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Abstract
In this study meal sharing is used as a way of quantifying food transfers between households. Traditional food-sharing studies measure the flow of resources between households. Meal sharing, in contrast, measures food consumption acts according to whether one is a host or a guest in the household as well as the movement of people between households in the context of food consumption. Our goal is to test a number of evolutionary models of food transfers, but first we argue that before one tests models of who should receive food one must understand the adaptiveness of food transfers. For the Ye'kwana, economies of scale in food processing and preparation appear to set the stage for the utility of meal sharing. Evolutionary models of meal sharing, such as kin selection and reciprocal altruism, are evaluated along with non-evolutionary models, such as egalitarian exchange and residential propinquity. In addition, a modified measure of exchange balance--proportional balance--is developed. Reciprocal altruism is shown to be the strongest predictor of exchange intensity and balance.

Keywords: evolutionary ecology, exchange, food sharing, meal sharing, reciprocal altruism, Ye'kwana (Venezuela)

Since 1995 a number of studies of food transfers among foragers and foraging horticulturalists have appeared (see Gurven 2004a for a review). All of these studies have dealt with the movement of food resources between households or, more recently, the movement of people between households in the context of meal sharing (Ziker and Schnegg 2005). Many of these studies have simultaneously tested multiple models of food transfers (e.g., reciprocal altruism, kin selection, costly signaling, and tolerated scrounging). More often than not, reciprocal altruism is found to be an important factor. We continue in this vein but employ a novel way to measure food transfers: behavioral observations of meal sharing. Meal sharing is defined as any food consumption event where an individual is observed eating food in a household in which he or she is not a member. It is the same act in the modern context when we invite someone over for a meal. We examine patterns of meal sharing and find that reciprocal altruism is the strongest predictor of meal sharing between households, whereas hypotheses based on kinship, egalitarian exchange, and tolerated scrounging (theft) fail to be supported. Finally, we attempt to address the issue *of why* meal exchange occurs so as to relate it to the *"who"* of exchange. That is, transfers should only occur if they solve some problem, such as reduction in the variance of food consumption, or permit an economy of scale in production. Once we know the potential utility of transfers we may be in a better position to make predictions about with whom and how many one should exchange.

Literature on Food Transfers

Recently, Gurven (2004a) has reviewed studies of ethnographic research on food transfers. Many of these studies test evolutionary explanations of food transfers, such as reciprocal altruism, kin selection, costly signaling, and tolerated scrounging. Of them all, reciprocal altruism has the most robust support: it has been demonstrated in eight different hunter-gatherer or foraging horticultural groups, and the number is now up to nine if we include Patton's (2005) recent Amazonian research in a multi-ethnic community. This is not to suggest that a society cannot have multiple modes of exchange depending on food type, or that food transfers cannot have multiple functions depending on context. We will briefly characterize the evolutionary models we tested (reciprocal altruism and kin selection) as well as a non-evolutionary model (egalitarian exchange). Although we are unable to carefully evaluate costly signaling or tolerated scrounging models, an egalitarian exchange model has a great deal in common with tolerated scrounging, as we will demonstrate.

Tests of reciprocal altruism are based on the idea that there should be a positive correlation between what one household gives to and what it receives from another household. This is referred to as *balance* (Hames 1987) or *contingency* (Gurven et al. 2000). It is founded on a simple premise from Trivers's (1971) theory of reciprocal altruism that givers and receivers should reverse positions on a systematic basis (Axelrod 1984) such that the amounts received and given should be correlated. One gives with the expectation that a return will be made in the future. It is not necessary that like be exchanged for like (e.g., meat for meat). Reciprocal altruism could be based on *trade,* a term coined to characterize exchanges involving different currencies (Kaplan and Hill 1985; Winterhalder 1986). The standard way to test this model is to correlate the number of transfers between individuals or household dyads. As mentioned above, reciprocal altruism is widely supported. However, as Gurven shows (2004a:551, Table 2), contingency rarely accounts for more than a third of the variance in giving and receiving.

Kin selection models of exchange derive from Hamilton's model of inclusive fitness (Hamilton 1964). An individual should be willing to share an item of food so long as the cost is less than the benefit, times the coefficient of relatedness between the individuals (or $C < B \times r$). A number of qualitative ethnographic studies have argued that close kin preferentially receive more food than distant kin or unrelated individuals (Gurven 2004a). Quantitative studies show that kinship is a factor for the Hiwi (Gurven et al. 2001), in Conambo (Patton 2005:142), and for the Ache when they are sedentary (Gurven et al. 2000) but not while on trek. When the Ache live in a sedentary village and depend on cultivated crops, kinship plays a stronger role in exchange, and it seems to be connected with reciprocity and propinquity such that kinship only becomes significant in the context of these two factors (see also Tucker's recent research [2004] on the Mikea of Madagascar).

In a paper on Yanomamö food exchange, Hames (2000) operationalized a model of egalitarian exchange. This model stems from the suggestion of Sahlins (1972) that resource flows should go from those who have high productive capacity and low relative need to those who have low productive capacity and high relative need. One way to capture relative household need is through calculation of the consumer-to-producer (C:P) ratio. Families with few adults and numerous children have greater C:P ratios than families with many adults and few children. Hence, households with high C:P ratios have greater needs because they have a more difficult time meeting their subsistence needs than those with low C:P ratios. Although one would not claim that such a model is evolutionary in formulation (in Sahlins's case it is Marxist), it is a useful model to explore given its popularity in anthropology.

To some extent, there is an overlap between egalitarian exchange and tolerated scrounging models (and "demand sharing" as well [Barnard 1993; Woodburn 1982]) such that one's current need as measured by the C:P ratio will induce others with more favorable C:P ratios to share. In addition, large households, irrespective of their C:P ratios, may be able to coerce smaller households into meal sharing as a simple function of their size. We also test this model. In the first quantitative test of the egalitarian exchange model, Aspelin (1979) studied food distributions among the Maimande, a foraging horticultural group in Brazil, and presented data showing that food moved between households based on relative need. In contrast, Hames (2000) demonstrated that C:P ratios did not predict patterns of food exchange among the Yanomamö. We test for the possibility of tolerated scrounging by examining the relationship among meal sharing, household size, and propinquity. Following several others (e.g., Patton 2005:140) we reason that close neighbors are less able to hide food preparation activities from each other than households who live farther apart. Thus, those who are in need are more likely to make successful demands, and large households may be able to intimidate smaller households. Nevertheless, we feel that propinquity may also play a role in kin selection and reciprocal altruism since it lowers the costs of transfer between cooperators.

Finally, according to costly signaling theory, resources that are difficult to acquire because their acquisition depends on superior skill, strength, or endurance may be transferred in order to demonstrate the phenotypic quality of the acquirer. Individuals who efficiently acquire such resources may be sought after as mates or allies (Hawkes 1991; Smith and Bliege Bird 2000). While it is true that acquisition of large game is avidly pursued by the Ye'kwana, we will not consider this model because acquisition of the vast majority of food resources shared at meals (i.e., garden food) requires skills and efforts that are not subject to much variation in productive abilities. Given the limitations in our data we only test models of kin selection, reciprocal altruism, egalitarian meal sharing, and, to some extent, tolerated scrounging.

The "Why" of Sharing

The models described above attempt to account for the patterning of food transfers: who gets and who gives, how often, and what the relationship is between giver and receiver. With the exception of costly signaling and tolerated scrounging, they do not, however, explain why exchange occurs in the first place, and how this explanation may influence the patterning of exchange. For costly signaling, exchange occurs because it permits the procurer to demonstrate his phenotypic qualities. In tolerated scrounging, transfers occur because receivers are in a stronger position to coerce food from possessors. Costly signaling models don't clearly specify who is to receive, whereas tolerated scrounging models predict that transfers will go to those who can dominate or intimidate because of their greater need. Most ordinary, interhousehold exchange may occur because it solves problems caused by the nature of food procurement and processing methods (Smith 2003:409). We would argue that researchers need to understand the utility of sharing ("why") before positing various evolutionary models (e.g., reciprocal altruism or kin selection) that deal with the patterning of exchange ("who") (see also Gurven 2004b:578). Tucker's work (2004:58-60) is an excellent example of integrating the "why" and "who" of exchange by showing how synchrony in acquisition and resource package size, both of which predict variance reduction, have implications for tolerated scrounging and reciprocity. What follows is a consideration of some "why" theories of the adaptiveness of exchange.

Variance in foraging success is commonly employed to explain the adaptiveness of exchange in relation to large-game sharing. Numerous ethnographers have shown that hunting is a high variance subsistence pursuit. Hunters may fail to bring anything home more than half of the time, and when they do succeed, package size may range from a few kilograms to several hundred kilograms of game. Kaplan and Hill (1985) have empirically demonstrated that hunting failure rates leading to high variance in success were a significant problem in achieving caloric sufficiency. For the Ache they showed that pooling (sharing) resources solves this problem: under conditions of game pooling the Ache had a daily caloric insufficiency only 3% of the time compared with 27% without sharing. This may be a very general explanation of sharing when there is high variance in hunting success and game is not synchronously acquired.

Winterhalder (1986) provided an extended mathematical analysis showing that pooling among no more than six hunters, in most cases, was sufficient to reduce variance in success to acceptable levels. In addition, Sugiyama and Chacon (2000) showed that the number of hunters necessary to reduce risk through pooling would have to be revised slightly upward to deal with frequent incapacitations (injury or illness) that reduce the pool of active hunters. Although variance reduction is probably a general mechanism for the sharing of large packages that are asynchronously acquired (but see Bliege Bird et al. 2002 for a negative instance), it provides little insight into the sharing of low-variance resources (many gathered, gardened, and fished resources) so common among the Ye'kwana and many other subsistence producers.

In other instances cooperative procurement (e.g., Pygmy net hunting or Inuit caribou drives) leads to sharing (Smith 1992). A number of studies (e.g., Alvard and Nolin 2002) have demonstrated that individuals who forage cooperatively share in the catch even if they were not the ones to acquire the resource directly. Another way in which cooperative procurement may lead to sharing was suggested by Hames (1990) when he noted that the location of certain gathered resources that are perennially available (e.g., wild palm fruit) is widely known by village members. In a sense, such resources are held in common, and these predictable resources can be procured by anyone who takes the time to gather them. Given relatively high fixed costs in transit time, it is more efficient for a few to harvest these resources serially and distribute them to co-villagers. This kind of coordinated procurement also prevents foraging overlap so individuals do not travel to the same patch only to find the resource has been taken.

A number of researchers (Gurven et al. 2001; Kaplan et al. 1990:137-138; Tucker 2004) suggest that economies of scale in agricultural food preparation may be key to understanding the adaptiveness of exchange for those food resources. By economy of scale we mean that the average per unit cost of producing an item falls or the yield increases (up to a point of eventual diminishing returns) as the number of producers increases (Smith 1992, 2003:410, Figure 21.2) such that the overall efficiency of production (or rate of return) is increased. We believe that economies of scale in manioc harvest and food preparation may be the reason for meal sharing among the Ye'kwana. Although only 54% of Ye'kwana shared meals were coded as consisting of garden food, this figure represents a coding decision that does not reflect the full complexity of Ye'kwana meals. Whenever a person was observed eating, the kind of food actually in a person's mouth or hands was recorded and what was on his or her plate was ignored. The Ye'kwana have a cultural rule that mandates that if someone is given fish or game at a meal they are also always given casabe. The Ye'kwana believe that it is improper for anyone to consume fish, invertebrates (e.g., crabs, termites, or wasp larvae), or game without consuming casabe. Although most fruits and vegetables may be given and consumed without casabe, some calorically dense fruits which the Ye'kwana associate with meat, such as Brazil nuts *(Bertholletia excelsa)* and avocado *(Persea americana),* are always given with casabe. Since casabe is a component of nearly all meals, meal sharing to a large extent revolves around the consumption of casabe.

A consideration of manioc preparation illustrates why frequent reciprocal exchanges from a limited number of cooperators may be the best model to account for Ye'kwana meal sharing. Manioc preparation in the form of casabe (flat cakes) or other products (*farina* and tapioca starch) is very time consuming, and the Ye'kwana like to eat these foods on the day they are prepared. Travel to the gardens requires a substantial fixed cost (at least one hour). Women (between the ages of 17 and 50) spend an average of 56 minutes per day harvesting (Hames 1978:234, Table V-5). After harvesting, roots must be peeled, soaked and/or grated, squeezed, sifted, and then baked. The fixed cost of manioc preparation is relatively high and constant, and similar costs must be paid whether one is preparing a few or many kilograms of the product. For example, manioc is squeezed in a long (1.4–1.8 m) basket sleeve called a *sebucan*. Squeezing time is about the same whether one is squeezing a full load (6-8 kg) or a smaller load. Given the set-up and elaborate stages of processing we feel that making a large batch is considerably more efficient (in terms of kilograms of prepared product per unit of effort) than making a small amount for family consumption. On average, Ye'kwana women (ages 17-50) spend 1.3 hr/day in manioc preparation (Hames 1978:325, Table VI-2). After harvesting and food preparation costs are combined, Ye'kwana women spend 2.23 hr/day in manioc production. This expenditure of labor represents 27% of a woman's daily labor time. Reciprocal food preparation may be significantly reducing casabe preparation time to this level. Alternatively, Michael Gurven (personal communication 2005) suggests that high and fixed travel costs to distant gardens may factor into an economy of scale, along with processing costs. We agree that this may be true in villages with distant gardens, but we believe that high processing costs are a chronic problem.

Finally, it seems to us that the sharing of meals may have some interesting sociopsychological dimensions that differentiate it from ordinary food exchange. There are several ways in which food moves between households. Ordinarily a young child from one household will deliver food to another household, usually garden or gathered foods. When large game is captured, the household that acquired it butchers it outdoors while male or female household heads wait to receive shares. Sometimes it is cooked before distribution. The same may apply to someone who has landed a large haul of fish. In these cases the air is festive, collective, and congenial as receivers contemplate a rich meal. They are public events, in contrast to the quiet, private transfers of vegetable resources. Likewise, meal sharing is a private event that takes place within households. Clearly all households could simply transfer food to other households without going through the formality of inviting them to share a meal. Meal sharing probably marks an important type of relationship that is intensified by the private sharing of meals. Perhaps the feeling of indebtedness and need to make a return are intensified as one eats with the providers in their house. It may also may serve to intensify a preexisting social relationship, much as it does in our own culture.

Ethnographic Background

The Ye'kwana, also known as the Makiritare, are Carib-speaking horticulturalists inhabiting about 30,000 km^2 of the Estado Amazonas in Venezuela, distributed in 30 villages with a total population of approximately 1,600. Village size ranges from 7 to 193 with a mode of 50 (Arvelo-Jiménez 1971). Most villages are located in the mid to upper reaches of major tributaries of the Upper Orinoco River. Research took place in the village of Toki (or Toki'fia) located on the lower middle course of the Padamo River. This river basin serves as a frontier separating the southwesternmost extent of the Yanomamö population and the southeasternmost extent of the Ye'kwana population. On the Padamo there are eight Yanomamö and three Ye'kwana villages within a day's motorized canoe trip from Toki. The village itself contains 88 full-time Ye'kwana residents, a number of Yanomamö associated with some of the Ye'kwana households, and two satellite Yanomamö villages with a combined population of 36.

Nuclear and joint households are the most important social and economic groups in a Ye'kwana village. They are the basic units of production, exchange, and consumption. Nuclear and joint households represent different stages of a basic domestic cycle. Joint households consist of the senior founding members, their subadult children, and one or more junior nuclear families of matrilocally married daughters. Junior families split from the larger joint family as their children age. Eventually, daughters in the newly formed household will attract husbands, and a new joint family will be produced. All households, whether joint or stem, have their own gardens which supply 75-80% of all daily calories. The balance is supplied by hunted, gathered, and fished resources. Less than five percent of food consumed is non-locally produced (Hames 1978).

Two published studies deal quantitatively with exchange of services, but not resources, between households. The first concerns garden labor exchange among the Ye'kwana (Hames 1987). In the creation of gardens, land is cleared jointly by groups of men on a serial basis. The tasks of weeding, planting, and harvesting are cooperatively performed by groups of women. For men, 48% of all garden labor was allocated to gardens other than their own, whereas for women it was 26% (Hames 1987:267, Table 2). Garden labor exchange was significantly correlated with household relatedness; closely related households engaged in higher frequencies of exchange (referred to as *exchange intensity*) than distantly related households. In addition, closely related households had greater imbalances of exchange (one of the pair gave much more labor to the other than it received in return) than distantly related households, which tended to have more balanced exchange relationships. Another study (Hames 1988) examined alloparental care of infants and toddlers and found that the amount of time a woman spent caring for (holding, feeding, grooming, and comforting) a child was determined by her relatedness to the child. As will be demonstrated below, relatedness, despite its documented importance in garden labor exchange and childcare, is not a significant factor in meal sharing.

Methods

Quantitative studies have measured food transfers in several ways. The first involves the direct observation of weighed food portions (e.g., Kaplan et al. 1984; Hames 1990). In these studies the procurer of the resource, its edible weight, and the amounts and proportions distributed to other households are recorded. In some cases, secondary distributions are also recorded (Guven et al. 2000). A second method, pioneered by Kaplan and colleagues (1984; also see Hames 1996; Gurven et al. 2000), involves the use of instantaneous scan sampling. Whenever a person is observed eating, the researcher notes the item consumed and asks the consumer who provided the food. From such records the analyst can calculate the frequency that individuals were observed consuming foods given to them by other individuals or households. Finally, other researchers (e.g., Patton 2005) use a variety of interview protocols in which receiving households are asked to rank the frequency with which other households or individuals in a settlement transferred food resources to them.

The method used to document food transfers in this study is a variant of the scan sampling technique. In the course of collecting time allocation data on economic and other behaviors, Hames noted the date, time, and location as well as the individual's behavior. In the data set used here, each record was a locationally differentiated observation of a person consuming an item of food. When an individual was observed eating in a household other than his or her own, this instance was scored as meal sharing. With these data we produced a series of matrices quantifying the number of times members of different families were observed eating in their own or in one of the seven other households in the village. If three members of a particular household were observed eating in another household, this was counted as three observations of meal sharing. This method is identical to the one used to measure garden labor exchange among the Ye'kwana (Hames 1987). There Hames noted the number of times an individual worked in his own household's gardens compared with other household's gardens.

Feeding guests in one's house provides a benefit to them at some cost to members of the host household. One could argue that this is not always the case if the guest had provided the host with food (e.g., American potluck dinners). However, the Ye'kwana do not bring food to other households, and they expect to be fed immediately upon arrival. We know from experience that guests were occasionally fed meals based in part on resources they had previously donated to the household. Nevertheless, the host household retains full control over its food resources and independently decides whom to provide with meals. In nearly all cases, guests were invited for the express purpose of sharing a meal, and they were not fed simply because they happened to visit. This method underestimates the actual intensity of sharing (defined by Hames [1990, 2000] as the amount of food a household consumed that was produced by another household) because food transferred to a household and consumed only by household members is not measured.

Table 1. Intensity of Meal Sharing among Households: Frequency of Shared and Unshared Meals by Resource Type

	Resource Type					
	Hunted	Gathered	Gardened	Fished	Store-Bought	Total
Unshared	81%	80%	76%	77%	57%	77%
(*n*)	(218)	(127)	(477)	(65)	(32)	(919)
Shared	19%	20%	24%	23%	43%	23%
(*n*)	(51)	(33)	(149)	(19)	(25)	(277)
Total (*n*)	269	160	626	84	57	1,196

Statistical Description of Ye'kwana Meal Sharing

The data presented here come from behavioral observations on residents of the Ye'kwana village of Toki collected in 1975-1976 over a 10-month period (Hames 1978). A subset of these data on meal sharing were then analyzed by McCabe (2004). The entire behavioral and locational data base on the Ye'kwana is available online at http://www-class.unl.edu/yekmap/html/index.html . The database can be queried on-line though an interface developed by McCabe, and many of the analyses presented here can be replicated.

A total of 18,947 behavioral observations were made on 81 Ye'kwana residents of Toki (originally there were 88, but 7 had insufficient observations and were excluded from the dataset). Of these, 1,196 (or 6.3%) were eating observations. The distribution of meal types (shared or unshared) is presented in Table 1. Less than 5% of all meals consumed were of store-bought foods. Characterization of what the individual was eating at the instant they were observed is a bit problematic. When recording the data Hames used a variety of rules to determine the kind of meal consumed. If someone was placing or about to place food in their mouth, it was easy to code the general type of food (as indicated in Table 1). If the person was pausing or conversing during the meal, then the predominant food in the person's hand, in his eating utensil, or in a serving basket was recorded. In actuality, most Ye'kwana meals consist of a several foods, and casabe (or other manioc products), as mentioned above, is by far the most common denominator in all meals.

There are a number of different ways to describe the flow of resources or services between households. They have been defined (Hames 1987, 1996, 2000) as intensity, scope, and balance. *General giving intensity* (or *receiving intensity*) measures the amount or proportion of a household's total food budget that is contributed by all other households. In a sense, it is a measure of subsidy from the entire settlement. *Specific giving intensity* is the amount or proportion of meals given to a household from those who do not live in the household where the eating event occurred. Therefore, specific intensity measures how much a household gave to or received from another household. As Table 1 shows, 23% of meals were consumed in households other than the consumer's household.

Table 2. Scope of Exchange or Number of Households with Whom Each Household Exchanged, and Number of Meals Shared

Household ID	Giving Scope	Giving Intensity	Average Count of Meals Given to each Household
1	4	6	1.5
2	3	12	4.0
3	7	78	11.1
4	6	91	15.2
5	3	13	4.3
6	1	2	2.0
7	3	4	1.3
8	3	71	23.7
Mean	4.13	34.6	7.8
s.d.	2.03	38.1	7.6

Scope measures the number of households with whom a focal household shares, irrespective of how many meals were shared. In Toki, the scope of sharing ranges from 1 to 7 with a mean of 4.13 (Table 2). This means that on average a household was observed to share meals with about four of the seven other households in the village. An average household gave meals 7.8 times to other household members during the 10-month sampling period. Five of the eight households did not share meals with members of half of the other households in the village during the sampling period. This does not necessarily mean that they did not transfer food; rather, no member of the other households was observed eating within the confines of their household.

Balance, like intensity, can be viewed generally or specifically. *Specific balance* in meal sharing is the difference, positive or negative, between household dyads in terms of what was given to and received from another household. *General balance* is the sum of meals given to all non-household members less the sum of meals received from all other households. Figure 1 is a histogram of specific balance between all unique household dyads. Mean specific balance is 2.48, which means that the average household is receiving about two and a half more meals than it is returning. The mode is zero, indicating perfect balance. In all six cases of perfect balance there was no meal sharing between the household dyads. Some measures of exchange are informative tests of the various models whereas others simply provide descriptive context. A model of reciprocal altruism can be tested by correlating specific giving and receiving intensity between unique household dyads: if household A gives a substantial amount to household B, then household B should reciprocate by giving a similar amount to household A. However, since household size varies considerably and there are a relatively small number of meal events, we feel that measuring giving and receiving as a percentage of all such acts represents a more reliable test of reciprocal altruism.

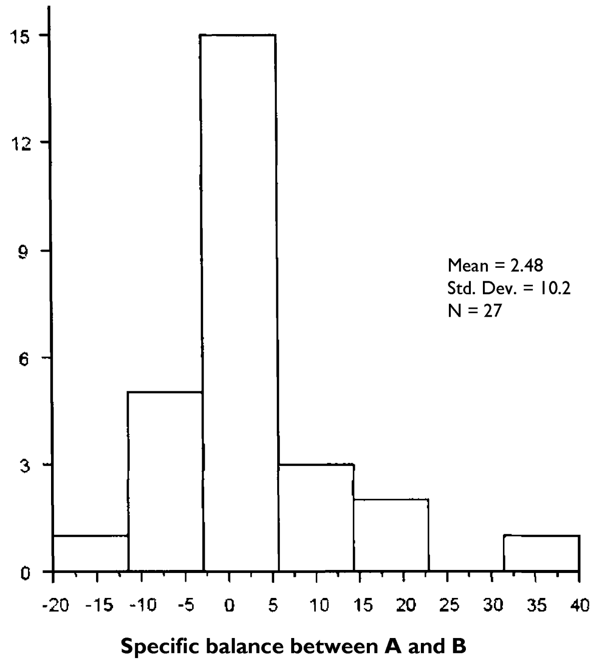

Figure 1. Histogram of specific exchange balance between all dyads.

If reciprocal altruism governs exchange relations between households, one would also expect that exchange events between household dyads should be correlated. If they were not, then one household could be seen as exploiting the other, a violation of reciprocal altruism. As others have noted (e.g., Allen-Arave et al., in press), however, this assumes that costs and benefits are symmetric through time or for each member of the exchange dyad. This is not always true, since costs of production and benefits of consumption can vary for each dyad as a consequence of situational factors. Given the limitations of the data and the possibility that reciprocation can occur through trade, we are hesitant to claim that balance is a strong test of reciprocal altruism. In contrast to meal sharing, trade occurs when different currencies are exchanged (Kaplan and Gurven 2005; Marlowe 2004). For example, one could reciprocate a meal with a food transfer or with labor assistance. Nevertheless, we feel that balance is an important concept, and we would expect that households that engage in high levels of exchange should have more balanced meal-sharing relationships than households that do not.

To analyze balance more accurately, we developed a method of calculating balance between households that attempts to control for the volume of exchange between households. When the volume of exchange across household dyads varies greatly, households with a lower total volume of exchange will almost invariably appear to be more balanced than those with a higher total volume of exchange. Hypothetical data in Table 3 depict this problem and its solution through a measure we call *proportional balance.*

Table 3. Example of Balance and the Proportional Measure of Balance

Dyad	Given	Received	Total	Standard Balance	Proportional Balance
A:B	5	7	12	–2	–0.167
C:D	15	12	27	3	0.111
E:F	74	83	157	–9	–0.057

The standard balance measurement seems to show that dyad A:B exhibits the most balanced exchange whereas E:F exhibits the least balanced exchange. However, the volume of exchange is more than ten times greater in E:F than in A:B, while the balance figure is less than five times greater. Proportional balance normalizes the measurement of balance based on exchange volume and expresses the difference between the amounts given and received as a fraction of the total volume of exchange between two households. This results in a closed interval of values from -1 to +1. A value of 0 signifies perfect balance, and other values (positive or negative) signify imbalance. A negative value signifies that the focal household gave less than it received and a positive sign signifies that it gave more than it received.

In egalitarian exchange one would expect that households who have a difficult time meeting consumer demand because of having a high consumer-to-producer (C:P) ratio should have high levels of receiving intensity and correspondingly low levels of giving intensity. Therefore, C:P ratios should correlate negatively with general and specific giving intensity and positively with receiving intensity. In addition, households with high C:P ratios should exhibit high negative balances (they should receive more than they give).

For kin selection models to be supported there should be positive correlations between relatedness and specific and general giving and receiving intensity. That is, close kin should both give more to each other than to distant kin and receive more. We also predict that close kin should tolerate relatively high levels of imbalance in exchange, a pattern documented in Ye'kwana garden labor exchange (Hames 1987).

Analytic Procedures

To test various models of exchange we generated a series of sharing matrices that display how much each household gave and received meals from all other households in the village and the degree to which households are in balance. These distributions of meal transfers were then associated with measures of household relatedness, consumer-to-producer ratios, and household propinquity.

Given the nature of Ye'kwana households and the collaborative production and consumption of food, the measurement of relatedness is analytically problematic. For our purposes, relatedness between each household dyad was measured as the mean relatedness between all members of each household paired with members of every other household in the village. This produced an 8 x 8 half matrix. This method is identical to the procedure followed by Hames in a study of garden labor exchange (1987; see also Ziker and Schnegg 2005). Other studies have measured relatedness as the closest relatedness between any two members of household dyads (e.g., Gurven et al. 2001). To our knowledge few attempts have been made (see Hames 1987 for one) to justify whether relatedness should be measured between families overall, as we do here, or between the two most closely related individuals in two families. Another feasible method would be to measure the relatedness between household heads. Nevertheless, we use mean relatedness between households here because shared resources are usually a joint household production effort and reflect a cost that affects all members in the donor household, and because several members of a receiving household typically receive the benefit of a meal simultaneously.

Consumer-to-producer ratios were calculated using time allocation data collected on the Ye'kwana (Hames 1978). Based on time allocation data a producer with a value of 1.0 was the mean labor time of all individuals between the ages of 20 and 50 years. Individuals older and younger than this span were deemed to be fractional producers depending on their time allocation to labor. Estimates of consumption rates were based on Kaplan's study of the Machiguenga (Kaplan 1994) and Kramer's (2002) research on the Maya. These groups are similar to the Ye'kwana in their labor time allocations, and they too subsist on horticulture and foraging.

We also added the variables of propinquity (measured as the distance, in meters, between households using well-worn paths) and household size as other factors that may enable us to test for tolerated scrounging. The tolerated scrounging model predicts that large households may have greater need and therefore may be successful at making demands on smaller households for food. Gurven and colleagues (2000:174) and Patton (2005:148) argue that a negative correlation between household distance and food received may be an indicator of tolerated scrounging. In other studies, propinquity and household size were discovered to be significant factors in exchange (e.g., Gurven 2006; Patton 2005).

Results

Below we review the results of several different evolutionary and anthropological models of meal sharing among the Ye'kwana. Of those, reciprocal altruism and propinquity consistently predict the patterning of meal sharing among the Ye'kwana whereas kin selection, tolerated scrounging, and egalitarian exchange do not. Unless otherwise indicated, tests are two-tailed.

Egalitarian Exchange

As noted, the ratio of consumers to producers in a household is a reasonable measure of household need in that it provides an index of how hard a household must work in order to meet subsistence requirements. As the number of consumers increases relative to producers, meeting all members' consumption requirements becomes more difficult. As noted earlier, egalitarian exchange and tolerated scrounging models are broadly similar in that households with high C:P ratios would be more motivated to demand resources because of the aforementioned difficulty in meeting household demand. We found no correlation between C:P and specific giving intensity (r = -0.059, p = 0.334, n = 56), specific receiving intensity (r = –0.125, p = 0.180, n = 56), general giving intensity (r =-0.098, p = 0.408, n = 8), or general receiving intensity (r =-0.521, p = 0.093, n = 8). Of note is a near-significant correlation between general receiving intensity and C:P ratio. Unexpectedly, the correlation is in the opposite direction: households with high consumer-to-producer ratios receive fewer meals than households with low consumer-to-producer ratios.

Kin Selection

In general, kin selection models predict that the more closely any two households are related, the greater the intensity of exchange. One might also predict that closely related households would permit greater imbalances in exchange, a pattern that was demonstrated in Ye'kwana garden labor exchange (Hames 1987). Presumably, the inclusive fitness of a closely related household would be enhanced if it was able to provide a more or less sustained one-way flow of resources to its to needy kin. In such a situation, marginal gains in inclusive fitness would partially compensate for a lack of reciprocation. However, we found that relatedness between households did not correlate with specific giving intensity (r = 0.003, p = 0.492, n = 56), receiving intensity (r = 0.003, p = –0.985), or proportional giving intensity (r = –0.041, p = 0.308, n = 56). Likewise, there was no correlation between relatedness and specific balance in exchange (r = 0.090, p = –0.325, n = 28).

Reciprocal Altruism

Most measures in the meal-sharing data provided reasonable levels of support for reciprocal altruism. As Figure 2 shows, there was a strong correlation between proportions given and received (r = 0.458, p = 0.01, n = 27). Although the numbers of meals that one household gave to another and received in return (specific intensity) were positively correlated (r = 0.345, p = 0.078, n = 27), the correlation was not statistically significant (one-tailed test). As mentioned earlier, we cannot correlate specific balance with giving or receiving intensity because the more one exchanges with another, the greater the likelihood that specific balance will increase. Proportional balance was positively associated with specific giving intensity (r = 0.431, p = 0.025) but uncorrelated with receiving intensity (r = –0.241, p = 0.225). At the same time, proportional balance was uncorrelated with proportion given (r = 0.075, p = 0.582) but was strongly correlated with proportion received (r = –0395, p = 0.003). The relation between balance and intensity of exchange, although significant in some cases, is not as predicted and will be discussed below.

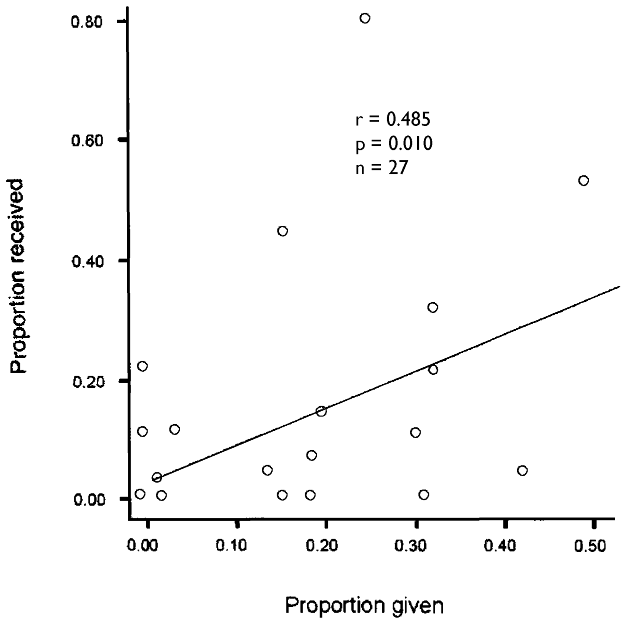

Figure 2. Proportional giving and receiving.

Propinquity There is a significantly negative correlation between distance between households and giving intensity (r = -0.389, p = 0.008, n = 56) as well as specific receiving intensity. Propinquity also correlates negatively with proportion received (r = -0.365, p = 0.006) and only marginally with proportion given (r = -0.253, p = 0.06). We should like to emphasize that propinquity per se probably does not lead to increased levels of sharing (see also Gurven et al. 2001:289 on the Hiwi and settled Ache). Rather, households that plan to engage in frequent meal sharing either decide to remain in the same area of the village or move closer to one another. Distance between households ranges from about 20 m to nearly 400 m. It seems reasonable that households that plan to share meals frequently would desire to minimize the distance between households with whom they habitually share. As expected, relatedness and propinquity are negatively correlated (r = -0.515, p = 0.000, n = 26). This means that relatives live near one another but, as noted above, kinship and meal sharing are uncorrelated. This is a surprising result.

Household Size

Having failed to find a correlation between C:P ratios and giving and receiving intensity, as would be predicted by an egalitarian model of sharing, we decided to examine the relationship between household size and giving and receiving intensity. This may be deducible from a tolerated scrounging perspective: large households would be in a superior position to demand resources from smaller households because they have greater needs and their superior size may allow them to coerce resources from smaller households. There is a highly significant positive relationship between household size and general giving intensity: larger households give or share meals more frequently than smaller households (r = 0.550, p < 0.000, n = 8). But there is no correlation between receiving intensity and household size (r = 0.004, p = 0.974, n = 8). These findings are just the opposite of what one would predict using a tolerated scrounging model. These relationships are inexplicable as well as interesting. In an earlier analysis of Yanomamö food exchange, Hames (2000:405, Table 18.2) documented a positive correlation between household size and general receiving intensity but not giving intensity—just the opposite of what we find here. For sedentary Ache, Gurven et al. (2001:289, Table 6) found a positive correlation between family size and specific giving intensity, mirroring what is found here. For the Hiwi, Gurven and colleagues (2000:198) found a positive correlation between family size and amount of food received and, apparently, given (Gurven et al. 2000:207–208). Initially we thought that members of large households would more frequently be recorded eating meals in other households simply because of their greater numbers. Not only was this not true but, as mentioned above, large households were more frequent givers of meals to other households.

Multivariate Analysis

Given that propinquity between households and proportion given were significant predictors of proportion of meals received, we performed a multivariate analysis using propinquity and proportion given as independent variables and proportion received as the dependent variable. In this model propinquity dropped out as a significant predictor (p = 0.201) whereas proportion given remained as a significant predictor of proportion received (p = 0.015).

Discussion

The evidence for reciprocal altruism as a key feature in patterns of meal sharing among the Ye'kwana is shown by a correlation between proportion given and received between household dyads. Although propinquity was initially significantly correlated, it dropped out as a significant factor of proportion received when proportion given is taken into consideration. Models of kin selection, egalitarian exchange, and tolerated scrounging received no support. We feel there is a simple theoretical reason why reciprocal altruism determines meal sharing. The key problem in reciprocal exchanges is the length of time between an initial act of sharing and the return or reciprocation. For resources that are infrequently acquired, this delay can reduce the value of the reciprocation and/or make it difficult for people to keep track of what is owed (Bliege Bird et al. 2002:316). Meals centered on agricultural resources are daily events, and failure to reciprocate can rarely be excused as poor luck in harvesting garden food or lack of time for food preparation. The condition of one's gardens is public knowledge or is easily ascertained: thus there is no opportunity to deceive about the ability to return a meal. For the most part, meal production is a simple application of effort. The only exception to this generalization would be garden failure (Hames 1987), something easily ascertained.

We predicted that the relationship between intensity and balance would lead to balance between households who frequently engaged in exchange. This is a reasonable deduction from the tit-for-tat nature of reciprocal altruism. That is, the proportional balance between households should have values approaching zero, or perfect balance, as the intensity or proportional intensity of exchange increased. Instead we have a pattern in which the more one gives to a particular household, the more likely it is that one's proportional balance is positive ($r = 0.43$, $p = 0.025$; Figure 3). This means that meals shared by households are not being reciprocated, at least not with meals. An opposite but non-significant trend ($r = -0.272$, $p = 0.172$) is found in the correlation between proportion received and proportional balance. That is, the more you receive, the more negatively balanced you become. This pattern clearly violates our expectations regarding reciprocal altruism. It is possible that trade may explain this anomaly. That is, shared meals at households that consistently give more than they receive from other households are being reciprocated in other ways, leading to economic specialization between households. If so, then lack of balance in meal sharing does not invalidate reciprocal altruism (Guven 2004a).

The relationship between household size and giving intensity (larger households share more meals with other households than do smaller households) is curious, and we have no theoretical explanation for it. Initially, we thought that large households might share more meals simply because they have more social ties and therefore attract more visitors, and that members of large households eat more frequently in other households for the same reason. Although the former is true, the latter is not (detailed above): members of large households do not receive more meals than members of small households. To better contextualize this pattern we examined the relationship between household size and the frequency that non-household members visited a household (visitors received) and the number of times household members visited other households (visits made) when visits were for purposes other than meal sharing. The correlation between household size and number of visitors received is quite strong ($r = 0.911$) and significant ($p < 0.002$). This relationship is stronger than the correlation between household size and giving intensity ($r = 0.550$, $p < 0.001$). However, there is a strong positive correlation between household size and the frequency with which its members visited other households ($r = 0.873$, $p = 005$); yet, as noted above, large households were not given more meals than small households. It is clear that large households received more visitors than small households and visited other households more frequently than small households. Nevertheless, more frequent visiting did not lead to greater frequencies of meal sharing for members of large households.

We have presented some plausibility arguments that economies of scale are at work, but we have presented no data that could test such a hypothesis. If the hypothesis of an economy of scale in manioc preparation is true, households

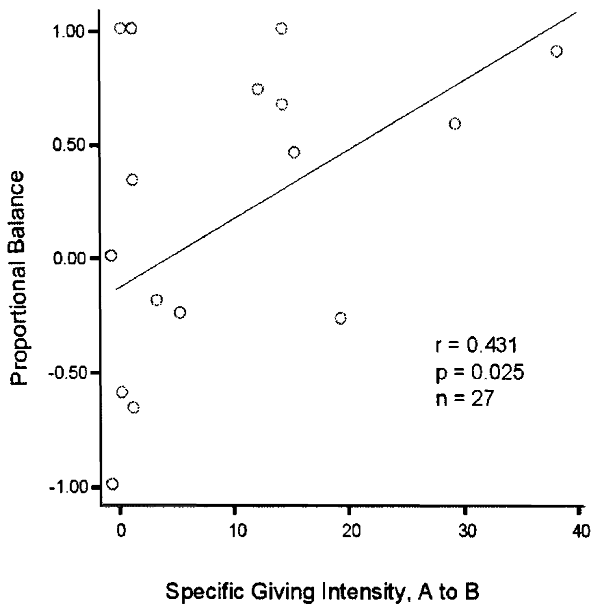

Figure 3. Proportional balance and giving intensity.

should be closely coordinating their meal-sharing arrangements. Turn-taking as an adaptation to reduce total labor in food preparation would only make sense if meal sharing alternated between households In other words, household A should provide meals to household B on one day, and B should reciprocate shortly thereafter. Furthermore, we should have no or few instances of A giving a meal to B on the same day that B gave a meal to A. One way to assess this hypothesis is to examine exchange between households over time. If coordinated economies of scale are working, we should find regular, back-and-forth sharing between households. This analysis is currently underway.

The finding that garden labor exchange and alloparental care among the Ye'kwana follow predictions from kin selection theory (Hames 1987, 1988) whereas meal exchanges follow a reciprocal altruism pattern suggests that a variety of mechanisms are being employed to regulate the flow of goods and services between households. Since food production activities such as garden labor exchange are intimately related to consumption events, one might predict that they would follow the same pattern. However, garden labor exchange is a complex phenomenon and seems to follow different patterns for men and women. Men reciprocally help each other clear forest for gardens in a serial pattern. All join in teams to clear a particular person's plot and then move on to the next plot until all are completed, a process that normally takes about six weeks. The activity is public, ritualized (workers are called together by a conch shell), competitive, raucous, and formal (workers are feted by the garden owners after clearing is completed). Women, on the other hand, exchange garden labor throughout the year and do so in smaller, private groups without fanfare or formality. The goal of the entire process appears to be a mechanism to provide insurance in case of family garden failure. That is, if a household's gardens fail or underproduce, one can make a claim of support from those that one assisted. Kin may be recruited in labor exchanges because helping a household with an inadequate food supply will probably mean that the assisting household will incur the considerable cost of decreased caloric intake. Kinship bonds may be the most durable and reliable mechanism to sustain such a cost. Furthermore, the Ye'kwana spread this obligation by working in many different gardens owned by close and distant kin. Consequently there will be a large pool of people who could assist in case of a garden failure. In contrast, failure to reciprocate in meal sharing may only mean an increase in labor time (assuming the economy of scale argument in food preparation is correct). Be that as it may, these considerations clearly suggest that the flow of goods and services between households may be governed by several mechanisms.

Conclusion

Even though nearly 25% of all meals the Ye'kwana consume are provided by other households and our analysis suggests that to some extent reciprocal altruism governs these exchanges, we feel that meal sharing may not be intelligible without reference to the entire web of exchanges that occur in Ye'kwana society. As noted above, garden labor and childcare are governed by kinship. Other collaborative activities such as house and canoe construction are common, as well as food transfers between households from hunting, fishing, gardening, and gathering. Trade may underlie reciprocal altruism given the multiple ways in which individuals assist one another. More to the point, we feel that future researchers need to focus on all relevant exchanges of resources and services in their evaluation of evolutionary models of exchange. This will undoubtedly prove to be a difficult task, requiring refined methods and a broader consideration of giving and receiving and relevant time periods.

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