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Evolution and Human Behavior 23 (2002) 297–321

Evolution
and Human
Behavior

Risk and reciprocity in Meriam food sharing

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Received 1 June 2001; received in revised form 7 January 2002; accepted 13 March 2002

Abstract

Foragers who do not practice food storage might adapt to fluctuating food supplies by sharing surplus resources in times of plenty with the expectation of receiving in times of shortfall. In this paper, we derive a number of predictions from this perspective, which we term the risk reduction reciprocity (RRR) model, and test these with ethnographic data on foraging (fishing, shellfish collecting, and turtle hunting) among the Meriam (Torres Strait, Australia). While the size of a harvest strongly predicts that a portion will be shared beyond the household of the acquirer, the effects of key measures of foraging risk (e.g., failure rate) are comparatively weak: Harvests from high-risk hunt types are usually shared more often than those from low-risk hunt types in the same macropatch, but increases in risk overall do not accurately predict increases in the probability of sharing. In addition, free-riders (those who take shares but do not reciprocate) are not discriminated against, those who share more often and more generously do not predictably receive more, and most sharing relationships between households (over 80%) involve one-way flows. © 2002 Elsevier Science Inc. All rights reserved.

Keywords: Human behavioral ecology; Torres Strait islanders; Fishing; Risk reduction; Cooperation

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PII: S1090-5138(02)00098-3

1. Introduction

Among those who forage for wild foods, sharing beyond the household is a common pattern. Yet foods are not shared randomly: certain foods are more likely to be shared after acquisition than others. Typically such foods include the meat from large game animals or highly valued resources such as honey, while foods that come in smaller packages or are acquired reliably tend to be rarely shared (Kelly, 1995). One prominent hypothesis to explain this pattern invokes risk reduction (e.g., Cashdan, 1992; Kaplan & Hill, 1985; Smith, 1988; Smith & Boyd, 1990; Winterhalder, 1996a). This explanation proposes that unpredictably acquired resources are more likely to be shared in order to buffer variation in harvest success or resource availability (risk) and, thus, reduce the possibility of a dangerous shortfall. The theoretical model most commonly invoked to provide an evolutionary rationale for such sharing strategies is reciprocal altruism (Alexander, 1979, 1987; Cosmides & Tooby, 1992; Trivers, 1971).

Thus, what we will term "risk reduction reciprocity" (RRR) proposes that resource sharing is a form of reciprocal altruism, wherein cooperating foragers pool their harvest after foraging, and then consume more or less equal shares from this common pot, reducing their own variance in consumption. Such pooling is a powerful mechanism for reducing the costs of relying on resources subject to a large amount of variance in harvest success (Winterhalder, 1990). Foragers contribute to the pool when successful and draw from the pool when unsuccessful, in effect paying insurance premiums to ensure that benefits will be paid out during periods of illness or bad hunting luck (see, for example, the chapters in Cashdan, 1990; Gurven, Allen-Arave, Hill, & Hurtado, 2000). While resource size and acquisition variance are almost always positively correlated, RRR predicts that foods should be more likely to be shared following a harvest if they are associated with high risk (harvest variance), even if they come in small packages. However, large package size can lower the cost of sharing (to the donor), assuming diminishing marginal consumption value to the acquirer and some degree of asynchrony between different acquirers (Winterhalder, 1990).

In the RRR model a forager's only benefit from sharing risky resources with nonrelatives is the opportunity to receive shares during periods of shortfall. It thus requires stringent controls in order to ensure stability (in the game-theoretic sense) and prevent exploitation by free-riders — those receiving shares without making contributions themselves (Hawkes, 1992; Smith & Boyd, 1990). These controls should involve contingent sharing; for example, generous sharers should be more likely to receive food (or receive more food) when unsuccessful than those who rarely or never share. Those who share with a partner should share more if that partner is in turn more generous with them.

Our goal in this paper is to evaluate the empirical accuracy of these predictions using observational data collected on food sharing outcomes following harvests of marine resources among Meriam living on Mer Island in Torres Strait, northern Australia. We begin by exploring the effect of harvest size on the decision to keep all or share some of a harvest. Following this, we investigate whether types of foraging with high-variance harvests are more likely to involve sharing than those with low-variance harvests. We then test predictions concerning reciprocity or "contingency" in the frequency or amount of foraged food shared beyond the household of the acquirer. We conclude with some general comments on the nature of food sharing in this small-scale society, and the implication of our analysis for current debates on reciprocity and sharing.

2. Background and methods

2.1. The Meriam

The Meriam are Melanesian inhabitants of the islands of Mer, Dauar, and Waier in the easternmost part of the Torres Strait Islands, Australia. The islands' current population is 430 individuals of Meriam and other Torres Strait Islander descent, scattered in approximately 84 households, the great majority of which are located along the northern and western shoreline of Mer (a small volcanic island of 3 km^2). Until the mid-1970s most Meriam subsistence came from intensive horticulture and marine foraging activities, but at present horticulture plays a very minor role in the diet, having been essentially replaced by store foods. However, marine resources from fishing, hunting, and collecting remain a significant component of the subsistence economy, providing an average of 630 kcal per capita per day (after sharing). For extensive details and references on Meriam ecology and social, political, and economic organization, both historical and contemporary, see Beckett (1988), Bird and Bliege Bird (1997, 2000), Bliege Bird and Bird (1997, 2002), Bliege Bird, Bird, and Beaton (1995), Bliege Bird, Smith, and Bird (2001), Haddon (1908), Sharp (1993), and Smith and Bliege Bird (2000).

2.2. Data collection

Three food acquisition and sharing data sets are used in this paper, and each analysis below will indicate which data set is being employed. The first data set includes sharing data for all foraged food resources for eight focal households (HHs) recorded over a period of 15 weeks from December 1997 to March 1998. The sample HHs were chosen on the basis of residential proximity to the fieldworkers, and willingness to allow the large number of HH visits required, and are, thus, not a random sample of the approximately 84 HHs on Mer. This data set includes 133 observations of food acquisition and 86 observations of sharing (61 transfers out from focal HHs and 26 transfers in to focal HHs). Members of each HH were interviewed at least twice per week as to the receipt or acquisition of any foraged food resources and the portion size of resources acquired, distributed, or received. Each interviewee characterized any foraged resources acquired by HH members or received from another HH either that day or the day prior, specifying the resource by species and the size of the harvest, down to number of fish and their average size (small, medium, or large for that species). When possible, we weighed portions acquired or shared. When it was not possible to directly weigh portions, catch reports were converted to weights using values we obtained for average weights of small, medium, and large specimens of each species. Weights were converted to energy using published values for caloric content by species in order to standardize over fish species with varying fat contents (fish captured range from 800 to 1600 kcal/kg, see Bliege Bird & Bird, 1997, 2002 for further details).

The second data set is drawn from 121 marine turtle (*Chelonia mydas*) acquisitions over a period of 1 year between March 1994 and March 1995. Details on the methods used for collecting these data and for earlier analyses of turtle sharing are provided in Bliege Bird and Bird (1997). We recorded sharing information on 121 turtles (out of a total of 123) that were acquired on Mer during this period, and conducted detailed follow-up interviews with acquirers. Turtle share portions vary little (Bliege Bird & Bird, 1997), and most portions during the study were given away in 10-liter plastic buckets. We weighed the buckets distributed from 11 turtles to obtain an average bucket weight that varied depending upon the number of buckets distributed. This data set includes information on 1199 transfers from acquirer HHs to other HHs or to feasting events. The turtle data set did not include failed attempts; to obtain a true estimate of variability, we therefore estimated failure rate from a subsample of known attempts and extrapolated these estimates to the total observed. Because hunting and collecting turtleS are primarily group activities, we calculated an average per capita return for 88 collections plus 18 estimated failures and 33 hunts plus 16 estimated failures where total hunt time and total amount acquired were known. We stress again that this data set includes (to the best of our knowledge) virtually all (98.4%) turtle acquisition and sharing events during the 1-year period indicated.

The final data set includes a series of 275 systematic focal individual foraging follows conducted over 27 months between January 1993 and July 1999, as detailed elsewhere (Bird & Bliege Bird, 1997, 2000; Bliege Bird & Bird, 2002; Bliege Bird et al., 2001). These data were collected for analysis of handline fishing (beach and offshore), spearfishing, and shellfish collecting to determine the return rates and time allocation to different foraging activities, as well as harvest sizes, failure rates, acquisition technique, and resource characteristics. Foraging activities considered here were categorized into 11 "hunt types" (sensu Smith, 1991). Hunt types are foraging activities that cannot be performed simultaneously due to geographic separation, availability in time, or technological requirements. On 109 of these follows we recorded the distribution of the catch. For many of the analyses that follow, we aggregate the sharing data from all three data sets to comprise a set of 363 observations of acquisition from 11 hunt types for which distributional data are known; hereafter, we refer to this aggregated database of acquisition and distributional information as the "aggregate data set."

2.3. Data analysis

Most of our analyses categorize sharing patterns as a dichotomous outcome variable: either all was kept within the household of the acquirer ("all kept") or at least a portion was distributed beyond the household(s) of the acquirer ("some shared"). We dichotomize the data in this way as opposed to using a continuous measure of sharing (such as percent of harvest shared) for two reasons. First, the majority of observations of sharing in the aggregated data set were either all or none; only 31% of all harvests (113/363) resulted in some percentage shared and some kept, nearly all of these involving turtle collections. In another 25% of all harvests (92/363) the entire harvest was shared (nothing kept by the acquiring household), while in the remainder (44% of harvests), the entire harvest was kept. Secondly, we consider the decision variable of "keep" or "share" to be the first decision a forager must make regarding distributions. Once a forager has decided to share, further decisions must be made regarding how much, how many portions will be distributed, and to whom they will be given. We consider percentage shared in only one test as a measure of generosity and tolerance for free-riders (see below). Because we wish to examine the effects of continuous independent variables (such as harvest size) and discrete ones (such as hunt type failure rate) on a dichotomous dependent variable (whether a harvest was entirely kept or at least some was shared), we use likelihood modeling. Likelihood models estimate a probability of sharing for a given value of the independent variable, and can involve multivariate analysis in which the effects of other predictor variables can be controlled.

Our analysis defines high-variance harvests as acquisitions from foraging activities associated with (1) large coefficients of variation for average energetic return rate, (2) high rates of acquisition failure, (3) a harvest size unpredictable by foraging time, or (4) low interhousehold harvest synchrony. Mean harvest size (in edible kilocalories) is calculated using methods reported in Bliege Bird and Bird (1997) and Bliege Bird et al. (2001), and includes harvests obtained by all adult foragers in the foraging-follow data set only ($n=275$). We exclude the observations collected through the 8-HH sample since these are biased toward successful harvests (thus inflating mean harvest size). CV is the coefficient of variation for mean returns (within-patch per capita returns, in kilocalories per minute), measured for all adult male and female foragers in the foraging-follow data set ($n=275$). Failure rate is measured as the frequency with which foragers failed to acquire any calories after committing to remaining in the patch for at least the average duration of a foraging bout. We do not include foraging bouts of shorter durations in calculations of failure rate because of the phenomenon of differential patch sampling, which occurs when foragers enter a patch to test return rates, often leaving after 10 or 15 min if the probability of future success appears low. If we included foraging episodes of all durations in our analysis, and if some hunt types are more likely to involve patch sampling than others, the hunt type might appear to be associated with high failure rate when in fact it is simply associated with a high rate of patch sampling for whatever reason (including expected high returns in nearby patches, see Charnov, Orians, & Hyatt, 1976).

Variation due simply to time spent in the patch may have a different effect on sharing outcomes than variation due to uncontrollable factors, such as intrinsic characteristics of the forager (skill or coordination), unavoidable and unpredictable variability in patch quality, or other random factors. If much of the variation in mean return rates is due to foragers spending different amounts of time foraging, sharing will fail to mitigate the effects of this type of variability, and in fact may foster free-riding as food flows from those who work hard to those who work fewer hours and share less. We therefore define predictability as a contingent relationship between harvest size and foraging time, and measure it as the extent to which harvest size in edible kilocalories in the foraging-follow sample is contingent upon time spent foraging, calculated as a linear regression of harvest size on foraging time.

Interhousehold harvest synchrony was measured for each hunt type using the 8-HH data set. On any given sample day, four households were surveyed as to their harvests and resources given or received. Hunt type harvest synchrony is measured as the number of households acquiring food in each hunt type that day, divided by the total number surveyed that day (4) and averaged across all 56 sample days. (Synchrony for turtle hunting and turtle collecting is aggregated in this analysis because there were so few turtle hunts in the sample.) On any given sample day, overall synchrony in marine resource acquisition is quite high: an average of 46.9% of households acquired food each day.

Frequency of sharing measures the percentage of observed successful harvests that were associated with any amount distributed ("some shared") beyond the acquirer's household.

2.4. Hypotheses

Our analyses are designed to evaluate the general prediction that food sharing is patterned by RRR by testing five hypotheses concerning the relationship between hunt type variability, harvest size, and the probability of sharing following the harvest.

> *Hypothesis 1: Marginal valuation*: Harvest size should have a significant effect on the probability of sharing some versus keeping all of a harvest. As harvest size increases, the marginal value to the acquiring HH of consuming the entire harvest decreases, and hence, the probability of sharing some should increase. This hypothesis is tested with a likelihood ratio test, using the size of each acquisition in the aggregate data set as a predictor variable and the observed outcome (shared some or all kept) as a dependent variable.
>
> *Hypothesis 2: Risk reduction*: As the harvest variance associated with a particular hunt type increases, the probability of sharing some of the harvest from that hunt type should also increase. This hypothesis is tested using likelihood ratio tests, with measures of risk and variance for the hunt type as predictor variables, and the observed outcome (shared some vs. all kept) as a dependent variable.
>
> *Hypothesis 3: Reciprocity is generalized*: Households that share more total quantity (i.e., totaled over all other households) should receive greater quantity. To test this hypothesis we use linear regression techniques on both the 8-HH data set and the turtle-sharing data set.
>
> *Hypothesis 4: Reciprocity is dyadic*: There should be a linear relationship between amount given to another and amount received from that household: the more that is given to a partner, the more will be received from that partner (linear regression, 8-HH and turtle-sharing data sets).
>
> *Hypothesis 5: Generosity is rewarded/Free-riders are discriminated against*: Households that share a greater percentage of their harvests should be given shares more often than those who share a smaller percentage, and those who share some should receive more than those who do not share at all (linear regression and *t* test, 8-HH and turtle-sharing data sets).

3. Results

3.1. Marginal valuation (Hypothesis 1): how does harvest size influence the probability of sharing?

The simplest explanation for the differences in sharing patterns across hunt types is that harvest size predicts whether a portion is given to another household or the entire harvest is kept within the household of the acquirer. While RRR implies some degree of diminishing marginal valuation, this condition is consistent with a number of alternative sharing models, including trade based on specialization, and tolerated theft (Kaplan & Hill, 1985; Winterhalder, 1990).

Fig. 1 is a histogram showing the distribution of harvest sizes for "some shared" and "all kept" acquisitions. Harvest-size data are log-transformed in order to more closely approximate normality, and a normal distribution for each type of acquisition is also plotted to indicate the degree of asymmetrical dispersion of harvest size in relation to sharing decisions. Fig. 1 shows that harvests where all is kept by the acquiring HH are smaller and show a good fit to a normal distribution, while "some shared" harvests are larger but also much farther from normally distributed (even after log-transforming the data). This difference is primarily

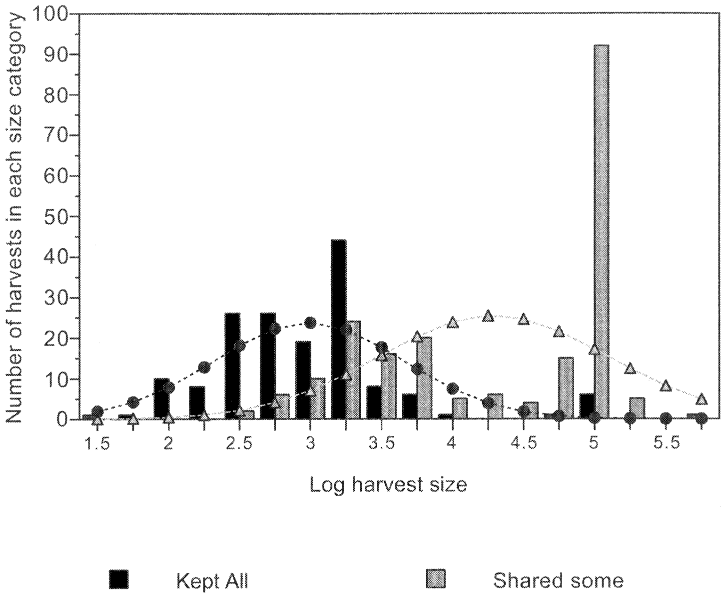

Fig. 1. Histogram showing the number of harvests in each size category compared to a hypothetical normal distribution of the same mean and standard deviation for those harvests where all was kept within the household of the acquirer (kept all) and those where at least some was given to at least one other household (shared some). Each interval on the x-axis represents an increment of $0.25\log_{10}$ harvest size (in kilocalories), with the first interval at $1.5\log_{10}$ harvest size. The number of harvests in each size category is measured on the y-axis. All hunt types are included; the spike at log 5 shows the large number of turtle acquisition observations.

due to the influence of turtle collecting/hunting, where harvest size varies little (most harvests are of a single adult female turtle) and harvests are nearly always shared (log 5 harvest size in Fig. 1). When we exclude turtle from the analysis, the distribution more closely approximates a normal curve, but "all kept" harvests are *still* significantly smaller than "some shared" harvests (t test, $df=198$, $t=-8.883$, $P=.0001$). For this reason, we exclude turtle from analyses of the effects of harvest variance on sharing (Hypothesis 2).

When we categorize the data by hunt type, the influence of harvest size on the decision to keep or share is strong within hunt types, but weak between them. Fig. 1 compares the mean harvest size associated with "all kept" and "some shared" harvests from each hunt type. The data clearly show that within each hunt type, those harvests that were shared were of higher energy value than those that were kept. However, the data show no clear relationship between harvest size and distribution pattern *across* hunt types — the mean energy value for some hunt types where all was kept is close to the mean energy value for other hunt types in which some was shared. Again, this suggests that the energy value of a harvest predicts very nicely whether or not a harvest from a particular hunt type will be shared, but it has less predictive power over the difference in the frequency of sharing across hunt types. Other factors that may be correlated with hunt type appear to be influencing sharing frequency.

3.2. Risk reduction (Hypothesis 2): does variance increase the probability of sharing?

The basic logic of RRR mandates that sharing should be structured as food flows from those who currently have food to those who are currently lacking. By extension, resources associated with high levels of variation in mean harvest return rates across foraging bouts will be more likely to be shared than those that are associated with low variation. Variation can be measured in a number of different ways, most of which are likely to be correlated with each other. Because of this autocorrelation, we examine each measure of variability separately to assess its impact on sharing frequency and compare the regression coefficients to a model including only harvest size as a predictor variable. In these analyses, we treat each measure of variability as a continuous variable. We then include the best measure of variability (as measured by the value of the partial correlation coefficient, R) in a multiple log-likelihood model. The measures of variability we use here are the CV in mean return rate across foraging follows, the proportion of foraging bouts of at least average length that end before any calories are acquired (failure rate), harvest size predictability (r^2) as a function of foraging bout length, and degree of temporal synchrony in acquisition between households. Table 1 summarizes the features of each hunt type: mean return rate, mean harvest size, and associated measure of variability, plus the frequency of sharing as in Fig. 1.

Table 1 shows that different hunt types are associated with different patterns of sharing and different levels of harvest variability. But which measure of variability best predicts whether some of the harvest will be shared? To answer this question, we treated each of the four variability measures as predictor variables in separate likelihood models. Each of these models includes a second predictor variable controlling for the differing number of observations in each hunt type (control) and a third predictor (constant) comparing the power of the model containing the predictor variables to one using only the constant as a

Table 1

Mean return rate, harvest size, measures of variance, and proportion of harvests shared, broken down by hunt type (focal follows only)

		Variance measures							
Hunt type	Mean return rate (kcal/h ± S.E.)	CV	Failure rate	Predictability (r^2)	Inter-HH synchrony	Mean harvest size (kcal ± S.E.)[c]	Maximum harvest size (kcal)	n[a]	Proportion of harvests shared[b]
Sardine net	9811 ± 1259	0.667	.000	.234	0.05	2547 ± 382	6,602	27	0.048
Rocky shore	575 ± 56	0.441	.000	.816	0.01	520 ± 80	963	14	0.140
Reef top	677 ± 171	1.134	.059	.611	0.05	988 ± 299	5,279	34	0.201
Small hook	356 ± 54	1.537	.245	.098	0.19	709 ± 119	5,874	101	0.300
Spearfish	328 ± 129	2.120	.500	.074	0	414 ± 129	3,280	29	0.300
Reef flat	1492 ± 173	0.796	.000	.479	0.01	1962 ± 247	8,268	47	0.357
Large hook	838 ± 158	1.761	.511	.039	0.08	735 ± 128	7,525	87	0.643
Bottom	1348 ± 231	0.707	.120	.523	0.06	3016 ± 686	10,464	23	0.652
Trolling	2312 ± 796	2.335	.540	.017	0.01	3076 ± 902	26,594	46	0.850
Turtle collect	20034 ± 2090	1.292	.170	–	0.04	42517 ± 4474	149,776	88	0.910
Turtle hunt	5615 ± 1830	1.815	.330	–	–	23908 ± 6103	128,128	33	1.000

See text for definition of variables.

[a] Sample size in this table refers to the number of follows for which mean returns per forager-hour were calculated.

[b] Proportion of acquisitions in which at least some of the harvest was shared, using the aggregated data set.

[c] Includes zero harvests (failed attempts), and thus, is lower than mean harvest size shown in Fig. 1, which is biased by the large number of successful harvests obtained through the 8-HH sample.

predictor. The regression coefficients from each model are compared in Table 2. Because turtle harvests vary little in size and are always shared, we do not include these in the analysis.

The two best measures of variability are failure rate ($R = .260$) and CV in mean returns ($R = .216$). These are highly correlated with each other ($r = .938$) but interestingly, neither is correlated with harvest size ($r = .102$ for CV and $-.005$ for failure rate). Since failure rate is a slightly better predictor, and is highly correlated with return rate CV, we use failure rate as our measure of hunt type variability.

How does failure rate compare with a model including harvest size as an independent variable? Which has the strongest effect in predicting the likelihood of sharing some of a harvest? The best model includes both harvest size and mean failure rate (Model 6, Table 2). Partial correlations of failure rate ($R = .163$, $P < .001$) and log harvest size ($R = .346$, $P < .0001$) in Model 6 indicate that both measures have a significant effect on sharing probabilities, but that the effect of harvest size is much stronger.

3.2.1. The effect of the relative effort of the sexes

One confounding effect on sharing outcomes may be the sex of the acquirer. One sex might be more likely to choose hunt types associated with particular failure rates than another, and sex might trump both harvest size and failure rate in decisions about whether or not to share a portion of the harvest (assuming the acquirer distributes his or her own harvest, which is generally the case for the non-turtle hunt types).

To control for the effects of the sex of the forager, or the composition of foraging groups, we simply add an additional independent variable to Model 7 (Table 2), classifying the acquirer as male or female. Since we do not know who distributed the prey from cooperative and mixed

Table 2

Logistic regression models showing the effect of different measures of variance, harvest energy value, and the sex of the acquirer on the odds that a portion of the harvest will be shared following acquisition (aggregated data set minus turtle)

Model	Predictor variable(s)	P value (Wald test α)	R (partial correlation)	P value (Pearson whole model goodness of fit test β)	Percent observations correctly classified (%)
1	Log harvest (kcal)	.0001	.370	.5814	76.4
Variance measures					
2	Failure rate	.0001	.260	.0001	69.4
3	Return rate CV	.0001	.216	.0001	69.4
4	Predictability	.0006	$-.173$	.0001	69.4
5	Synchrony	.4949	.00	.0001	60.3
6	Log harvest (kcal)	.0001	.346	.1469	77.3
	Failure rate	.0006	.163		
7	Log harvest (kcal)	.0001	.278		
	Failure rate	.0019	.169	.2366	79.0
	Sex of acquirer	.6539	.00		

sex hunts, we exclude these cases from this particular analysis. There is no significant effect of the sex of the acquirer in the model ($R = 0$, $P = .654$). Meriam men and women are equally likely to share when they acquire harvests of the same size and failure rate level.

3.2.2. Do increasing levels of failure increase the probability of sharing?

Clearly, failure rate has some small but significant effect on sharing outcomes. But a better test comes through examining the effect of changes in failure rate on the likelihood that some of the harvest will be shared. Toward this end, in Model 8 (Table 3) we use logistic regression to examine the influence of different levels of failure on sharing outcomes, again controlling for harvest size and the number of observations in each hunt type. In this analysis, we use failure rate as a discrete ranked variable. By doing so, we can compute a unique odds ratio for each failure rate, which allows us to examine the outcome (the odds of sharing) associated with each hunt-type failure rate (see Table 1). We expect to see some consistent relationship between the odds of sharing and increases in hunt type failure rate level.

To test the prediction that increasing levels of failure across hunt types predict increases in the probability of sharing, we compare sharing outcomes from the harvests of hunt types with zero failure rate (sardine netting, rocky shore harvesting, and reef flat collecting) to those of harvests from hunt types with higher failure rates. There are three hunt types with greater than zero failure rate (reef top handline, small hook beach fishing, and large hook beach fishing) that have harvests that are equally or less likely to be shared than the harvests from zero-failure hunt types. Only two hunt types with greater than zero failure rates yield harvests that are significantly more likely to be shared (trolling and spearfishing). We conclude that there is no predictable increase in the likelihood of sharing with increases in failure rate across hunt types.

3.2.3. The effect of macropatches

The inability of failure rate to explain global differences in sharing probability across all hunt types suggests that the importance of failure rate may be relative to other possible foraging options occurring at the same time and place. In other words, failure rate may only

Table 3
Logistic regression model showing the odds that a portion of the harvest of a given hunt type and associated failure rate will be shared, relative to hunt types with zero failure rate (aggregated data set minus turtle)

Model	Hunt type	Predictor variable	Odds ratio	P value (Wald test α)
8[a]		Log harvest (kcal)	17.05	.0001
	Reef flat, sardine net, and rocky shore	Failure rate: 0	1.00	Reference level
	Reef top	Failure rate: .06	0.06	.0098
	Bottom fishing	Failure rate: .12	1.99	.2830
	Small hook	Failure rate: .25	0.00	.0153
	Spearfish	Failure rate: .50	39.73	.0267
	Large hook	Failure rate: .51	1.36	.6435
	Trolling	Failure rate: .54	15.28	.0029

[a] Model log likelihood = – 108.8, whole model fit test $df = 205$, $\chi^2 = 263$, $P = .004$, 78.9% of observations correctly classified, model $r^2 = .323$, $N = 242$.

predict increases in sharing probabilities within macropatches (by which we mean a temporal and spatial grouping of simultaneously available hunt types). The nine hunt types included in these analyses are grouped into three macropatches: beach (small-hook handline, large-hook handline, and sardine netting), reef (reef flat collecting, rocky shore harvesting, spearfishing), and offshore (reef top fishing, bottom fishing, trolling).

Table 4 presents the results of a logistic regression of the effect of log harvest size, failure rate, and group composition on sharing probabilities within each macropatch. For beach macropatch hunt types, increases in failure rate are associated with increased probabilities of sharing (relative to sardine netting, the hunt type least likely to be shared). Thus, small-hook fishing is over 15 times more likely to be shared (odds ratio = 15.4, $r = .169$, $P = .013$), and large-hook fishing is 38 times more likely to be shared ($r = .235$, $P = .002$). These differences are significant even after controlling for the confounding effects of forager sex and harvest

Table 4
Logistic regression models showing the probability of sharing within macropatches (aggregated data set minus turtle)

Model	Hunt type	Variables	Slope coefficient	S.E. of coefficient	*P* value (Wald test)	*R*	Odds ratio
Beach[a]		Shared some: constant	– 10.71	2.67	< .0001	– .312	.00002
	Sardine net, small hook, large hook	Failure rate 0	Reference				1
		Failure rate .245	2.74	1.10	.0132	.169	15.42
		Failure rate .511	3.64	1.15	.0016	.235	38.26
		Log harvest size	2.25	.72	.0017	.233	9.46
		Sex is F	Reference				1
		Sex is M	.06	.51	.9108	.000	1.06
Offshore[b]		Shared some: constant	– 16.15	4.16	.0001	– .349	.0000001
	Reef top, bottom fishing, trolling	Failure rate .059	Reference				1
		Failure rate .120	.24	1.09	.8273	.000	1.27
		Failure rate .540	2.60	1.19	.0292	.161	13.35
		Log harvest size	4.33	1.16	.0002	.335	75.75
		Sex is F	Reference				1
		Sex is mixed sex	.65	1.27	.6070	.000	1.92
		Sex is M	– .32	1.28	.8021	.000	.73
		Sex is M group	1.49	1.33	.2642	.000	4.44
Reef[c]		Shared some: constant	– 12.22	3.43	.0004	– .414	.000005
	Rocky shore, reef flat, spearfishing	Failure rate 0	Reference				1
		Failure rate .500	– 1.04	1.12	.3557	.000	.35
		Log harvest size	3.92	1.17	.0008	.384	50.15
		Sex is F	Reference				1
		Sex is M	– .12	.99	.9014	.000	.88

[a] Model log likelihood = – 53.3, whole model fit test $df = 89$, $\chi^2 = 92.76$, $P = .3716$, 75.2% of observations correctly classified, model $r^2 = .261$, $N = 113$.

[b] Model log likelihood = – 25.8, whole model fit test $df = 66$, $\chi^2 = 51.6$, $P = .9037$, 89.6% of observations correctly classified, model $r^2 = .517$, $N = 77$.

[c] Model log likelihood = – 20.0, whole model fit test $df = 45$, $\chi^2 = 37.2$, $P = .7908$, 78.9% of observations correctly classified, model $r^2 = .361$, $N = 52$.

size. Harvest variability thus seems to increase the likelihood of sharing harvests from beach hunt types.

For offshore hunt types, the odds of sharing increase with failure rate. Compared to reef top fishing at a failure rate of .06, bottom fishing (.12 failure rate) produces harvests that are only 1.27 times more likely to be shared, while trolling (.54 failure) is over 13 times more likely to be shared. After controlling for harvest size, the small difference in the odds of sharing between bottom fishing and reef top fishing is not significant ($P = .983$), but the difference in sharing probabilities between reef top fishing and trolling remains significant ($P = .029$). Harvest variability thus seems to have a mixed effect on the likelihood of sharing among offshore hunt types.

For reef hunt types, the high (.50) failure rate in spearfishing is not associated with significant increases in the odds of sharing relative to shellfish collecting (reef–flat and rocky-shore hunt types, both with zero failure rate). Here, harvest size is the only significant influence on sharing probabilities (odds ratio = 50.15, $P < .001$). This is because shellfish collecting produces very large harvests with no risk of failure, and such harvests are infrequently shared, while spearfishing produces very small harvests that are rarely large enough to share. In sum, harvest variability has no effect on the likelihood of sharing between reef hunt types.

The results of these analyses again suggest that failure rate is not a good global predictor of the probability of sharing, and that the observed weak effect of failure rate on the probability of sharing may be due to other correlated factors.

3.3. Generalized contingency (Hypothesis 3)

Reciprocity (in food sharing or other social interactions) can be measured in a number of ways, including general contingency, which focuses on the total amounts or frequencies with which any individual or household gives to and receives from the sharing network, and dyadic or specific contingency, which focuses on each of the possible pairs in the sharing network (Gurven, Allen-Arave, Hurtado, & Hill, 2001; see also Hemelrijk, 1990). We will treat each measure in turn.

If sharing is patterned by general contingency, those households that give greater quantities to other households should receive greater quantities. Fig. 2A shows the relationship between the total amount in calories given away to other households (log scale) and the total amount received by those households per sample day, using the eight-household sample. Those who give away more calories do not receive significantly more calories than those who give away less ($r = .119$, $P = .779$, $n = 8$).

Fig. 2B shows the results of the same analysis using the turtle-sharing data set. In this data set, there is a single outlier biasing the regression (represented by the open circle). The outlier represents a household that hosted the New Year's island-wide dance competition over 3 days in 1995, and during this period tremendous amounts of food were flowing in and out of this single household as it hosted the largest and longest feast occurring yearly on the island. It is not representative of the pattern of food flows during the remaining 362 days of the year. Retaining the outlier results in a significant positive slope ($r = .310$, $P = .011$, $n = 66$), but with much unexplained variance ($r^2 = .096$). With the single outlier removed, there is no

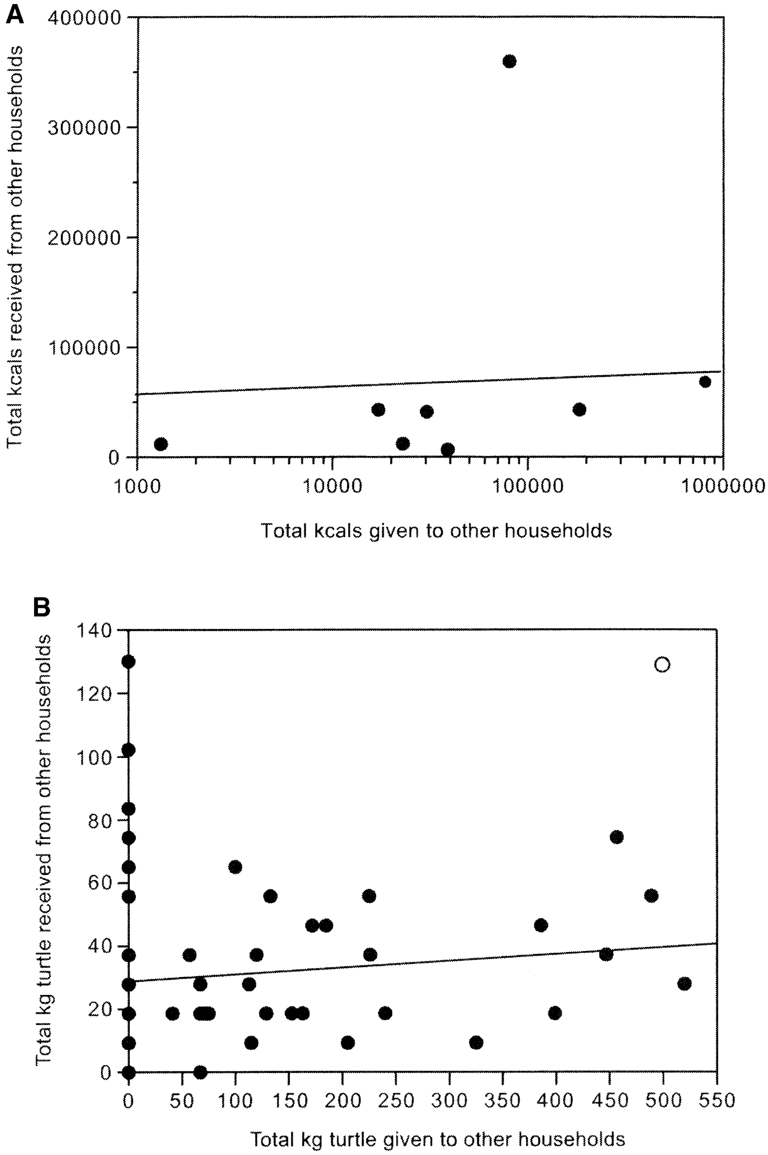

Fig. 2. Linear regression of relationship between the sum total given by a household and sum total received by that household through sharing transfers. (A) Kilocalories given and kilocalories received in the 8-HH data set (log–log plot). (B) Kilograms given and kilograms received per household in the turtle-sharing data set. Each point represents a single household's total over the year. Open circle indicates outlier household discussed in text.

significant effect of the total kilograms of turtle meat supplied to other households on the total kilograms of turtle received ($r = .175$, $P = .162$, $n = 65$).

While the above analyses examine general contingency in terms of *amounts* shared (kilocalories or kilograms), it can also be measured in terms of the *frequency* of giving and receiving. This would take account of the possibility that households might assign different marginal values to a given portion of turtle meat. Doing so, we find no effect, regardless of whether or not the outlier is present ($r=.000$, $P=.991$, $n=66$).

3.4. Dyadic reciprocity (Hypothesis 4)

If sharing is patterned by dyadic reciprocity, those households that give more to a particular household should also receive more from that household, as measured in either amounts given and received or sharing frequencies. To test this hypothesis, we computed the correlation between the total amount of food transferred by ith household to the jth household in each sharing dyad and the total amount of food transferred by jth household to the ith household. In the 8-HH data set, there were 22 dyads not involving feasts, 18 of which were characterized by one-way flows. There was no significant correlation between the amount given and amount received across the 22 household dyads ($r=.141$, $Z=.620$, $P=.536$).

In the turtle-sharing data set, there were 118 dyads not involving feast transfers, 106 of which were characterized by one-way flows. Here too there was no correlation between kilograms of turtle given and received across household dyads ($r=.005$, $Z=.054$, $P=.957$). Fig. 3 shows the amounts transferred between households in which two-way flows occurred ($n=12$). The amount given by the more productive member (i) to the less productive member (j) of each dyad (i,j) is plotted on the x-axis. If households were in exact balance, the slope of the best-fit line across points would equal 1.0. If the more productive member of the dyad tolerated less from the less productive member, as we might expect if more productive households put a lower marginal value on turtle than did less productive households, the slope might be some fraction of 1. The data suggest some possibility of balance for smaller amounts transferred, but beyond about 40 kg, additional amounts transferred to one's sharing

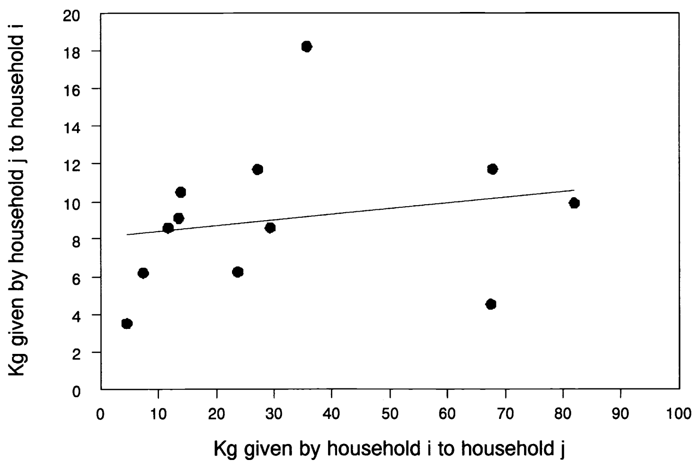

Fig. 3. Linear regression of dyadic non-feast turtle-meat sharing (two-way transfers only, arrayed so the larger amount given in each household pair is plotted on the x-axis).

partner are not matched, and the linear regression shows a weakly positive slope (0.03) and is not statistically significant (Fig. 3). In addition, it must be remembered that 89.8% of

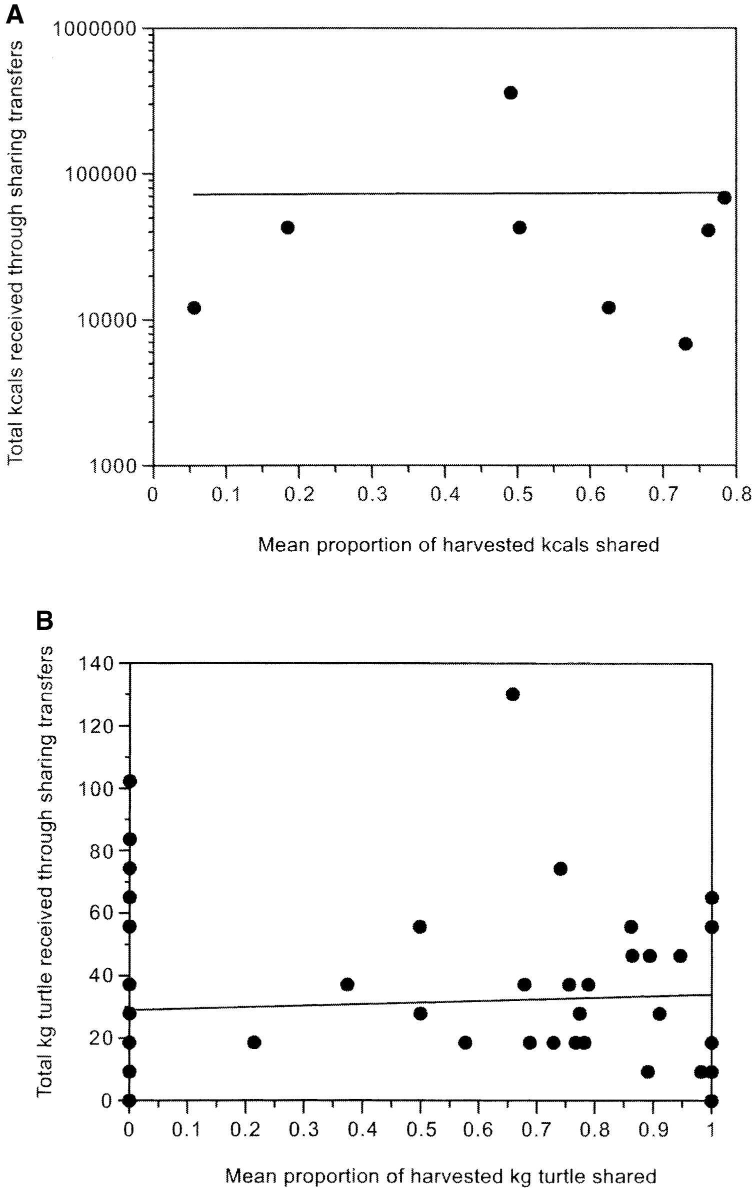

Fig. 4. Linear regression analyses of relationship between proportion of harvested resources given away by a household and the amount received by that household through sharing transfers. (A) Proportion of harvested kcal given away to other households versus amount received (on log-scaled axis), all resources (8-HH data set). (B) Proportion given away versus total kilograms received, turtle meat only (turtle data set).

non-feast turtle-sharing events over the course of the year were one-way flows; these are not shown in Fig. 3.

3.5. Free-rider discrimination (Hypothesis 5)

Given the prisoner's dilemma payoff structure involved, RRR requires some discrimination against free-riders in order to ensure its stability (Hawkes, 1992; Smith & Boyd, 1990). We have already shown in Fig. 2 that those who fail to acquire or share foraged resources are not less likely to receive than those who acquire and share more. However, that analysis did not distinguish between those who did not share because they did not acquire, and those who did not share because they kept all they acquired. We might expect that discrimination would be aimed particularly at those who harvested resources and thus were capable of participating in the pooling network, but refrained from doing so. In that case, we predict that those who acquire resources and do not share them should be less likely to receive food from others; conversely, those that are more generous should be preferred sharing partners and thus should receive more food in total from more of the other households.

Fig. 4A portrays generosity as the proportion of total calories harvested that were given to other households by each household in the eight-household sample, plotted against the total calories received through sharing transfers. A linear regression reveals no significant effect of generosity on the amount a household receives from other households ($r=.005$, $P=.991$).

Fig. 4B tests this hypothesis using the turtle-sharing data set, measuring generosity as the proportion of turtle kilograms harvested that are given to other households. A linear regression reveals a slight but nonsignificant negative trend toward receiving less with greater "generosity" ($r=-.109$, $P=.529$), which is counter to the hypothesis under test. Those households that share a greater proportion of the turtle they harvest do not receive more kilograms of turtle in total.

4. Discussion

Our results are summarized in Table 5. The predictions concerning marginal valuation were strongly supported: harvest size clearly influences the decision to share, at least within hunt types. Yet harvest size does not totally account for variation in sharing across hunt types; when we control for the effect of harvest size on sharing, there remain significant differences between most hunt types and between some failure rate levels. Furthermore, marginal valuation (sharing contingent on harvest size) is not a necessary or sufficient condition to distinguish between RRR and other models of sharing (Kaplan & Hill, 1985; Winterhalder, 1996b).

Our analysis reveals that certain hunt types are more likely to be associated with sharing than others, and that failure rate seems the most likely candidate of all risk-related variables examined for explaining this difference. Although failure rate accounted for a significant portion of the variability in sharing probabilities, its overall effect was weak compared to harvest size. The inability of other measures of foraging risk (CV in mean returns,

Table 5
Summary of analyses

Hypothesis	Prediction	Results	Supports RRR?
Marginal valuation	Increases in harvest size significantly predict increases in the probability of sharing.	Harvest size is a moderate and significant influence in increasing the odds of sharing.	±
Risk reduction	Measures of variance in acquisition significantly predict increases in the probability of sharing.	Failure rate is the best predictor of all measures of variance. Yet failure rate alone has a weak partial correlation with sharing probability, and increases in failure rate do not result in increases in sharing probability.	–
General contingency	Households that share in greater quantity to all other households receive in greater quantity.	Households who share more do not receive more.	–
Dyadic contingency	Those households that share in greater quantity to a partner receive more from that partner than they do from other partners	Some household dyads have more balanced flows, but more than 80% of dyads have one-way flows. Some households give more to reciprocators than to nonreciprocators, others do not.	±
Free-rider discrimination	Those households that share a smaller percentage of their take receive less than those who share more generously.	Those who share less generously, or who share nothing at all are not discriminated against in sharing distributions.	–

predictability, synchrony) to influence sharing probabilities as strongly as failure rate suggests either that those measures are inadequate indicators of foraging risk, or that sharing may not be designed to ameliorate foraging risk.

The prediction that increases in failure rate would result in increased probabilities of sharing was not globally supported: failure rate differences are associated with significant differences in sharing probabilities, but not in any predictable way across all hunt types. This seems to be due to the fact that failure rate interacts with harvest size in complex ways, particularly with reference to other hunt types within the same macropatch. When we group the hunt types according to failure rate within each macropatch (beach, offshore, and reef), reef hunt types show no significant changes in sharing probabilities with differences in failure rate, and offshore hunt types show an equivocal pattern, with bottom fishing at twice the failure rate showing no significant increase in the probability of sharing. Within the reef macropatch, harvests from spearfishing (with a 50% failure rate) are actually less likely to be shared than those from reef flat collecting or rocky shore harvesting (hunt types with zero failure rates). This pattern seems entirely due to harvest size, and the fact that reef flat collecting provides the largest harvests in this macropatch. But with zero failure rate, why share? Meriam shellfish foragers suggest one answer to this question: with more and more people unable to meet the window of opportunity for efficient shellfish collecting created by tidal conditions (due to work obligations or general lack of access to clan lands with good reef exposure), those who do forage for shellfish may sometimes work harder to collect larger harvests to share with relatives who are unable (or unwilling) to forage themselves.

Another problem with the failure rate prediction is the weak effect of failure rate relative to harvest size in all of the models. In fact, failure rate is more important than harvest size only for large-hook beach fishing, suggesting that harvest size has less to do with sharing decisions in this hunt type than in any other. Overall, the logistic regression models suggest that sharing decisions are affected by both harvest size and failure rate, but that the relative importance of each varies according to hunt type. Importantly, we did not find any independent effect of forager sex or group composition in sharing decisions: women are not more likely to share than men once we control for differences in harvest size and hunt type failure rate (although women are far less likely to participate in hunt types associated with high sharing frequencies; Bliege Bird & Bird, 2002).

We did not find any support for the prediction concerning general contingency. Households that share larger amounts of food, or share more frequently, do not receive more food from others.

The results of our test of dyadic reciprocity — whether households share more with partners who reciprocate — revealed no correlation between the amount given to a household and the amount received from that household, primarily because 87% of dyads in the turtle-sharing data set (over an entire year) and 82% of dyads in the eight-household sample were characterized by one-way flows.

Finally, we did not find any support for the prediction that free-riders should be discriminated against; those who did not share or who shared a smaller percentage of their harvests did not receive less from other households. This suggests that Meriam food sharing is not structured in the conditional manner required to stabilize RRR.

The limitations of the eight-household data set used to test some of the predictions of contingency, dyadic reciprocity, and free-rider discrimination bear mention. First, the eight-household data set covers only a 3.5-month period, and the frequency of sharing in this sample is such that our observations of any contingent sharing would be quite rare. Our interpretations concerning dyadic reciprocity using this data set must therefore be considered very provisional. Despite these limitations, there is empirical and theoretical support for the provisional conclusions we have drawn from analysis of this data set. First, the eight focal households were not observed to benefit by sharing turtle in terms of receiving more of other resources; for example, those focal households that never shared turtle ($n=5$) received 298 ± 117 kcal of fish per day, while those that shared turtle ($n=3$) received 57 ± 57 kcal of fish per day. Secondly, we note that during the 3.5-month period covered by this data set, turtle is by far the most significant single resource consumed by island households, comprising 80% of all calories acquired through foraging. A household that receives a portion of turtle in a household distribution event (as distinct from a feast) receives on average more than 10,000 calories at one time (Bliege Bird & Bird, 1997). Paying this gift back in any foraged resource other than turtle would take many long hours of foraging for any resource but sardines. Yet sardines have one of the lowest frequencies of sharing: only 4.8% of sardine harvests are shared beyond the acquirer's household.

The turtle-sharing database covers a longer window of time (1 year) and a much wider sample of households, as it records the distribution of all turtles acquired in the village during this time. The focal-follow database covers even a longer period (27 months) and an even broader sample of Meriam foragers. It is of course possible that reciprocal food sharing is played out over even longer time frames than these, but we consider that to be relatively problematic grounds for discounting our negative results concerning reciprocity. First, lengthy delays in reciprocation will make it difficult for foragers to "keep accounts" of who owes them shares. Second, such delays raise the problem of time-discounting, since shares repaid years hence will generally offer lower fitness benefits than those paid now (e.g., Axelrod, 1984), and indeed mortality or residential moves may make repayment impossible. Third, while it is always possible to rescue the reciprocity hypothesis by arguing that there hasn't been sufficient time for repayment, doing so threatens to make the hypothesis untestable in practice.

While the eight-household and focal follow data sets cover all foraged resources, the turtle-sharing database covers only a single resource, and thus cannot evaluate the possibility of reciprocal exchange involving trade of turtle for other foods, let alone other types of goods or services. It must be noted, however, that during this 1-year period turtle harvests represent about 50% (by kilocalories) of all foraging harvests, thus leaving little room for major reciprocation of foraged foods. For the contemporary Meriam economy, foraged foods are the domain in which risk-reduction reciprocity would need to operate, as purchased foods are not subject to significant fluctuations in availability, all households have access to money through government transfer payments, and horticulture is of very little nutritional importance. Thus, it seems unlikely that our finding of a lack of evidence for risk-reduction reciprocity in food sharing would be reversed if we had access to data on sharing of nonforaged resources.

Recently, Hames (2000) interpreted significant positive correlations between donated and received food between Yanomamö households as reciprocal altruism. Hames also tested a prediction that village size should be negatively related to scope of exchange if reciprocal altruism was patterning resource sharing; he found significant negative correlations for all but the sharing of game. Similarly, Gurven et al. (2001) analysis of Ache sharing patterns suggests that reciprocity-based explanations are more likely to apply to the sharing of non-game or non-forest resources, though the opposite pattern was found for Hiwi sharing (Gurven, Hill, Hurtado, & Lyles, 2000). The Meriam data are similar in some ways to the Ache and Yanomamö cases: large-package resources associated with hunt types that have high failure rates are in many circumstances shared more frequently than resources from more reliable activities, but not necessarily reciprocally.

Qualitative support for our conclusion that little of Meriam food sharing is structured as conditional reciprocity comes from ethnographic data concerning what the Meriam themselves say about sharing. Many of the Meriam we have lived with interpret unconditional generosity such as donating turtles to feasts or sharing turtles or fish with neighbors quite differently than conditional reciprocity (which also has a place in their social and economic lives). A common Meriam ideal of generosity involves reference to the concept of *debe tonar*, which means "the good way." *Debe tonar* constitutes a set of principles to guide everyday social interactions, and adhering to those principles is considered a signal of Meriam moral and ethnic identity. Following *debe tonar* is said to provide long-term benefits in the form of an enhanced social reputation as a "good person." Subsistence decisions intersect with the aspect of *debe tonar* that specifies generosity with food (*derapeili* — to share portions out). There are strong social sanctions against conditional or contingent sharing of "table food" between households following a harvest of wild or cultivated resources. Similarly, there are social norms governing the provisioning of food to feasts: such foods are explicitly designated public goods (*kies*) subject to unconditional consumption. *Debe tonar* states that such unconditional sharing is its own reward; to share contingent upon a return in kind is to share selfishly, and to return a portion freely given is to imply the giver had selfish motives. A Meriam adage states "When you expect payment back, you can't *esak gem* blo em" (you don't make a lasting impression). Sharing with expectation of return is equivalent to not sharing at all: both are referred to as being "*gobar*," greedy with food. While *derapeili* and *kies* sharing are explicitly unconditional, there are exchange contexts within which conditional reciprocal arrangements are considered proper: markets (*tama*), labor exchange (*irapu* — work party feasts), ceremonial exchange partners (*wauri tebud*), and repayments (*bodomelam*) for use — rights to certain individually or corporately owned items (land or foraging areas, or often items like boats and tools). Repayments in such contexts are usually made quickly or within an agreed timetable to limit confusion about whether the loan has been repaid or not.

5. Conclusion

The results discussed here suggest that sharing patterns among the Meriam are strongly influenced by the marginal valuation of food to the acquirer, but only weakly affected by harvest variance. We also found little or no evidence for reciprocal sharing of foraged food, exclusion of noncontributors from sharing networks, or generous contributors gaining more or larger shares in return, though some limitations in our data sets make these conclusions somewhat uncertain. An overall weak relationship between increased foraging risk and increased sharing probabilities, a strong role for marginal valuation, and a lack of evidence for reciprocal sharing arrangements together lead us to conclude that sharing on Mer is probably not designed to reduce foraging risk. These results cast considerable doubt on RRR as an explanation of Meriam food sharing.

Our negative findings concerning reciprocity are not unusual. While the explanatory power of reciprocal altruism has been supported by models and simulations designed to identify strategies that render reciprocity evolutionarily stable (e.g., Axelrod & Hamilton, 1981; Boyd & Richerson, 1988), empirical evidence for such behavior in nonhuman species has been limited to a few cases such as the regurgitation of blood meals by vampire bats (Wilkinson, 1984) and the sharing of information about food sources by ravens (Heinrich & Marzluff, 1995). This has prompted suggestions by behavioral ecologists for extensive revisions to the reciprocity paradigm (Brembs, 1996; Clements & Stephens, 1995; Connor, 1996; Dugatkin, 1997; Roberts, 1998). Experimental economists and anthropologists (Gintis, 2000; Hawkes, Blurton Jones, & O'Connell, 2001; Henrich et al., 2001) have raised similar theoretical and empirical objections in studies of humans. The limitations of reciprocal altruism stem from the very stringent contingency requirements that must be met (Axelrod & Hamilton, 1981; Boyd & Richerson, 1988; Trivers, 1971). Just as insurance by risk pooling can only be stable if coverage is limited to those who pay premiums, reciprocal altruists can only succeed if they exclude nonreciprocators.

While this paper does not attempt to develop or evaluate alternative explanations of food sharing, we suggest that foraging risk may simply be correlated with other variables that influence sharing frequency. For example, status benefits may accrue to those participating in difficult endeavors that serve to advertise the foragers' skills (Bliege Bird et al., 2001; Hawkes & Bliege Bird, 2002; Smith & Bliege Bird, 2000; Sosis, 2000), and this may apply primarily to resources whose harvest is subject to high variance and/or large package size. Evidence on Meriam foraging presented elsewhere indicates that for at least some hunt types, acquisition risk may facilitate "honest advertising" because foragers exhibit differing mean individual failure rates, and that difference is linked to their intrinsic skill or other hidden qualities such as competitive ability (Bliege Bird et al., 2001). Advertising such qualities may thus lead to increased social status and/or bargaining power, a point long recognized (Zahavi, 1977) but only recently formally modeled (Gintis, Smith, & Bowles, 2001).

For example, spearfishing has a higher failure rate than shellfish collecting, but lower sharing frequency due to small harvest sizes. Yet spearfishing confers status that shellfishing does not, and skilled spearfishers show significantly greater return rates and lower failure rates than other individuals (Bliege Bird et al., 2001). On the other hand, sharing following small-hook and large-hook beach fishing seems conditioned primarily by failure rate. If, as our analysis suggests, there is little conditional reciprocity associated with beach fish sharing, this would suggest again that the greater probability of sharing large-hook beach fish is related to the advertising value such fish possess (relative to small-hook fish) as honest signals of skill or other attributes of the forager. (For a more detailed discussion of sharing following fishing, see Bliege Bird & Bird, 2002.)

Other hunt types seem to follow a different pattern. For example, as Smith and Bliege Bird (2000) have suggested, sharing could signal commitment to an ongoing social relationship if sharers pay a cost to ensure the honesty of their signal. This might explain why some shellfish collectors work longer and harder to obtain a harvest large enough to share with another individual, often increasing the cost by cooking and seasoning the portion before distribution. These various possibilities underline the necessity for further analyses of sharing data from the Meriam and other societies in order to clarify the mix of factors motivating food sharing in varying social and ecological contexts.

Acknowledgments

We thank the Meriam community foremost, especially Chairman Ron Day for his foresight and tolerance, our Meriam families, particularly the Passis, and all of the foragers who volunteered information and invited us on hunting and fishing trips. We also wish to acknowledge the invaluable field assistance of Andrew Passi, Dalcy Gibas, Ron "Sonny" Passi, Edna Kabere, and Del Passi. Craig Hadley has been a vital participant in this project, particularly in collecting sharing data on Mer. We are especially grateful to John Beaton, Jim O'Connell, and Kristen Hawkes for their support and encouragement. Research in 1998–1999 was supported by NSF grant SBR-9616096 to RBB and EAS, NSF grant SBR-9616887 to DWB and EAS, and research in 1994–1995 was supported by grants to RBB and DWB from AIATSIS, the L. S. B. Leakey Foundation, the Wenner Gren Foundation for Anthropological Research, and a NSF predoctoral fellowship to RBB and a NSF Dissertation Improvement Grant to DWB. GCK was funded by the Andrew W. Mellon Foundation during part of his involvement in the project. For very helpful comments on earlier versions of the manuscript, we thank Elizabeth Cashdan, Michael Gurven, and Alan Rogers.

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