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Food-Sharing Networks in Lamalera, Indonesia: Status, Sharing, and Signaling

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Abstract

Costly signaling has been proposed as a possible mechanism to explain food sharing in foraging populations. This sharing-as-signaling hypothesis predicts an association between sharing and status. Using exponential random graph modeling (ERGM), this prediction is tested on a social network of between-household food-sharing relationships in the fishing and sea-hunting village of Lamalera, Indonesia. Previous analyses (Nolin 2010) have shown that most sharing in Lamalera is consistent with reciprocal altruism. The question addressed here is whether any additional variation may be explained as sharing-as-signaling by high-status households. The results show that high-status households both give and receive more than other households, a pattern more consistent with reciprocal altruism than costly signaling. However, once the propensity to reciprocate and household productivity are controlled, households of men holding leadership positions show greater odds of unreciprocated giving when compared to households of non-leaders. This pattern of excessive giving by leaders is consistent with the sharing-as-signaling hypothesis. Wealthy households show the opposite pattern, giving less and receiving more than other households. These households may reciprocate in a currency other than food or their wealth may attract favor-seeking behavior from others. Overall, status covariates explain little variation in the sharing network as a whole, and much of the sharing observed by high-status households is best explained by the same factors that explain sharing by other households. This pattern suggests that multiple mechanisms may operate simultaneously to promote sharing in Lamalera and that signaling may motivate some sharing by some individuals even within sharing regimes primarily maintained by other mechanisms.

Keywords

food sharing; status competition; costly signaling; social network analysis; ERGM; Lamalera

1. Introduction

Costly signaling is a mechanism by which natural selection can produce apparently costly or wasteful phenotypic traits because they honestly communicate information about an individual to others (Grafen, 1990a, 1990b; Spence, 1973; Zahavi, 1975, 1977). Such traits or “signals” can evolve when (1) the signal conveys information about some otherwise unobservable characteristic of the individual, (2) receipt of that information causes some

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other individual to react in a way that benefits both themselves and the signaler, and (3) the benefit provided by the other's reaction outweighs the cost of producing the signal. To ensure the honesty of the information communicated such signals must be costly to produce. This cost ensures a correlation between the intensity of the signal and the quality of the unobservable characteristic, which in turn makes it difficult, unprofitable, or even impossible for a lower-quality individual to dishonestly signal higher quality. Costly signaling is a general mechanism that has been used to explain complex physiological and behavioral phenotypes in a wide variety of evolutionary contexts, including mate choice, mating competition, predator-prey interactions, and altruistic behaviors (Zahavi and Zahavi, 1997).

Costly signaling has also been proposed as an explanation for human food sharing. One model, building on earlier work by Hawkes (1991, 1993), has focused primarily on the reproductive and prestige benefits to males (Bliege Bird et al., 2001; Hawkes and Bliege Bird, 2002). In this model, hunters pursue large, difficult to acquire prey which is then distributed widely within the group. Hunters compete to provide this public good because it signals otherwise unobservable qualities such as their skill, bravery, strength, or diligence, and in return better hunters secure reproductive benefits and social deference from other group members. These models generally assume the hunter cannot preferentially direct shares to specific individuals because of tolerated scrounging (Blurton Jones, 1984, 1987): defending a carcass from the demands of others is more costly than its value to the hunter. Because hunters in this model are unable to preferentially direct shares to their own families research in this area has contributed to an ongoing debate about men's foraging goals and the evolution of the human family (Gurven and Hill, 2009, 2010; Hawkes et al., 2010).

Several empirical studies support predictions of this model. In a few societies game is widely shared throughout the group (Forest Aché: Kaplan & Hill, 1985; Hadza: Hawkes, 1993; Meriam: Bliege Bird & Bird, 1997). In some cases, men engage in hunting that is less efficient than alternatives (Hadza: Hawkes 1993; Meriam: Bliege Bird et al. 2001) or even energetically costly (Ifaluk: Sosis, 2000; Meriam: Bliege Bird et al. 2001, Smith et al., 2003). A review (Smith, 2004) of studies in five foraging societies shows that better hunters often have higher reproductive success (Aché: Hill & Hurtado, 1996; Hadza: Hawkes et al., 2001; !Kung: Wiessner, 2002; Lamalera: Alvard & Gillespie, 2004; Meriam: Smith et al., 2003). While such reproductive benefits are consistent with costly signaling, there are other mechanisms (such as spousal and offspring provisioning, or phenotypic correlation) that might produce a correlation between reproductive success and hunting status (Smith, 2004).

In other societies where food sharing has been systematically studied, hunters retain control of their kills and are able to preferentially direct shares to others (Aché on reservation: Allen Arave et al., 2008; Achuar/Quichua: Patton 2005; Dolgan/Nganasan: Ziker & Schnegg 2005; Hiwi: Gurven et al., 2000b; Iñupiat: Magdanz et al. 2002; Lamalera: Nolin 2010; Yanamamo: Hames 2000; Ye'kwana: Hames and McCabe 2007). Where donors can directly choose the recipients of aid, sharing may serve as a signal of intent rather than a signal of individual quality. Patton (2005) has proposed a coalition-support hypothesis in which food sharing serves a signaling role in establishing and maintaining political alliances. Gurven et al. (2000a) suggest that excess sharing may serve as a costly signal of generosity, group commitment, or prosocial intent in a sharing regime otherwise dominated by reciprocity. Those who have established a reputation for generosity may receive help from others when ill or injured. Such long-term incapacitation may pose a greater hazard than the day-to-day variance in food acquisition faced by foragers (Hill & Hurtado, 1996; Sugiyama, 2004; Sugiyama & Chacon, 2000).

Whether sharing serves as a signal of individual quality or prosocial intent, where sharing functions as a costly signal those who share more are expected to be accorded higher regard than their peers, predicting an association between greater sharing and higher status or reputation. Most of the societies where the sharing-as-signaling hypothesis has been tested have been smaller communities with little or no formal status or role differentiation. In these societies, greater sharing is associated with acquired roles such as “hunt leader” (e.g. Smith et al., 2003) or a reputation as a better hunter (e.g. Hill & Hurtado, 1996). However, in larger, more hierarchically organized societies, such as the site considered here, we might also expect to find an association between sharing and formalized high-status roles.

Central to the argument made here is the observation that costly signaling is not mutually exclusive of other evolutionary mechanisms promoting food sharing such as kin selection (Hamilton 1964) or reciprocal altruism (Trivers, 1971). It is possible that several mechanisms may be operating simultaneously to promote food sharing within the same society (or even by the same individual). Models of competitive altruism suggest that costly signaling may act in conjunction with other cooperative mechanisms, such as reciprocal altruism, by signaling generosity, loyalty, or intent to cooperate (Nowak & Sigmund, 1998; Roberts, 1998; Gintis et al., 2001). Biological market theory suggests that costly signaling may emerge in many cooperative contexts where partner choice has adaptive consequences (Noë and Hammerstein, 1994, 1995). In Lamalera, the site considered here, reciprocity explains 44.9% of the model deviance in food-sharing patterns among households, with apparent preferences for genealogically close kin and residentially close neighbors as exchange partners (Nolin, 2010). This does not preclude costly signaling as a motivation for some food sharing, but does suggest that any sharing-as-signaling will occur in the context of a sharing regime otherwise dominated by reciprocal altruism. The question addressed here is *not* whether costly signaling is the primary motivation for food sharing throughout the community. Instead the focus here is on variation in sharing patterns among households: Do high-status households share more than others, as predicted by the sharing-as-signaling hypothesis?

2. Site description

2.1. Subsistence and sharing

Lamalera is a fishing and sea-hunting village on the island of Lembata in southeast Indonesia. In 2006, the resident population of Lamalera was 1,227 people in 317 households (excluding the resident Catholic priests and some students from neighboring villages; see Nolin, 2010: note 3). This is substantially larger than other communities where food sharing has been systematically studied, and may make it possible to discern within-population variation in sharing strategies not readily apparent within smaller populations. From May through September of each year, large prey (primarily sperm whale and three species of ray; Alvard, 2003; Barnes, 1996) are hunted in paddle- and sail-powered vessels called *téna*. In recent years, outboard motors have entered the village, and motorized boats (called *jonson* after a common brand of outboard motor) are now used to hunt smaller prey (primarily porpoise, ray, tuna, and marlin). In 2006 there were 14 *téna* and 15 *jonson* in operation. These were used in a mixed foraging strategy: *téna* were used when sperm whale had been sighted or were expected in the area and *jonson* were otherwise used to hunt smaller prey. Small-boat net fishing dominates the off-season. Throughout the year, vegetable foods are obtained through trade with agriculturalists from the interior of the island (Barnes & Barnes, 1989; Barnes 1996).

The primary distribution of prey has been extensively described elsewhere (Alvard, 2002; Alvard & Nolin, 2002; Barnes, 1996). Briefly, *téna* are owned by a corporation of members most of whom are drawn from a single patrilineal lineage. These corporation members, as

well as crewmen on the boat and certain specialist craftsmen who helped build the boat and its gear, have share-rights in any prey caught by the boat. Prey caught by *téna* is divided among these share-right holders according to a complex system of norms. Share-rights in *jonson* are similarly organized, with additional shares allocated to the owner of the motor and the individual who purchased the fuel.

Once a shareholder receives his portion of the catch, he returns home and cuts it into strips. Much of this meat is dried on open-air drying racks, to be consumed later or traded away for vegetable foods. However, other portions are given away as *běfānā*, gifts of food from one household to another. In strong contrast to the highly formalized system of norms that governs the primary distribution of prey, there are no explicitly articulated rules that govern this secondary distribution of *běfānā* to other households (Nolin, 2010). There are no rules, for instance, that dictate which types of prey must be shared or that obligate one to give to a certain class of relative. Nor are there formalized exchange partnerships such as the seal-fin partnerships of the Central Eskimo (Damas, 1972) or the *hxaro* partnerships of the !Kung (Wiessner, 2002). Giving *běfānā* is voluntary and discretionary.

2.2. Boat masters, harpooners, and master carpenters

Several formal roles are particularly important in the organization of a boat (Alvard, 2003; Alvard & Nolin, 2002; Barnes, 1996). The first of these is the *téna alep* (or *jonson alep*), the boat master. This is frequently a senior male from the boat owning lineage. The duties of the *téna alep* include organizing a crew at the start of each hunting season, securing contributions of materials as well as food and drink from corporation members for workers when the boat needs repairs, and arranging with craftsmen to keep the boat and its gear in good repair. The *téna alep* thus coordinates the three groups that compose any *téna* as a social entity: the corporation, the crew, and the craftsmen.

The *lama fa*, or harpooner, is the most important member of the crew. The *lama fa* represents the crew in important ceremonies and meetings at the start of each hunting season. He also faces a greater hazard of injury or death than other crewmen: when the boat closes on the prey, the harpooner leaps from a platform on the bow of the boat, gripping the butt of the harpoon shaft to add his weight to the force of the blow when it strikes. Harpooners have been injured or killed by becoming entangled in the harpoon line, and a harpooner who does not quickly swim back to his boat may find himself left behind if a whale tows his boat away. Good harpooners are in short supply: few men have the agility and balance needed to stand on the harpooning platform as the boat crashes through the waves in pursuit of prey.

The *ata molā*, or master carpenter, is the most important craftsman associated with a boat. The *ata molā* does not single-handedly build the boat, but instead directs its construction and repair. Each *téna* must be built according to the design of the very first *téna* bearing its name, a design that is passed down by each *ata molā* to his successor (Barnes, 1996). Where current construction does not match the original design, special marks must be carved into the hull by the *ata molā* where the original joints would have been, for it is believed that whales will otherwise notice and strike at these flaws. Historically, *ata molā* were believed to have supernatural power beyond their abilities as shipwrights. However, in the present day many of the *ata molā*'s past functions, such as blessing the boat at the beginning of each hunting season, have been usurped by the Church, and his status appears to have diminished as a consequence.

Holders of all three offices receive special shares from the primary distribution of prey (Alvard, 2002). A *téna alep* typically holds at least one corporate share in the boat and also receives a share equivalent to a single crewman's share, both for his household's own

consumption. In addition to these shares, the *téna alep* is also charged with the distribution of several "discretionary shares" from the primary distribution of prey. These are typically distributed to the households of individuals who help with the operation of the boat but are otherwise not directly affiliated (for instance, those who help drag the boat to and from the water each day), or to widows or other dependents within the lineage. Harpooners receive a regular crew share, and frequently hold a corporate share in the boat. A special share is also allocated to his oldest living patrilineal male relative. From ray, harpooners receive a large steak cut from one wing, and from whales they frequently receive a share reserved for the person who deals the killing blow. If they provide their own bamboo harpoon shafts (as is frequently the case) the harpooner may receive a share for that role as well. Master carpenters receive one of the largest single shares from whales and may also hold a corporate share in the boat.

All three of these roles are nominally hereditary, with the sons of the previous office holder having a right to claim the office in order of seniority. In practice, an heir may choose not to claim the role, he may have left the village, or he may not be fit for the role. A boat master who does not have the necessary leadership skills to organize and operate a boat may voluntarily step aside in favor of someone with more desire and talent for the role (or he may be quietly persuaded by shareholders in the boat corporation to do so). Similarly, there is no guarantee that the son of a good harpooner will also have the agility and balance necessary to be a good harpooner himself. Good harpooners are scarce in Lamalera, and it is not uncommon for a boat's harpooner to come from outside the boat-owning lineage. The same is true for master carpenters: not all heirs show the same aptitude or interest in the office as their fathers. Some hereditary lines of master carpenters appear to have been abandoned entirely, with the offices passed on to the master carpenters of other boats. While there is a hereditary component to eligibility for these offices, the individuals holding the offices are frequently those who have shown an aptitude for the role.

Jonson motor boats are a recent development and lack the hereditary component seen in *téna* offices (Nolin, 2008). Like *téna*, most *jonson* are owned by a corporate group holding share-rights in the boat, but unlike *téna*, *jonson* corporations may include friends and neighbors as well as close kin. (Two of the motor boats operating in 2006 were owned entirely by single individuals rather than a corporate group.) The *jonson alep* is typically the individual who has organized this group to commission the construction of a boat after having first secured a motor, either by purchasing one himself or as a gift from a wealthy relative residing outside the village. The master carpenter and harpooner for each *jonson* are recruited from the existing pool of talent within the village.

2.3. Contemporary sources of status

Lamalera is administratively divided into two villages, or *desa*, Lamalera A and Lamalera B, each with its own village head (*kepala desa*) and village officers. Each village is divided into wards (*dusun*), which are further divided into neighborhoods (*rukun tetangga* or "*RT*"), headed by ward captains and neighborhood chairmen, respectively. These positions carry annual honorariums ranging from 200,000 Rp for *RT* chairmen to 3,600,000 for the *kepala desa* (or roughly \$23 to \$409 in 2006 US\$). Office holders are nominally elected by the constituents they represent, though elections can be a formality. In practice, candidates, especially for lower offices, may be selected by consensus before the election and run uncontested.

Material wealth provides another way of increasing one's status outside of the traditional roles of the fishery or the administrative hierarchy of the village. In 1913, the first school on the island of Lembata was established in Lamalera. When the civil administration and educational system began expanding in Lembata in the first half of the 20th Century,

educated Lamalerans were well positioned to fill these newly created positions (Barnes, 1986, 1996). Lamalerans have thus had a long history of participation in the broader economy of the region. While the local economy remains largely a subsistence economy, remittances from relatives living outside the village are an important source of cash for some families. School teachers, the village nurse, and some pensioners have cash incomes.

2.4. Illustration of the problem

Figure 1 depicts the sharing relationships among the households in one ward of Lamalera. Each circle represents a household. The size of each circle is proportional to the number of reported food-giving relationships emanating from that household (in network terminology, its out-degree). The out-degree value is also given beside each node. Note that because sharing relationships with households outside the ward have been omitted from this figure, the out-degree value and the number of relationships displayed will not necessarily match. Darker, thicker lines indicate reciprocal sharing relationships between households; lighter, thinner lines indicate unidirectional sharing from one household to another. Arrows indicating the direction of transfer have been removed for clarity of presentation.

This figure graphically illustrates the high degree of variation in how households share food in Lamalera. Households in this ward give food to a mean $\pm$ s.d. 10.7 ± 9.8 other households, and most (68.9%) of these sharing relationships are reciprocated. (Village-wide, the out-degree (mean $\pm$ s.d.) is 9.8 ± 8.3 , and 67.1% of ties are reciprocated.) A few households who share substantially more than others stand out. These households provide an illustration of the apparent relationship between sharing and status. The out-degree and statuses of the five largest nodes (by out-degree) in this ward are given in Table 1. The first these is the household of one of the highest ranking individuals in the village administration, a boat master, and a man of high wealth. The second household is that of a man who is a boat master, a harpooner, a master carpenter, and also wealthy. The other high out-degree households similarly hold high-status roles or offices.

The goal of this paper is not to explain what motivates the vast majority of sharing that occurs between households of ordinary status. As already mentioned, the greatest predictor of sharing in the network as a whole is reciprocity, with apparent preferences for reciprocal exchange among close kin and residentially close neighbors (Nolin, 2010). Instead, the goal here is to explain why some households give food to substantially more households than others, and specifically to test whether such excessive sharing is associated with higher status as predicted by the sharing-as-signaling hypothesis.

2.5 The ecological context of sharing

Lamalera differs in a number of important ways from other societies where support for the sharing-as-signaling hypothesis has been found. Cooperative large-prey hunting in Lamalera appears to be economically rational rather than energetically costly: it delivers higher returns per unit effort than other, less cooperative alternatives (Alvard & Nolin, 2002). Sharing is not community-wide, nor are large prey a public good: individuals hold normatively recognized property rights to portions in the form of shares (Alvard, 2003). Similarly, the secondary distribution of food (sharing between households) shows little evidence of tolerated scrounging (Blurton Jones, 1984, 1987). Successful producers do not attract crowds of neighbors requesting handouts, but are instead able to process their household's share unmolested by others, with shared portions delivered directly to intended recipients. Likewise, little effort is taken to protect meat and fish hung on drying racks from outright theft, suggesting that property rights in food are generally recognized and respected, and that theft is rare.

Food sharing would be a rather inefficient signal of a producer's productivity, effort, or skill in Lamalera, as this information is readily available. Nearly all of the large hunting boats (with the exception of two motor boats) leave from a single, central beach. The success and failure of each boat can be directly observed, and the news of which boats have caught what prey is relayed throughout the village as the boats return each afternoon. Likewise, who was on which boat is easily observed. Essentially, information on individual effort and the success of the fishery is a positive externality of primary economic activity (Gintis et al., 2001). Additionally, the cooperative nature of hunting in Lamalera dilutes the benefits to any individual of signaling his productivity or effort: such a signal would reflect on the quality of the enterprise as a whole rather than any particular individual.

One finding consistent with the signaling hypothesis is that hunting boat crewmen and especially harpooners, have higher reproductive success than other men. In the case of harpooners, this appears to be due to an earlier age of marriage and onset of reproduction (Alvard & Gillespie, 2004). However, this association need not be a consequence of information signaled through food sharing: boat masters and master carpenters, for example do not exhibit higher reproductive success than others (Alvard & Gillespie, 2004). The association may instead be due to phenotypic correlation: the same traits that make men reliable crewmen or skilled harpooners may also make them more attractive mates (Smith 2004). Furthermore, although polygyny was permitted in the pre-Christian era, monogamy is now the rule and divorce is rare. The inability to attract multiple wives reduces the value of signaling as mating effort, especially for married men. Direct observations of secondary distributions suggest that both the husband and wife of a household have a say in determining to whom *běfānā* is directed. This is supported by the observation that both husband's and wife's relatedness to other households are predictive of giving (Nolin, 2008, 2011). Collectively, these factors suggest it would be difficult for a man to use food sharing to pursue a reproductive agenda contrary to his wife's interests. In this context greater sharing by high-status households might be due to alliance building (Patton, 2005) or signaling generosity, group commitment, or other prosocial intent (Gurven et al., 2000a) rather than mating effort (Hawkes, 1991; Bliege Bird and Hawkes, 2002).

3. Methods

3.1. Household sharing interviews

Field research was conducted by the author in Lamalera from April through December, 2006. Household interviews were conducted in Indonesian following the end of the active hunting (*léfa*) season, from September through December, 2006, with most (84%) interviews conducted from October 16 through November 16. Interviews were conducted with one or more household heads from each household in the village in respondents' homes. Respondents were asked to name those to whom they had "usually, more than once" given *běfānā* during the preceding *léfa* season. They were similarly asked from whom they had received *běfānā* during the same period. The order of these questions was alternated from interview to interview. Because these recall measures were a generalization of behavior over a period of several months, the purpose of limiting recall to transfers occurring "usually, more than once" was to capture individuals' most typical behavior (Nolin, 2010). The purpose of limiting recall to the preceding *léfa* season was to improve respondents' recall accuracy by temporally bounding the recall period (Loftus & Marburger, 1983). All 317 households chose to participate. The resulting data set represents a full census of between-household sharing relationships in the village.

3.2. Constructing the sharing network

The social network of between-household sharing was constructed using all positive sharing nominations, that is, all reported giving and reported receiving. The rationale for this is more fully explained elsewhere (Nolin, 2010) but briefly, using both donors' and recipients' responses helps correct for respondents' lapses of memory when there is a high Type II (false negative) error rate in responses (Marsden, 1990). The resulting network has 3111 directed sharing relationships (the network ties) among the 317 households (the network nodes) in the village, giving an overall network density of 3.1% of the possible 100,172 ties between households. Ties in this network are *directed*, meaning they have a node of origin and a node of destination, and are *binary*, meaning ties are either present or absent and lack value or magnitude. This network provides the dependent variable in the following analyses. Sharing relationships within one ward of this network are displayed in Fig. 1. For a depiction of the entire network, see Nolin (2010: Fig. 1).

3.3. Boat roles and household productivity

All boat masters (both *téna alep* and *jonson alep*) were interviewed and lists of boat role holders and shareholders were compiled. Using this information, households were then coded for the presence of key role holders (boatmasters, $n = 25$; harpooners, $n = 36$; and master carpenters, $n = 19$). As a measure of household productivity, the total number of corporate and craftsmen shares held by each household was calculated, and to this value were added a number of crew shares equal to the number of household males that were active in the fishery during the *léfa* season. Only shares and roles in boats that were "active" (having at least one successful hunt) during the 2006 *léfa* season were counted. This value, *total shares*, provides a measure of a household's productivity (mean $\pm$ s.d. = 2.98 ± 0.81 shares).

3.4. Administrative officials

A list of all administrative office holders was compiled and a four-point ordinal scale of political status was constructed based on position in the administrative hierarchy. Households of village heads were assigned a value of 3. Village officers and ward captains were assigned a value of 2. Neighborhood chairmen were assigned a value of 1. All other households were assigned a value of 0.

3.5. Household wealth

During household interviews, notes were made about the construction of and improvements to the respondents' home. Materials such as cement, brick, plaster, and tile cost money, and laborers must be provided with meals and palm wine. Thus, improvements to a house are a good proxy measure of a household's access to cash, either as income generated by the household itself (such as from an administrator's or teacher's salary) or through remittances received from relatives residing outside the village. These housing features were used to construct a Mokken latent scale of wealth (Mokken, 1971). Mokken scaling is related to Guttman scaling, a procedure sometimes used by anthropologists to estimate wealth where wealth cannot be directly measured (e.g. DeWalt, 1979). The Mokken scaling procedure creates an ordinal scale of a latent trait (wealth in this case) based on the presence or absence of items expected to be good proxy indicators of the underlying trait. Items are included or excluded according to the number of errors they introduce into a Guttman scale constructed from the same items. The Mokken scaling procedure was performed using the *msp* and *loevH* (Hardouin, 2004a, 2004b) packages for Stata 10.0. Details of the scaling procedure are provided elsewhere (Nolin, 2008, pp. 107–112). The resulting eight-point scale was based on the presence or absence of the following features (in order of prevalence): half-height brick walls, cement floors, full-height brick walls, an electric meter, plastered walls, a

satellite dish, and tile flooring. The scale reliability, measured using Loevinger's (1948) H statistic, is 0.70, indicating very strong scalability of these items. (By convention a Loevinger's H of 0.30 is the minimum acceptable value for a weak scale, and a value greater than 0.50 indicates a strong scale.)

3.6. Status covariates

In the results presented here, dichotomized versions of the household wealth and political status scales are used. Doing so puts all status covariates into a common binary metric and facilitates comparisons of model coefficients. The political and wealth scales were dichotomized where noticeable cut points occurred in the sharing patterns between scale steps (between wealth levels 6 and 7, and between political statuses 1 and 2). Households were then coded as being households of senior officials (administrative scale levels 2 and 3, $n = 13$) or high wealth (Mokken wealth scale levels 7 and 8, $n = 32$). Use of the full ordinal version of these scales does not qualitatively change the results presented here, and in many cases the dichotomized variable provides a better model fit (by AIC comparison) than the ordinal version of the same variable.

The five statuses considered here (boat master, harpooner, master carpenter, senior official, and high wealth) are not mutually exclusive of each other. As indicated by the example in Table 1, it is possible for a household to have multiple statuses. Of the 88 households having at least one of the five statuses, 60 households have only one status, 21 have two, five have three, and two households have four of the five statuses. The most common statuses shared by a household are roles associated with boats (boat master, harpooner, and master carpenter); boat masters who serve as senior officials; and boat masters who have high wealth.

4. Results

4.1. Exponential random graph modeling (ERGM)

The analyses presented below use exponential random graph modeling (ERGM) to estimate the effects of household status variables on the probability of giving or receiving food. ERGM is a method for modeling the generative processes producing ties in binary networks (Holland & Leinhardt, 1981; Robins et al., 2007; Wasserman & Pattison, 1996). The log odds of a tie from one node to another node in the network can be modeled as a function of characteristics of the individual nodes, characteristics of dyads of nodes, or as a function of structural properties of the network itself (that is, configurations involving multiple ties). When structural network elements are included in the model, their effects must be estimated using Markov-chain Monte Carlo (MCMC) methods: since the probability distributions of such structures are not *a priori* known, they are estimated by generating a sample of networks similar to the observed data.

When no structural network covariates are included in the proposed model, MCMC estimation is unnecessary and the resulting model is identical to ordinary logistic regression performed on the matrix of ties among nodes (Goodreau et al., 2008; Hunter et al., 2008). Such models assume a property called "dyadic independence", that is, they propose that the probability of a tie from one node to another node is independent of any ties either node of the dyad may have to other nodes in the network. ERGM coefficients are interpreted like logistic regression coefficients. Each coefficient represents the effect of a unit change in the corresponding covariate on the log odds of a tie from one node to another. Because log odds are often difficult to interpret, ERGM coefficients can be converted into odds ratios (OR) to aid interpretation. Odds ratios greater than one indicate a positive effect of the covariate compared to the reference population; odds ratios less than one indicate a negative effect.

In the analysis presented here, the nodes of the network are the 317 households in Lamalera and the network ties are the reported directed sharing relationships from one household to another. Binary household status variables indicate the presence of boat masters, harpooners, or master carpenters in the household; the presence of senior administrative officials; and high household wealth. Household productivity is captured by the total shares held by a household. The only structural covariate employed in the analyses presented here captures the propensity for reciprocity of ties between nodes. (In the language of social network analysis, reciprocity in directed binary networks is called “mutuality”. Though I have used the term in the past (Nolin 2010), I avoid the term here because of the potential for confusion with the mode of cooperation termed “mutualism” by evolutionary ecologists.) All analyses were performed using the statnet package (Handcock et al., 2003, 2008) for the statistical programming language R (R Development Core Team, 2007).

4.2. Status effects

The main effects of the different statuses on the odds of giving to or receiving from other households are given in Table 2. Each row in the table represents a separate model (one for each status). The “edges” term in these models controls for the overall number of edges or ties in the network, and acts as an intercept term. In network terminology, the edges term controls for the density of the network. In the present analysis it may be interpreted as reflecting a household’s baseline propensity to share when all other covariate values are zero. The status “giving” effect indicates the effect of being a household of the listed status on the odds of giving to another household; the status “receiving” effect indicates the effect of being a household of the listed status on the odds of receiving from another household. Coefficients are given in log-odds. AIC values are also provided for comparison with models presented in later tables. The coefficients for the household status giving and receiving effects have been converted to odds ratios and are presented visually in Figure 2.

Households of each of the five statuses show an increased propensity to give to other households (compared to households not having those statuses), and in all cases these differences in odds are significant. Likewise, households of each status receive with greater odds than households not having that status. The observed association of giving with status is consistent with the relationship predicted by the signaling hypothesis; however, a greater propensity to receive is not predicted by the sharing-as-signaling hypothesis. An association of greater giving with greater receiving is more consistent with direct reciprocity. Given that direct reciprocity is a strong predictor of sharing in Lamalera (Nolin, 2010), this suggests an alternative explanation. It may be that higher-status households are better able to establish reciprocal relationships with other households. Furthermore, their ability to do so may be due not to their higher status *per se*, but instead may be due to their higher productivity. As noted in Section 2.2, several of the statuses considered here receive special shares from the primary distribution of prey. It may be that increased odds of giving observed in Table 2 are not a product of status *per se*, but rather a function of the higher productivity of high-status households. (The Pearson correlation coefficient between total number of shares held by a household and total number of statuses held by household members is $r = 0.53$.) Those with more may choose to share more in order to establish more reciprocal relationships with other households.

4.3. Controlling for productivity and reciprocity

If costly signaling motivates any of the sharing exhibited by high-status households we might expect it to manifest it two ways. First, high-status households ought to exhibit greater levels of giving than expected based on their productivity alone. If their greater giving is merely a function of their higher productivity then we should see no status effect after controlling for household productivity. Second, high-status households ought to exhibit

greater odds of unreciprocated giving than other households. If (as might be expected in a sharing regime largely motivated by reciprocity) greater giving results in greater receiving from others, then the cost of giving is in doubt, calling into question the value of sharing as a signal. If giving is motivated by reciprocity alone, then we should see no status effects after controlling for reciprocity.

Table 3 presents ERGM models of status effects on sharing, controlling simultaneously for household productivity and reciprocity. (Models including these controls individually are presented in the supplementary online material, Tables S1 and S2.) The productivity (total shares held) effects on giving and receiving indicate the effect of holding an additional share in a boat on the log odds of giving to or receiving from others. The reciprocity coefficient indicates the increase in the log odds of household A giving to household B, *given that B gives to A*. When these controls are included, the status giving and receiving coefficients reflect the additional propensity of high-status households to give and receive, beyond that predicted by their productivity, and without regard to reciprocation.

Three of the statuses considered (boat masters, harpooners, and senior officials) show patterns of giving consistent with the sharing-as-signaling hypothesis. These three statuses all show increased odds of giving beyond those expected based on their productivity or propensity to reciprocate (Figure 3). Boat masters and harpooners also show reduced odds of receiving from others. Despite receiving more from others, these households have lower odds of receiving *without reciprocation*, suggesting they are better able to reciprocate what they receive from others. (Note that more productive households in general exhibit a similar pattern.). Master carpenters, on the other hand, show odds of giving and receiving no different from other households of similar productivity.

The pattern for high-wealth households contrasts strongly with that seen for boat masters, harpooners, and senior officials. Wealthy households receive without reciprocation more than would be predicted based on their productivity alone. Despite giving more overall (Table 2) they give without reciprocation less (Table 3) than households of similar productivity. Together with their increased odds of receiving without reciprocation from others, this suggests that wealthy households are more often targeted for sharing by others, but cannot or do not reciprocate this excess.

5. Discussion

5.1. Sharing, status, and leadership

The different statuses considered here demonstrate very different patterns of sharing. Boat masters, harpooners, and senior officials are all fairly similar in the pattern they exhibit: they give with greater odds than predicted by their productivity alone, and have higher odds of unreciprocated giving. Controlling for reciprocity, they receive with odds no different (senior officials) or even lower (boat masters, harpooners) than other households. This is in striking contrast to master carpenters whose increased sharing appears to be entirely due to their greater productivity: after controlling for reciprocity and productivity, master carpenters give and receive with odds no different from ordinary households.

Evidence of excessive sharing is strongest for those statuses that reflect leadership roles: boat masters, harpooners, and senior officials in the village administration. The findings presented here are merely correlational, and the causal relationship between leadership and sharing is unclear. Observations of an association between leadership and sharing are common in the ethnographic record. Well known examples include the potlaches of the Native Americans of the Pacific Northwest or the pig feasts of big men in New Guinea and Melanesia. When goods are pooled from multiple other individuals, their redistribution may

serve as a costly signal of the network of social support the leader can draw upon (Bliege Bird & Smith, 2005). In these settings, redistributive sharing serves to display one's support.

Arguably, excessive sharing by boat masters and harpooners might signal their success in managing a boat corporation or leading a boat crew, and serve as an indication of the support they receive from those they lead. However, as mentioned above, information about the effort and success of boats is already directly observable by others and widely known, suggesting that further signaling of this information is unnecessary. Furthermore, such an explanation does little to explain the excessive sharing of administrative office holders whose base of support is unrelated to their ability to coordinate economic production. It is also worth noting that excess sharing by these office holders is directed to individual households, and not to a general audience as might be expected if the aim were to demonstrate one's social support to others. If sharing is functioning as a costly signal, then "broadcast efficiency" – sharing widely to reach a broad audience -- (Smith & Bliege Bird, 2000) does not appear to be a concern.

Instead, excess sharing by those holding leadership roles in Lamalera may be aimed at securing and maintaining support rather than displaying it. As discussed above, all three of the traditional roles in boats are nominally heritable but in practice may be assumed by those showing interest or aptitude. Boat masters and harpooners especially may be under continual pressure to demonstrate their worthiness to hold office to their "constituents" (boat corporations and boat crews, respectively). Those holding elected political offices may be under similar pressures. Excessive sharing by men holding these offices may be a strategy designed to build alliances and secure political support (Patton 2005). Alternatively, sharing may not have a direct alliance-building function but may instead signal characteristics such as generosity or prosocial commitment that others value in their leaders (Gintis et al., 2001; Gurven et al., 2000; Nowak & Sigmund 1998; Roberts, 1998). Regardless, sharing by those in leadership roles in Lamalera appears more consistent with a strategy of securing and maintaining support than with a strategy of demonstrating their support to others.

Why do master carpenters not show similar evidence of excess sharing? This exception may prove the rule: Master carpenters do not have to exercise the kind of continual leadership expected of other office holders. Their skills as leaders are tested only periodically, when work parties are organized and boats are refurbished. Importantly, while the master carpenter directs the work, these parties are typically organized by the boat master, who must coordinate contributions of food and palm wine from corporation members to feed the work party. Furthermore, a master carpenter's status is partly dependent on heirloom knowledge that others cannot independently acquire. Convincing a master carpenter to step down also means convincing him to pass on this information. For these reasons, master carpenters may be politically more secure compared to other role holders. This may explain why they show no evidence of excess sharing beyond that predicted by the number of shares held: they have little need to obtain and sustain the support of others in order to maintain their position.

5.2. Wealth

The reversed sharing pattern seen for households of high wealth is more difficult to explain. Lower odds of giving and higher odds of receiving after controlling for reciprocity and productivity indicates that wealthy households give without reciprocation less, and receive without reciprocation more, than households of similar productivity. This pattern suggests that wealthy households are net recipients of food from others. One reason for this apparent pattern may be that wealthier households reciprocate with cash, loans, commercially purchased goods, or some other good or service not measured in this study. Another possibility is that access to cash makes wealthy households targets of strategic generosity by

others who anticipate making future requests for material help. While food may be acquired through subsistence effort, other important goods such as medicine, clothes, tools, and school tuition must be bought with difficult-to-acquire cash. In the context of a sharing regime dominated by reciprocity, others may hope to instill in the wealthy a sense of obligation to reciprocate, making future requests for monetary aid more difficult to refuse (Mauss [1925] 1990). Wealthy households might even encourage such behavior if they stand to benefit when others compete for their favor (Weiner 1992).

5.3. Relative importance of status effects on sharing

Much of the sharing observed by high-status households is explained by the same factors that explain sharing throughout the village. It is only some excessive, residual sharing beyond that observed for other households that appears to be explained by status. The magnitudes of these status effects are not great (Figure. 3). For example, controlling for productivity and reciprocity, the household of a boat master gives with odds 76% greater than an ordinary household (OR = 1.76); for the household of a harpooner the odds are 50% greater (OR = 1.50); for a senior official they are 69% greater (OR = 1.69). Furthermore, while a household's status may have a measurable effect on its own patterns of giving and receiving, differences in status among households do not explain much of the observed variation in sharing in the network as a whole. The models presented in Table 3 each explain about 2.8% more of the model deviance remaining after controlling for network density than a model containing reciprocity alone (cf. Nolin, 2010, Table 2). By comparison, reciprocity alone explains 44.9% of the residual deviance, and the presence of a receiving tie from another household increases the odds of giving to that household by 192 times (Nolin, 2010).

6. Conclusions

In Lamalera, households of men holding leadership roles give food to more other households than expected based on household productivity or the propensity to reciprocate alone. This excess, unreciprocated sharing by households of high status is consistent with the sharing-as-signaling hypothesis. The transparent context of primary economic activity suggests that excess sharing is not a signal of economic effort or productivity. Monogamous marriage and shared decision making with wives suggests excess sharing has reduced value for men as a mating strategy. Because the food shared by the households of leaders comes from their own stocks and is not pooled from others, and is provided to specific other households rather than as a public good, it seems unlikely that excess sharing serves to signal a leader's network of social support. Instead, food sharing by leaders may be more consistent with a strategy of building support, either through direct alliance building (Patton, 2005) or by signaling personal qualities, such as generosity, prosociality, or group commitment, that others value in their leaders (Gurven et al., 2000; Nowak & Sigmund, 1998; Roberts, 1998). Further research is needed to determine the specific reputational or material benefits leaders receive for their generosity.

Overall, this analysis finds only modest evidence of status-motivated signaling in Lamalera. Much of the sharing by high status households appears to be motivated by the same factors motivating sharing by other households. While costly signaling appears to explain inefficient modes of food acquisition and widespread sharing in some settings (Bliege Bird et al., 2001; Hawkes & Bliege Bird, 2002; Smith et al., 2003; Sosis, 2000), excessive sharing in Lamalera occurs in a context of mutualistic cooperative production (Alvard & Nolin, 2002) and a sharing regime dominated by reciprocity (Nolin, 2010). This does not preclude costly signaling as an explanation for some sharing. As the growing literature on biological markets makes clear, costly signaling of individual quality is favored in many settings where partner choice has adaptive consequences, including when the interaction

between partners is mutualistic or reciprocal (Noë & Hammerstein, 1994, 1995; Noë van Hooff, and Hammerstein, 2001; Bshary & Noë 2003; Hammerstein & Hagen, 2005). This underscores the observation that multiple adaptive explanations may be operating simultaneously in the same society, each explaining part of the total variance in sharing among households. Furthermore, different adaptive mechanisms may each explain some of the sharing exhibited by a single household or individual. In Lamalera status-oriented signaling may not be important for most households, but some of the excessive sharing exhibited by households of men holding positions of leadership may be motivated by signaling, even while other sharing by these same households is better explained by other adaptive mechanisms.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig.1.

A circle plot of food-sharing relationships in one example ward (*dusun*) of Lamalera. Circles represent households, with the size of the circle proportional to the number of its giving relationships (also indicated by the adjacent number). Black lines represent reciprocal sharing relationships between households; grey lines represent unidirectional giving relationships (for clarity, arrows indicating direction are omitted). Note that ties to households outside of this ward are not displayed so the value next to each node may not match the apparent number of ties.

Fig. 2. Odds ratios (OR) of food sharing for households having the listed status relative to households not having that status. Asterisks above bars indicate significant departures from OR = 1 (the dashed line) as follows: ^{ns} $p > 0.05$; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fig. 3. Odds ratio (OR) of food sharing for households having the listed status relative to households not having that status, controlling for household productivity and reciprocity. Asterisks above bars indicate significant departures from OR = 1 (the dashed line) as follows: ns p > 0.05; * p < 0.05, ** p < 0.01, *** p < 0.001.

Table 1

Statuses of top givers in one example ward (*dusun*) of Lamalera.

Out Degree	Boat Master	Harpooner	Master Carpenter	Senior Official	High Wealth
50	x			x	x
31	x	x	x		x
28	x	x			
26				x	
25		x			

Table 2 Baseline status effects on sharing relationships (log-odds coefficients $\pm$ S.E.)

Status	AIC	Edges (Intercept)	Status Giving Effect	Status Receiving Effect
Boat Master	27369	-3.592 ± 0.021 ***	0.963 ± 0.049 ***	0.390 ± 0.059 ***
Harpooner	27626	-3.529 ± 0.021 ***	0.512 ± 0.048 ***	0.142 ± 0.055 **
Master Carpenter	27617	-3.511 ± 0.020 ***	0.652 ± 0.060 ***	0.265 ± 0.069 ***
Senior Official	27449	-3.542 ± 0.020 ***	1.030 ± 0.062 ***	0.618 ± 0.072 ***
High Wealth	27681	-3.505 ± 0.021 ***	0.245 ± 0.055 ***	0.325 ± 0.054 ***

Wald test: ^{ns} $p > 0.05$;*
 $p < 0.05$,**
 $p < 0.01$,***
 $p < 0.001$

Table 3
Status effects on sharing relationships, controlling for total shares held by household and reciprocity (log-odds coefficients $\pm$ S.E.)

Status	AIC	Edges (Intercept)	Status Giving Effect	Status Receiving Effect	Shares Held Giving Effect	Shares Held Receiving Effect	Reciprocity Effect
Boat Master	14504	-4.993 ± 0.042 ***	-0.567 ± 0.080 ***	-0.245 ± 0.095 **	0.150 ± 0.008 ***	-0.076 ± 0.009 ***	5.617 ± 0.080 ***
Harpooner	14515	-5.031 ± 0.042 ***	-0.404 ± 0.069 ***	-0.269 ± 0.077 ***	0.170 ± 0.007 ***	-0.083 ± 0.008 ***	5.622 ± 0.081 ***
Master Carpenter	14560	-5.004 ± 0.041 ***	-0.075 ± 0.089 ns	-0.007 ± 0.104 ns	0.175 ± 0.008 ***	-0.087 ± 0.009 ***	5.596 ± 0.079 ***
Senior Official	14530	-4.996 ± 0.041 ***	-0.523 ± 0.093 ***	-0.074 ± 0.108 ns	0.165 ± 0.007 ***	-0.088 ± 0.008 ***	5.591 ± 0.079 ***
High Wealth	14516	-5.032 ± 0.041 ***	-0.268 ± 0.076 ***	-0.438 ± 0.074 ***	0.184 ± 0.007 ***	-0.095 ± 0.008 ***	5.622 ± 0.078 ***

Wald test: ns $p > 0.05$;

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$