.054$, $R^2 = 0.43$). Older women transfer significantly more of what they acquire than do younger women. From the regression, a 55-year-old woman is expected to transfer about one and a half times more food than does a 30-year-old woman. This result is consistent with various versions of the "grandmother" hypothesis (Hawkes, 1989; Kaplan *et al.,* in press).

If we examine the age effect of recipients, we see that individuals age 25 to 55 receive the most, while young children receive very little (Table V). This does not mean that young children eat very little while older individuals gorge themselves. Instead, primary sharing distributions are biased toward adult members, who are then expected to provision their families. This pattern suggests obligations to other producers and not to consumers who do not produce (i.e., children), although all Hiwi are aware that food given to parents will often be transferred to their children.

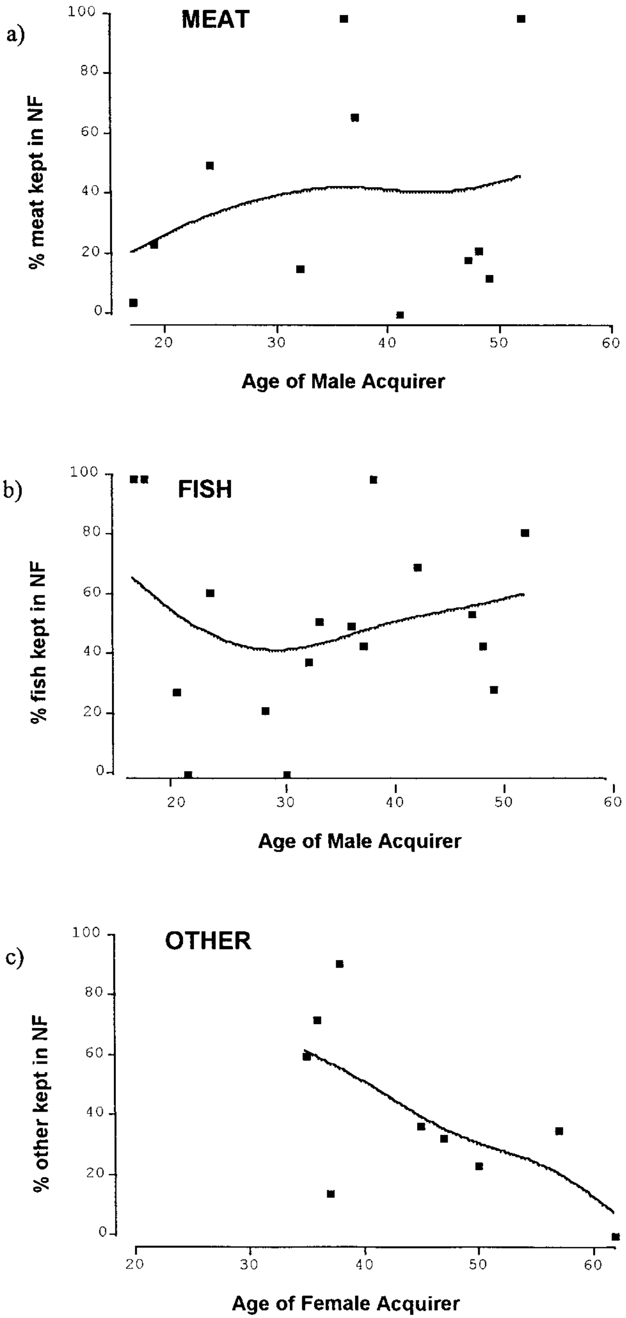

Fig. 5. Age effect of acquirer as a function of sex and resource type. Percentage of total acquired that are kept within the NF as a function of age of the acquirer for (a) meat, (b) fish, and (c) all collected resources. Fits to data are lowess smooth curves.

Table V. Age Effect of Recipient (Rec), Primary Sharing

Age of rec	No. individuals in age class	kg received from others	Avg. kg/rec
<15	36	42.28	1.17
15 to 25	16	90.3	5.64
25 to 55	39	577.56	14.81
≥55	15	135.87	9.06

Sex Effect

On average, men kept 31.6% of what they acquired in the NF, while women kept 44.0% (Table VI). If we take the distribution pattern of different resources as a given, this difference makes sense. The low figure for men is due to the distribution pattern of game (shared extensively as shown above), which is acquired almost solely by men, whereas the higher figure for women is largely due to their targeting roots. If men on average target resources that are often transferred (Hawkes, 1993), we cannot yet argue that they target those specific resources *because* they will be transferred. Unfortunately, only one resource in our sample was targeted by both men and women—mangoes. Mangoes were generally acquired in long day or overnight collecting trips by several individuals together and brought back to the village in large bags. Although in our sample women kept only 2.1% of their mangoes for their NF, whereas men kept 91.3% (34.0% for mangoes acquired by husband–wife pairs), this huge disparity is probably a sample size artifact ($n = 3$ and 4 for males and females, respectively).

Kinship Effect

Figure 6 shows the percentage of the total acquired that is given to a single NF in each kinship class, with relatives listed in order of decreasing coefficient of relatedness, r. We list kinship classes, with similar r in order

Table VI. Sex Effect of Acquirer, Primary Sharing

Sex of acquirer	% kept within NF by sex of acquirer by resource type				
	Meat	Fish	Roots	Other	Total
Male	19.6	45.3	N/A	85.6	31.6
Female	0.0[a]	64.3[a]	83.4	28.1	44.0
Total	20.7	45.2	83.7	35.6	

[a] Constructed from a very small sample size.

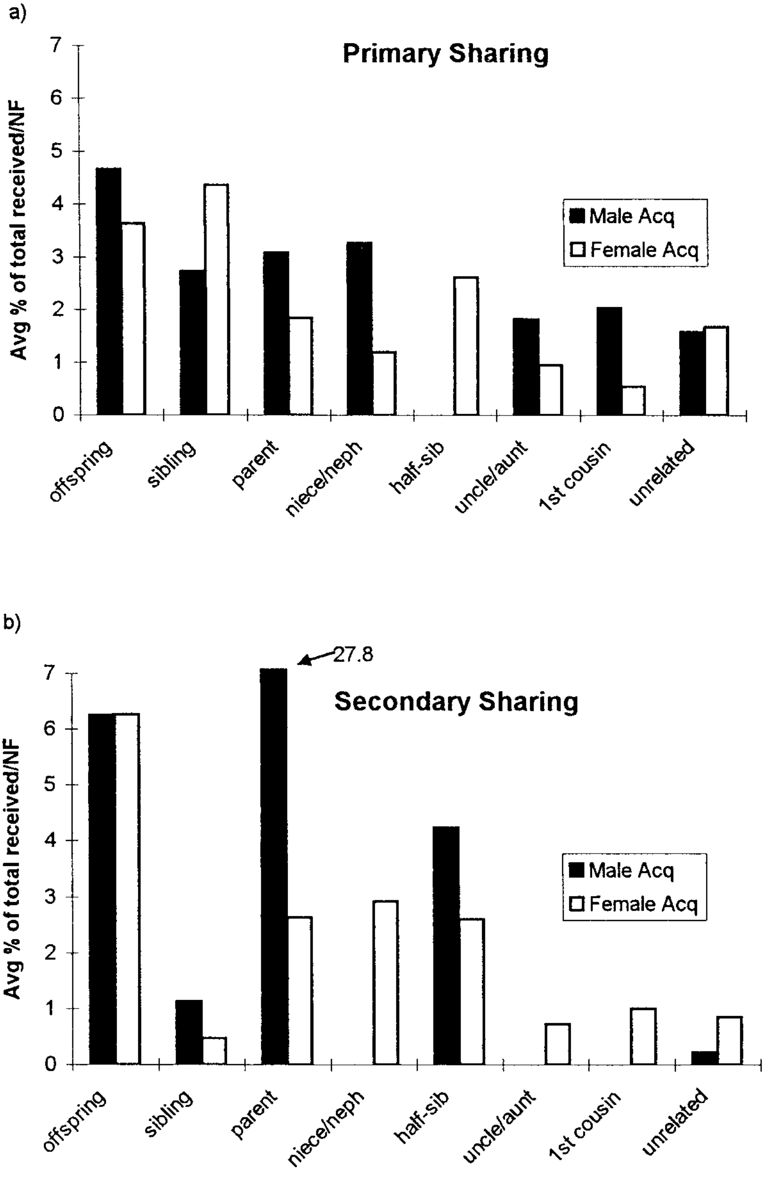

Fig. 6. Sex effect and kinship bias in shares. Average percentage of total kilograms received per NF by relation and sex of acquirer for (a) primary sharing events and (b) secondary sharing events.

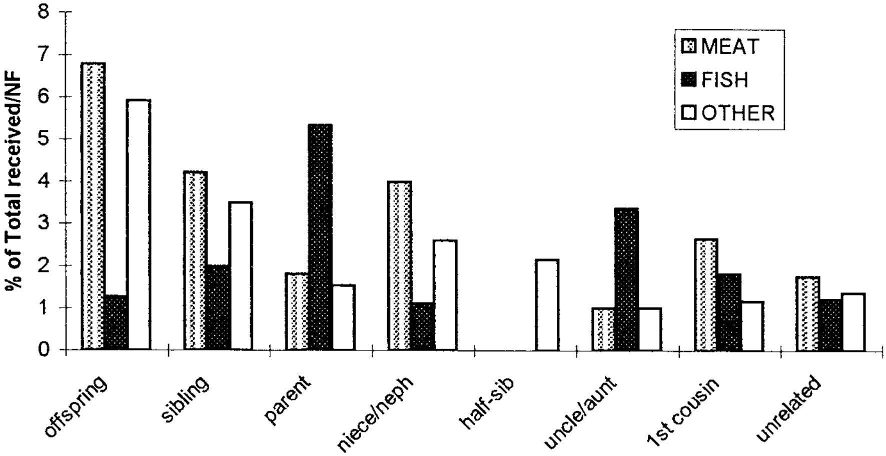

Fig. 7. Average percentage of total received per NF by relation to acquirer and resource type for primary sharing events.

of decreasing reproductive value. Thus, we rank from highest to lowest (as a function of increasing age)—independent offspring, siblings, and parents. Offspring in this analysis are adults since by definition they are outside the NF. There is a definite bias toward adult offspring, siblings, nieces, and nephews, in comparison with unrelated individuals in primary sharing events. Only offspring and parents receive significantly more than unrelated individuals in secondary sharing events.

If men are targeting resources that are likely to be transferred, we might expect for men to be less interested in provisioning family and kin than in either showing off or trading with nonkin for some other benefit. However, Fig. 6a shows that men and women do not differ greatly in the percentages they give their offspring, siblings, parents, or unrelated individuals in primary sharing events. Figure 6b shows a similar pattern for provisioning within the NF (self and offspring), but men gave substantially more to parents.[10] It is interesting to note that women also give more to unrelated individuals.

If we examine kinship bias by resource type (Fig. 7), we see that for meat and other collected foods there is a significant bias toward provisioning offspring and siblings, while for fish, the kinship bias appears smaller. To understand better the quantitative differences between kin and nonkin in

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[10] Because we coded relatedness between any two NFs as the closest kinship relationship between any pair of individuals from each NF, the category "parents" includes both actual parents and in-laws.

receiving shares, we performed regression analyses on the percentages of per-event packages received for all events by r for each resource type. All regressions showed statistically significant effects, with $p < 0.0001$. We illustrate the maximum effect of kinship by graphing the percentage increase above baseline ($r = 0$) a NF with $r = 0.5$ could expect to receive (Fig. 8), controlling for geographical proximity between the appropriate paris of NFs.

Proximity Effect

Families in close geographical proximity to acquirers generally receive more food than those located at greater distances (Fig. 9; $p = 0.009$, $R^2 = 0.53$). However, there is a noticeable anomaly in the trend; a few families far away receive on average as much as those nearby, indicative perhaps of some trade network, kin relations, or reciprocity partners.

Family Size Effect

If we examine how much food each family received in redistributions during our sample period, we find a significant positive relationship between amount received and family size (counting each family member as one

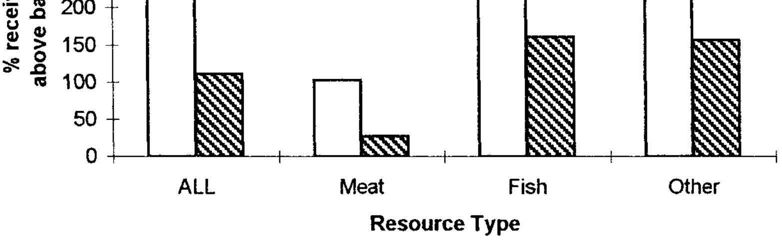

Fig. 8. Kinship effect on percentage received per event. Percentage above baseline ($r = 0$) that close relatives ($r = 0.5$) receive per event. Hatched bars control for the confounding effect of residential distance between NFs on kinship effects.

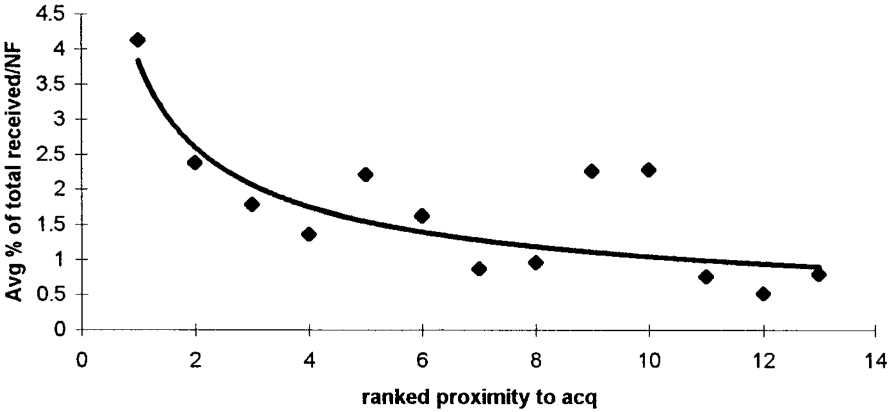

Fig. 9. Proximity effects on sharing. Average percentage of total received per NF by ranked residential proximity to acquirer.

person) (Fig. 10a; $p < 0.001$). There also seems to be a slight positive relationship between family size and how much families keep within the NF, but this trend is not statistically significant in our sample (Fig. 10b; $p = 0.101$).

Reciprocity

Models of food transfers based on some form of RA often predict that the size of a share received during a distribution or the probability of receiving a share should be contingent on previous transfers (and expected future transfers) between a potential recipient and the redistributor. Whether or not contingency is a critical component of an acquirer's decision to transfer food has been difficult to determine empirically. In this study, we examine the percentage of total acquisition transferred between all pairs of NFs over the entire study period to see if NFs who gave a larger proportion of their production to some other NFs were in turn more likely to receive a larger proportion of those NFs' food production. This was done for each resource type—meat, fish, other collected goods, and all resources. The latter, pooled category considers trade of different food types, while the first three focus on contingency within single resource types.

Only families that were adequately sample, having acquired at least 10 kg of food, were included for analysis. We also raised this requirement to 20 and 40 kg on the pooled sample to examine the results of food transfers among families whose distribution patterns are better docu-

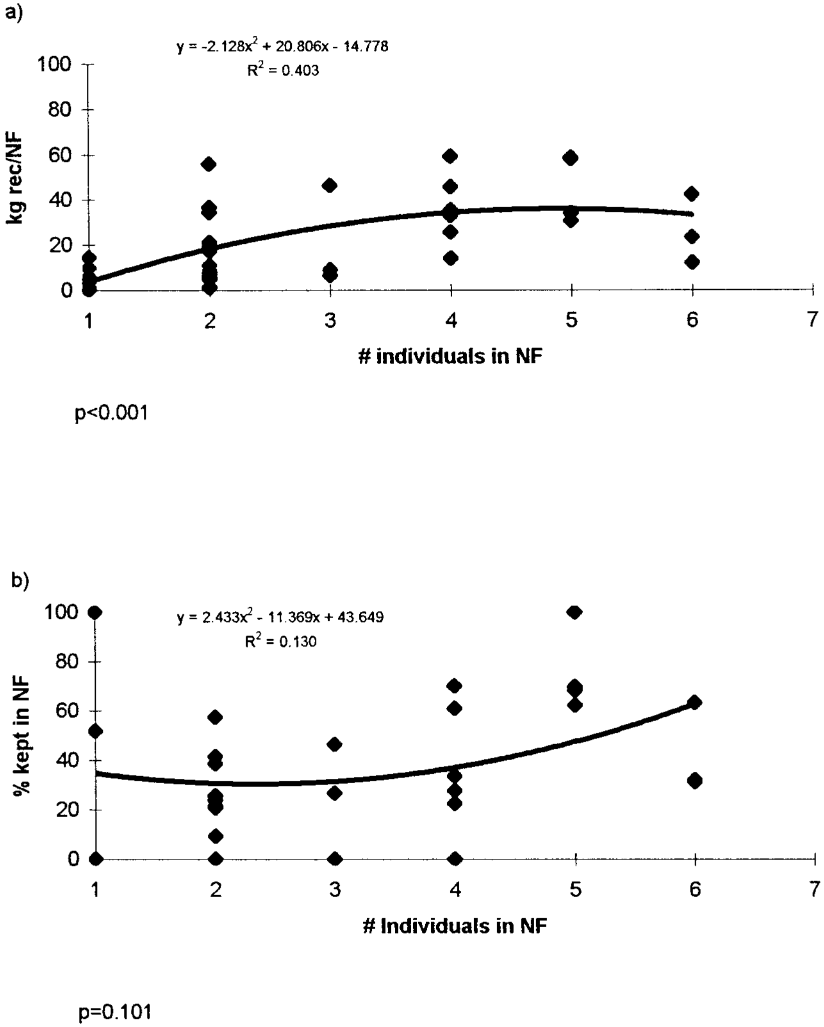

Fig. 10. Family size of NF effects. (a) Total kilograms received by others as a function of family size. (b) Average percentage kept within the NF as a function of family size.

mented; however, this reduces the number of families we can include in our analysis. For example, the 10-kg requirement reduces the number of families we consider from 37 to 21.

In considering two families, A and B, we calculate the percentage of a resource type A acquired over the sample period given to B, and vice versa. This was done for each pair of NFs. However, this relationship for any given pair of NFs produces two perfectly correlated data points. If the percentage that A gave to B is the dependent variable and the percentage that B gave to A is the independent variable, then it is also true that B giving to A will be the dependent variable and A giving to B the independent variable of the correlated data point. This results from the lack of any natural ordering of the NFs. We adjust for this correlation by employing two methods. In the first, we run univariate linear regressions using a *t* statistic based on half the sample size. This is better than randomly choosing one data point from each pair to halve the sample, especially for the resource-specific analyses which have smaller sample sizes. There should be little difference in parameter estimates for the pooled sample which has a large sample size, with the same slope and intercept expected as would be using half the data.

In the second method, we perform a multiple regression of the percentage of A's total given to B for all NFs A and B on our other independent variables: family size of B, age of oldest individual in A, relatedness of B to A, distance from B to A, and total percentage A kept within the NF. We then pair the residuals from this regression such that the residual obtained from looking at A giving to B is paired with the residual obtained from how much B gave to A. If there is contingency, these pairs of residuals should be correlated. We compute an intraclass correlation, which compares differences between and within pairs of residuals.[11]

Table VII summarizes the results of the first method looking at closely related and more distantly related families (defined as $r < 0.5$) in four food classes. Fish transfers between distant and nonkin show the highest contingency, with each incremental increase of 1.0% of family A's total given to family B being reciprocated with an average increase of 0.45% of family B's production being transferred to family A. Transfers to close kin show no evidence of contingency across any resource type. However, there is some indication that close kin transfers display contingency when all

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[11] Alternatively, we randomly assigned each element of the pair to be *X* or *Y*. We do this for all pairs, then calculate the correlation coefficient. We performed 100 Monte Carlo simulations and computed the average correlation over all trials. The results were similar to those obtained from the intraclass correlations. We also report the minimum and maximum correlations observed in each set of 100 trials.

Resource type	r_{avg}	r_{min}	r_{max}
Meat	0.382	0.329	0.473
Fish	0.414	0.384	0.563
Other	0.094	0.081	0.124
All	0.188	0.182	0.226

Table VII. Relationship Between the Percentage NF A Gives to NF B and the Percentage NF B Gives to NF A by Resource Type

Resource type	Slope	*p* value	R^2	df	*t*
	Both kin and nonkin relations				
Meat	0.333	0.012	0.111	55	2.598
Fish	0.446	0.000	0.199	71	4.166
Other	0.032	0.445	0.003	181	0.765
All					
(≥10 kg)	0.215	0.000	0.046	419	4.507
(≥20 kg)	0.288	0.000	0.083	209	4.344
(≥40 kg)	0.385	0.000	0.149	131	4.761
	Kin–kin relations ($r = 0.5$)				
Meat	—	—	—	—	—
Fish	−0.043	0.900	0.002	10	−0.129
Other	−0.010	0.894	0.001	35	−0.134
All					
(≥10 kg)	0.140	0.253	0.017	76	1.152
(≥20 kg)	0.669	0.008	0.234	28	2.874
(≥40 kg)	0.776	0.011	0.295	20	2.817
	Nonkin/nonkin relations ($r < 0.5$)				
Meat	0.349	0.010	0.122	53	2.683
Fish	0.467	0.000	0.218	60	4.060
Other	0.058	0.307	0.007	145	1.025
All					
(≥10 kg)	0.222	0.000	0.056	342	4.475
(≥20 kg)	0.215	0.002	0.055	180	3.228
(≥40 kg)	0.289	0.000	0.109	110	3.655

resources are pooled. Strong contingency effects for meat, fish, and all foods are found between distantly related and unrelated NFs. Collected foods exhibit little contingency regardless of kinship between families. Our sample data also show that as distribution patterns are more reliably measured, the contingency effect becomes more pronounced. Both the slope and the R^2 value for all regressions increased, as we included only families whose distributions were recorded on acquisitions of at least 20 or 40 kg of food (Table VII).

The results of the second method are given in Table VIII. The implications of these results are identical to those from the first method. Fish transfers display the highest contingency, followed by game, and then all resources pooled. In our sample, NFs that gave a greater portion of their production to a given NF were also more likely to receive a greater percentage of that NF's food production. It should be emphasized at this point that significant univariate contingency relationships can be due to other causes, such as proximity or kinship, and that only a multivariate analysis can show a true contingency effect (see below).

Path Analysis

Having investigated the single effects of package size, sex, and resource type on how much food should remain within the NF, and the effects of age, sex, kinship, distance, family size, and contingency on how much food should be given to other NFs, we present two path models which attempt to weigh the relative importance of these different effects on both dependent variables. We model these "How much to keep?" and "To whom to give?" decisions separately but recognize that the two are closely linked.

Path analysis is a procedure for teasing apart the effects of multiple, often codependent, variables that are related through some causal process (for a review see Loehlin, 1987). It was first developed by the geneticist Sewall Wright in the 1920s and, since then, has been widely applied in the social and behavioral sciences. One generally proceeds by constructing a path diagram of the causal relationships among manifest (and latent) variables. One then constructs equations, whose terms are the paths connecting a given pair of variables. The sum of these terms must equal the correlations between those variables. The values for each path are calculated by solving a set of simultaneous equations. Path values are expressed as standardized parameter estimates, so 1 standard deviation unit increase in the variable at the base of each arrow 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. Both path models were computed using the PROC CALIS procedure in SAS, which employs a maximum-likelihood algorithm for estimating path coefficients.

Table VIII. Intraclass Correlations (r) of "Contingency" Based on Residuals (See Text)

Resource	r	p value	df
Meat	0.336	0.036	27
Fish	0.395	0.007	35
Other	0.087	0.205	90
All	0.184	0.004	209

Path Model 1: How Much Should an Individual Acquirer Keep Within the NF?

Here we focus on age and sex of acquirers, package size, family size, and a production variance index for resources. Sex is a categorical variable with value 0 for a female acquirer and 1 for a male acquirer. We employ a variance index for resources as a simple means of capturing aspects of the variance-reduction hypothesis in a single measure. The production variance index is a composite of three separate measures—$VI = (V_e + V_g)V_a$, where V_e is the variance in encounter rates per person-hour spent searching, V_g is the variance in energy obtained per pursuit, and V_a is the degree of asynchronicity of acquisition, or the opposite of "interforager correlation" (Winterhalder, 1986). Each resource in the sample was ranked on all three variance measures, each ranging from 0 for lowest to 5 for highest. This ranking was done by K.H. based on foraging experiences and without prior knowledge of the extent of food transfers of each resource. *VI* was structured so that complete synchronicity in acquisition ($V_a = 0$) leads to an index value of 0, regardless of the level of variance in the other measures.

We diagram the hypothesized relationships between our variables in Fig. 11. Solid lines with single-headed arrows imply causality, while dashed lines with double-headed arrows represent correlations between exogenous or source variables. Theoretically derived predictions concerning the direction of each relationship are labeled in Table IX. We can judge the relative importance of effects by comparing the relative magnitudes of statistically significant path coefficients. It is clear that package size, family size, and the variance index are the most important influences on how much is to be kept (Table IX). Most of the effects of package size are direct, with remaining effects operating through variance. There appears to be a definite bias of men targeting high variance foods, as might be expected since game has the highest average variance index of all resource types (*VI* averages: game = 43.8, fish = 12.0, collected goods = 11.7, all resources = 20.4). Although men target high variance foods more than women, the total effect of sex on the percentage kept is small [sum of paths E + AF + cv1v4 (H + CF) = 0.053], suggesting that men also target low-variance foods and that substantial portions of high-variance food are kept in the NF. From the path model, we estimate that the acquirer of a large, high-variance resource who has a small family gives away 92% more of the resource than the acquirer of a small, low-variance resource who has a large family.

One of the most common goodness-of-fit indices for path models is the chi-square test (Hatcher, 1994). This is essentially a test of the null hypothesis that the theoretical model fits the data. A good model therefore should have

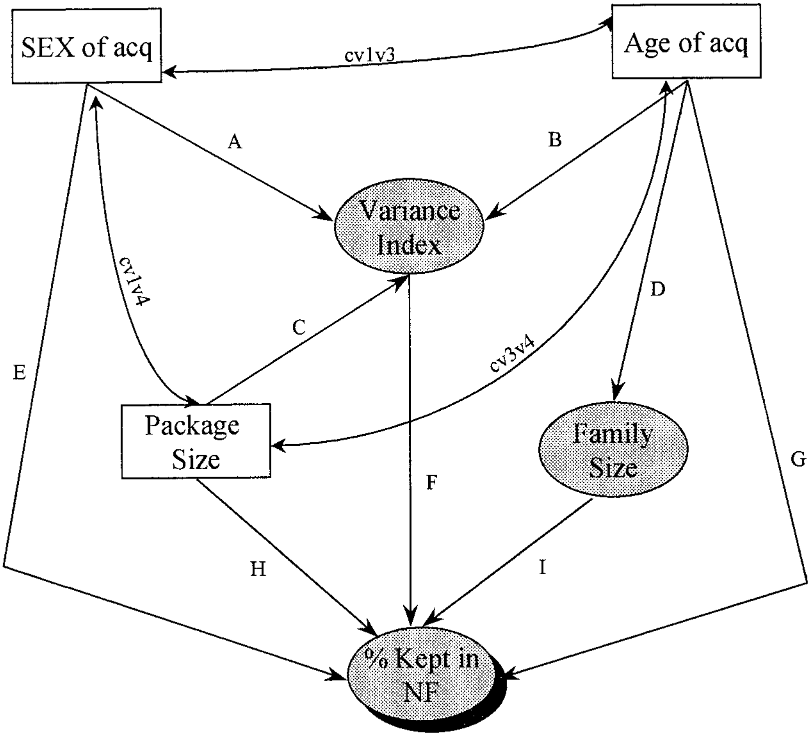

Fig. 11. What determines how much an individual acquirer keeps in the NF? Rectangles represent extrinisic or source variables; ovals represent endogenous variables.

a low chi-square value and the *p* value associated with the chi-square should be larger than the standard cutoff value of 0.05. Two other common goodness-of-fit indices are Bentler and Bonett's (1980) normed-fit index (NFI) and Bentler's (1989) comparative fit index (CFI). Values of both indices range from 0 to 1, with values greater than 0.9 indicating a relatively good fit. Using these goodness-of-fit measures, our model adequately fits the data (*p* value from $\chi^2 = 0.354$, NFI = 0.981, CFI = 0.996; Table IX).

Path Model 2: What Determines How Much NF A Should Give to NF B?

Figure 12 depicts the relationships between those variables that affect how much NF A's total is exchanged with NF B's total—family size of NF B, age of the oldest member of NF B, residential distance from NF A to NF B, closest biological kinship between members of NF A and members

Table IX. How Much Should an Acquirer Keep in the NF?

Path coefficient	Estimate	Predicted direction	Theory[a]
A	0.319***	+	SO
B	−0.001	−	SO
C	0.266**	+	
D	−0.111		
E	0.155	−	SO
F	−0.196*	−	TT, RA
G	0.058		
H	−0.376***	−	TT, RA
I	0.285***	+	BT
cv1v3	−0.260		
cv1v4	0.092		
cv3v4	0.192		
p-value	0.354		
Bentler's CFI	0.996		
Bentler's NFI	0.981		

[a] TT, tolerated theft; RA, reciprocal altruism; BT, bargaining theory; SO, showoff hypothesis.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

of NF B, and percentage of NF B's total given to NF A. Although there should really be two bidirectional arrows between "A→B" and "B→A," we choose to include only one arrow in our model for methodological reasons. The lack of any ordering of A and B requires the relationship between these two variables to be analyzed as a correlation.[12] Standardized parameter estimates for all path coefficients and their predicted directions based on previously mentioned theories are listed in Table X. Estimates are listed for the separate analyses by resource category.

Our inclusion of the full sample ensures that each A will be a B and each B will be the A in the correlated pair. For this reason, we do not make our path model completely symmetric; to do so would be redundant. We focus on A as our dependent variable and B as the independent variable. This precludes adding "family size of A" or "% B kept in NF" to our

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[12] The CALIS procedure takes as input the correlation or covariance matrix of all endogenous and source variables in the path model. Because of the lack of any natural ordering of NF A and NF B in our model, we calculated the correlation between "A→B" and "B→A" the same way we did above. We performed 100 Monte Carlo simulations of randomized orderings and calculated the average correlation over all 100 trials.

Our inclusion of the full sample ensures that each *A* will be a *B* and each *B* will be the *A* in the correlated pair. For this reason, we do not make our path model completely symmetric; to do so would be redundant. We focus on *A* as our dependent variable and *B* as the independent variable. This precludes adding "family size of *A*" or "% *B* kept in NF" to our model. Similarly, we consider only the effects of *B*'s sharing on *A*, and not vice versa.

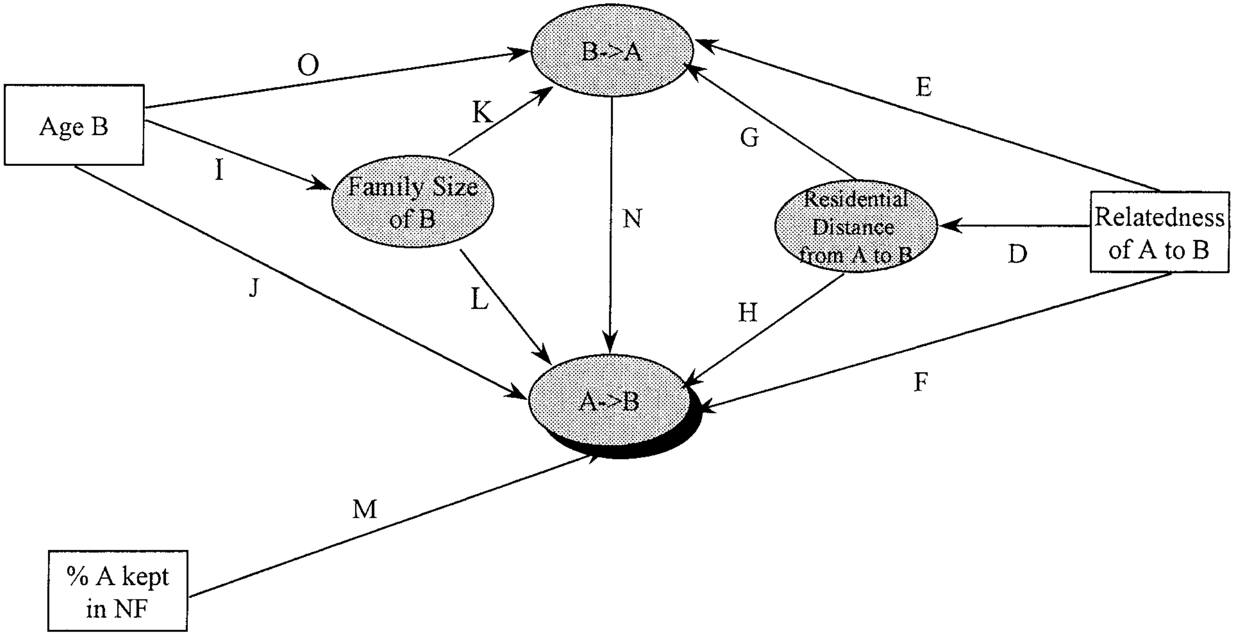

Fig. 12. What affects how much NF A gives to NF B?

Table X. What Determines How Much NF A Gives to NF B?

Path coefficient	Standardized parameter estimate				Predicted direction	Theory[a]
	Meat	Fish	Other	All		
D	−0.479***	−0.439***	−0.393***	−0.417***	−	
E	−0.122	−0.069	0.12	0.096	+	KS
F	−0.015	−0.072	0.05	0.102*	+	KS
G	−0.317*	−0.118	−0.11	−0.142**	−	TT, RA
H	−0.257*	−0.15	−0.151	−0.145**	−	TT, RA
I	−0.224	−0.008	−0.73***	−0.294***		
J	0.143	0.038	−0.074	0.043	+	BT
K	−0.056	0.047	0.182	−0.001	−	BT
L	0.281*	0.321***	0.009	0.14**	+	BT
M	−0.247	−0.117	−0.106	−0.187***	−	
N	0.303*	0.459***	0.056	0.185***	+	RA
O	0.162	−0.054	0.249*	0.084		
p-value χ^2	0.086	0.000	0.000	0.008		
Bentler's CFI	0.835	0.615	0.819	0.943		
Bentler's NFI	0.786	0.643	0.81	0.921		

[a] KS, kin selection; TT, tolerated theft; RA, reciprocal altruism; BT, bargaining theory.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

model. Similarly, we consider only the effects of B's sharing on A, and not vice versa.

Among meat, fish, and pooled samples, contingency (path N) has the strongest direct effect on the percentage of NF A's production transferred to NF B when we control for other influential factors. For meat exchanges, family size of recipient, distance between NF's house structures, and contingency are highly significant factors. The effects of kinship appear to be operating through residential distance (total effects = F + E × N + D × H + D × G × N; 0.117 for meat, −0.0014 for fish, 0.118 for other, 0.191 for all resources). However, the kinship effect may be underestimated since some of our data for close kin in meat exchanges were not included in analyses because of the requirement that included families must have acquired at least 10 kg of meat. Transfers of fish and pooled resources from NF A to NF B are significantly associated with contingency, family size of B, and residential distance. Effects in collected goods transfers are more indirect and diffuse.

We use the path model to describe the conditions that elicit the extremes in food transfers between NFs. A large (six-people), unrelated ($r = 0$) NF that lives in close proximity (distance, < 5 m) and that transferred food (25–40%) to NF A is likely to receive 31% more of NF A's total meat production and 36% more of NF A's total fish production than a small (one-person), closely related ($r = 0.5$) NF that lives far away (distance, >100 m) and that gave little (<1%) of these foods to NF A. Similarly, a large, closely related NF that lives in close proximity to NF A and that transferred food to NF A is likely to receive 16% more of NF A's total food production and 10% more of NF A's total "other" production than a small, unrelated NF that lives far away from NF A and that did not transfer much of its food to NF A.

SUMMARY AND DISCUSSION

We present a list of our significant results.

(1) On average, only 17% (34% prior to processing, 51% after processing) of acquired foods were consumed by the NF. This is a significant level of food transfers, especially considering acquirers did not give to everyone in the community.
(2) Acquirers transferred food to an average of 3.8 NFs on any particular event.
(3) Meat was the most widely transferred resource type, with an average of 5 other NFs each receiving 16.5% per event.
(4) Large packages were transferred more extensively than small packages for all resource types.
(5) Most food transfers in primary sharing events were to middle-aged individuals.
(6) There was little evidence for sex differences in food transfer patterns.
(7) The percentage of food production received by NF A from NF B was a strong predictor of the percentage of food production given to NF B by NF A for exchanges of meat, fish, and all resources pooled.
    (a) This effect is strongest among unrelated individuals.
    (b) Among NFs that were frequently sampled in the field site, the contingency effect becomes stronger.
(8) Package size, variance index, and family size of the acquirer are all important determinants of the total percentage of food kept by the NF of the acquirer. Sex effect is significant only through the variance index.
(9) The percentage of food production received from a specific NF is the strongest predictor of the percentage that a specific NF will be given when other factors are included in a multivariate path model. Residential distance and family size of the acquirer are two of these important factors. Kinship effect is moderated through residential distance but also has some effect on the percentage received.

Kin Selection

While there is a clear kin bias in food transfers between NFs (Figs. 6–8), the overall effect of kinship on the percentage of a NF's food production that is received from other NFs appears small in comparison to the effects of contingency, family size, and residential distance. This suggests that kin selection may not be a very powerful mechanism for regulating between-NF food transfers. It is important to remember, however, that the strongest predictor of consumption after any acquisition event is whether an individual is a member of the NF of the acquirer. Thus, kin selection operating on parent–offspring provisioning is the most important factor in all Hiwi food sharing.

It is difficult to assess the overall importance of kin selection for between-NF food transfers because of potential confounding effects. We have already seen that much of the apparent kinship effect operates through residential distance; families living in close proximity to acquirers that tend to receive more also tend to be close kin. If unrelated individuals living in close proximity to acquirers receive more than close kin living further away, does this violate the predictions of kin selection? Or must unrelated individuals receive more than kin when both live the same distance from an acquirer? It seems that we might identify ''proximity to acquirer'' as the important determinant of who receives, rather than biological relatedness. If kin groups lived in close proximity to each other throughout the course of hominid evolution, it might appear that kin selection was crucial in the emergence of food sharing, even though residential distance (through increasing probability of future interactions and allowing easier monitoring of others' returns) is the distal variable of immediate importance.

However, it is also possible that the effects of kinship *and* residential proximity are associated with a latent variable not included in our model that we identify as the ''desire to share.'' The ''desire to share'' might motivate kin to stay in close proximity to high producers and unrelated families to move closer to potential trading partners.

It is important to acknowledge that the kinship effect may be underestimated for meat exchanges because our sample size requirement that all included families must have a total meat acquisition sample size of at least 10 kg significantly reduces the number of kin-related pairs of families. Hence, if good acquirers unconditionally share meat with kin who acquire no meat (and may or may not return the favor in some other currency), this would not be detected in the path model. Figures 7a and 8 suggest that at least some of the kinship effects are missing in the path analysis of meat transfers.

Tolerated Theft

Our findings that package size and residential distance are important determinants of how much families receive agree with several predictions of TT. However, the existence of a contingency effect violates the TT assumption that food is given away as a consequence of differences in marginal value and resource holding potential between the acquirer and potential recipients. Also, only a few families receive food on any given event, even though the number of potential recipient families is much larger. The Hiwi village is open and flat, with no obstructions or walls to block the view of all food resources brought back from foraging. The fact that only a few of the families that are aware of food acquisition receive a portion on any given event is also confirmed by the frequency distribution of various share sizes (Fig. 2). It is not the case that food packages are being divided into thumbnail-sized pieces to accommodate all hungry recipients having high marginal value for the particular resource being distributed. Finally, portions given to other NFs tend to be smaller than those kept within the NF, in direct contrast to the strict TT prediction that shares must be equal (Fig. 3).

While these findings diminish the importance of TT among the Hiwi, they certainly do not eliminate TT as an explanation for why some food is transferred in this sample. Even if we accept that families receive back 33, 45, 3, and 22% of what they give for meat, fish, other, and all resources pooled, respectively (Tables IX and X), we might explain a large proportion of the remaining 67, 55, 97, or 78% given away as a result of TT. However, these rough figures represent, if anything, an upper limit on the influence of TT (see below).

Since Hawkes' showoff hypothesis requires TT-based food sharing, we address her notion that men target foods that will be transferred because of social benefits. The data suggest that men do not target game or fish simply because they are more widely transferred, nor does their food production appear to be primarily a form of mating effort. While on average, men did transfer more than women over the study period, there was little overall difference in the pattern of share allocations to kin and nonkin. Men provision mainly kin, those who live nearby, and those who provision them. However, a strong test of whether there are sex differences in food transfers due to male mating strategies demands a large sample of a single resource type acquired by both men and women. Unfortunately, we do not have such data for the Hiwi. While we have shown that men target high-variance foods and that variance is negatively associated with percentage kept within the NF, this results in a small overall effect of sex on percentage kept ($0.319 \times -0.196 = -0.063$). Although not statistically significant at conventional levels, the independent path of sex on percentage kept is 0.155, which suggests that men keep more within the NF than do women when we control for the variance in the resources men and women acquired. The fact that food production is not extensively directed toward obtaining other mates might be specific to the Hiwi, since their male-biased sex ratios across most age groups and the pattern of relatively stable monogamous pair bonds provide little incentive to invest in other potential mates (Hurtado and Hill, 1991). We might still expect unmarried men to ‘‘display’’-share more than pair-bonded men, but our small sample of unmarried men prevents an adequate test. However, as shown above, there was no significant age effect on distribution patterns.

Reciprocal Altruism

Some of the results listed above that agree with predictions of TT also agree with predictions of various forms of RA. The fact that high-variance foods coming in large packages are transferred extensively and that families living in close proximity to acquirers receive more food tells us that certain constraints may limit which forms of RA can appear among the Hiwi and among other traditional groups with similar distribution patterns. However, the additional evidence that percentage of food production received by a NF is a strong predictor of the percentage of food production that this NF gives to other NFs is a close approximation of the contingency effect that is necessary for any kind of RA to exist. Contingency might take many different forms. For example, (1) give larger portions to those who give larger portions to me or my family, (2) give a portion to those who give a portion to me when they have some, (3) give a portion of large packages to those who give portions of large packages to me, or even (4) give a portion to those individuals who made an effort to acquire something today and who give some to me on days when I make an effort to acquire something.

Our calculation of contingency does not consider the time period, *t,* over which contingency may be calculated but, instead, considers the existence of contingency *after* such decisions have already been made over the entire observation period. Nonetheless, the result strongly suggests that RA is an important component of food transfers. Since acquirers give food to only a few partners on any acquisition event, this suggests that families engage in small sharing networks of several families for the exchange of many foods. Because the contingency effect is the strongest direct path in our path model of pairwise transfers of meat, fish, and all resources pooled

(Table X), it could be argued that RA is the most important component in explaining food transfers.

It should be mentioned that the lack of contingency effect for collected resources (which account for about 42% of the diet) implies that variance reduction is a poor explanation for transfers of these goods. Collected foods are the least transferred resources; a combination of high predictability, low variance in return rates, and synchronous acquisition across individuals makes reciprocal sharing of these resources unnecessary. Although carbohydrates are limiting macronutrients through much of the year, the marked seasonality of roots and other starches ensures that interforager acquisition variance is very small. Thus, there are few variance-reduction benefits to reciprocal sharing of these goods. Hiwi women have been observed to share roots reciprocally (without a time delay), but these exchanges more likely act to reinforce existing trade and/or kin networks. Such *ritualized* sharing, designed to signal the continuation of a reciprocal relationship, probably indicates the importance of contingency in Hiwi food sharing.

In the perfect TFT world of food sharing, we should expect our estimates of contingency to be close to 1.0 (although sample error would surely deflate our estimate). Deviation from this perfect correlation would be interpreted as evidence against TFT-based RA. However, as we have argued in previous sections, it is unlikely that TFT is a realistic model of RA. We have shown that larger families receive more food than smaller families and that this is a result of larger families receiving larger shares rather than larger families receiving more frequently from many distributions (regression of family size on per family frequency of receiving, $p = 0.598$). Thus, larger families are able to extract more food from existing sharing partners, and do not receive from more partners. According to bargaining theory, the *marginal value* of utility determines the "prices" interested parties pay for individual shares. An exchange of equal utility between members of different sized families is expected to result in an imbalance in quantities exchanged. A paretooptimal solution leading to maximum summed utility for both parties will result in a behavioral outcome where larger families receive more (and give less) than smaller families. Despite the lower bargaining power of individuals with large families, those with larger families should display a higher marginal value for food items and should therefore receive more food at distributions if the implicit bargain between families is the exchange of equal value (and therefore equal satisfaction). However, we might expect larger families to pay a higher price for nonfood goods or services offered in exchange for food.

This illustrates a fundamental trade-off. The desire to provision a large family may motivate individuals to keep more food within the family, resulting in less food (all else being equal) for investing in establishing and maintaining a greater number of sharing partnerships, or to keep little food in the family, resulting in more food for investment in sharing relationships. Although having more sharing partners might increase the probability of receiving at any particular distribution event, large dependable sharing networks might also be more difficult to maintain over long periods of time. For this reason, it seems that the Hiwi engage in small reciprocal sharing networks with other families.

CONCLUSION

The results of our analyses indicate that a combination of factors are important in structuring food transfers. Part of the reason for this is that transfers involve multiple behaviors with multiple motives of potential interactants. Our focus in this paper is on food transfers, but these transfers can be isolated only artificially from the larger context of sociality and trade of many utility-bearing goods and services. It seems unlikely that any single explanation can or should be expected to account entirely for why food acquirers transfer food to other individuals. Given characteristics of food resources and various attributes of the relationship between acquirers and potential recipients, we can make predictions about how much will be transferred and who will receive a share. However, the predictive power from theoretically derived regressions is still qualitative rather than quantitative. We have confirmed only that certain factors increase or decrease the amount transferred by acquirers and increase or decrease the amount that families of certain types will receive. For example, there is still no theory to explain why Hiwi should keep only 17% of all food in the NF, and not 21% or 30%.

It appears that among the Hiwi, meat and fish are transferred more extensively than collected goods and that transfers of meat and fish are more influenced by prior transfers by potential recipients. The widespread transferring of meat relative to fish or collected resources may be a result of the higher variance index for meat allowing more of a variance-reduction benefit and of the large package size allowing for the distribution of biologically significant pieces to more individuals. We suspect that meat transfers display less contingency than fish because the larger interforager acquisition variance associated with game might cause inequalities in protein and lipid consumption to result in more scrounging. The larger package size of meat allows for the distribution of more shares, some of which may be "given" to scroungers through TT.

We hope that this attempt at a multicausal analysis of food transfers will spur new research efforts aimed at understanding the larger context of food exchange and cooperation. Although our analyses incorporate many important and relevant factors derived from various behavioral ecology models, these factors together still account for less than half of the variance in the endogenous variables in our path models.[13] Undoubtedly, much of the error is due to sampling and measurement-related problems, but it is also likely that we are missing some very basic contextual information that can affect cost–benefit analyses. In particular, we know nothing about nonfood goods and services among the Hiwi which could be traded for food shares. Other problems are linked to bargaining between individuals, which is difficult to quantify since it is unclear when and how any bargains are struck and how the terms of any bargain change over time.

Whereas early discussions of the evolution of cooperation take RA as a given because of its theoretical appeal (Trivers, 1971; Binmore, 1994; Axelrod, 1984), a few recent discussions argue for its nonexistence in at least some foraging populations (Hawkes, 1993; Bleige-Bird and Bird, 1997). The status of RA in forager populations (and, ultimately, of the evolution of cooperation in our hominid ancestors) rests on the presentation of appropriate quantitative evidence. It is clear from this and previous efforts that RA is difficult to measure because of its scale-dependent properties. Its elusiveness results from the relatively unknown temporal and spatial scales upon which it operates among different pairs of individuals or families (and even across events). Finally, we might overemphasize exchange imbalances if we focus too heavily on quantities of resources and not on their marginal values to potential recipients. In light of these difficulties, we hope that our analysis is a push in the right direction toward understanding the ecology of food transfers.

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[13] We calculate R^2 by performing two sets of linear multiple regressions using the same variables as in the path models. For path model 1, $R^2 = 0.24$ (df = 128, $p < 0.001$). For path model 2, the pooled sample gives us $R^2 = 0.12$ (df = 209, $p < 0.001$—including only NFs with a sample greater than 10 kg), $R^2 = 0.26$ (df = 104, $p < 0.001$—greater than 20 kg), and $R^2 = 0.37$ (df = 65, $p < 0.001$—greater than 40 kg). For meat, $R^2 = 0.30$ (df = 27, $p < 0.08$—including only those NFs with a sample greater than 10 kg) and $R^2 = 0.60$ (df = 14, $p < 0.04$—greater than 20 kg). For fish, $R^2 = 0.42$ (df = 35, $p < 0.05$—greater than 10 kg). For other resources, $R^2 = 0.05$ (df = 90, $p < 0.30$—greater than 10 kg).

Maisawah, Baara, Yaduwa, and Paula. We dedicate this paper to the memory of Freddi, the best student at the Hiwi elementary school, killed in 1992 by unidentified Venezuelan ranch hands while foraging on the Capanaparo River. His death, like so many others of the Venezuelan Hiwi since the Rubiera Massacre of 1968, was never investigated.

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