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A Marginal Model of Tolerated Theft

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Using marginal analysis to represent Blurton Jones's concept of tolerated theft, I show how equilibrium resource transfers among individuals might be affected by foraging behavior, resource qualities, and number of participants. The model applies to hominids and other species that exchange or share food or other resources. Among the results: Tolerated theft enhances the value to be derived from resources, packets intermediate in size are most likely to be subjected to tolerated theft, packet division is more likely to be unequal than equal, division is a function of group size, and tolerated theft is most likely in small groups. The model also suggests that among reciprocators the widest possible exchange or sharing is in the self-interest of the individual procuring the resource. In general, evolutionary cost-benefit accounting should track marginal changes in the value (fitness or utility) of resources. Marginal valuation is conceptually primary and may produce results that differ from direct measures of quantity.

KEY WORDS: Food sharing; Foraging theory; Hominid origins; Primitive exchange; Reciprocal altruism; Tolerated theft; Scrounging.

Dense trafficking in food, tools, materials, and obligations of effort or support is a commonplace in human groups. There is evidence that this practice has a long history of development among our hominid ancestors. Resource sharing occurs as well in foraging species as diverse as bats (Wilkinson 1988), ravens (Heinrich and Marzluff 1995), and chimpanzees (Stanford 1995). Explanation of exchange behavior—its origin,

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elaboration, and proliferation into diverse forms, in humans as well as other organisms—is an important goal of evolutionary anthropology and biology.

I develop here a graphical model in order to refine and extend a concept important for analyzing the origins of exchange: *tolerated theft* (Blurton Jones 1984, 1987). An explicitly evolutionary analysis undertakes a two-part obligation: (1) it must establish that it is consistent with evolutionary mechanisms based in neo-Darwinian principles, and (2) it must provide a cost-benefit analysis of behavioral alternatives as they are affected by the relevant environmental context. The present paper contributes mainly to the latter effort by advancing understanding of the costs and benefits of tolerated theft in relation to environmental circumstances (resource qualities and availability), group size, and individual behavior with respect to food procurement and transfers. I will focus (as did Blurton Jones) on humans, although I will mention implications of the model for research on non-human species. More generally, the model has consequences for evolutionary analysis of cooperation, reciprocity, altruism, sharing, and scrounging.

TOLERATED THEFT

According to Blurton Jones (1984, 1987), food transfer among individuals may have its origins in tolerated theft produced by simple, individual-level selection. Once initiated, tolerated theft generates the conditions necessary for the evolutionary development of reciprocal altruism and sharing. It joins kin selection and clustering (Axelrod and Hamilton 1981) as mechanisms that might secure the initial viability of reciprocity, which becomes stable in a population only when there is a sufficient frequency and an indefinite future of interaction among reciprocators. The idea of tolerated theft is adapted from biological models of contests.

The tolerated theft model begins with an ecological constraint: Foragers encounter and harvest food items in natural units that can be called *packets*. For the baboon collecting very small packets such as grass stems, an increment of foraging time produces an increment of food. Gathering and consumption are coterminous. Effort ceases when individual needs are met. Assume however that a forager's diet includes one or more large packet resources, irregularly encountered. If members forage separately, such acquisitions are likely to be sporadic, unpredictable, and out of phase. An encounter with a large packet presents a surfeit of plant or animal flesh for the individual acquiring it. For example, a wildebeest cannot be harvested in meal-sized portions.

The value (in terms of fitness, utility, or another currency that might have analytical salience) to an individual of food packets of increasing size can be represented by a curve of diminishing marginal returns. For the successful but hungry forager, the post-capture meal provides high nutritional value. The portions given hungry mates or offspring act to like effect. But each additional portion eaten on the spot by the forager or dependents offers relatively less value. If the packet is large enough (the forager and small family group becoming satiated,

the wildebeest carcass still heavy with flesh), much is left over. Other individuals, perhaps only modestly successful in acquiring some small packet items that day, will look covetously on the remains. They have strong incentives to acquire what for them will be high-value portions, the same portions that the possessor has little incentive to defend. Individual interest in the marginal units of the resource packet is strongly asymmetric among the haves and have-nots.

Assume that no member of the group has a permanent advantage in his or her ability to take food or defend it; each has equal resource-holding potential. Each also gains equally in avoiding conflicts that might reduce fitness. Thus, the possessor of a large packet should cede portions and the supplicants take them until there is an equilibrium of their individual interests. Hirschleifer (1991) gives a formal justification for this assumption and describes more precisely the conditions under which it will hold.

Blurton Jones describes the outcome of this contest over resources in this way: "The prey should be divided, not exactly equally but to the point at which each participant gains the same fitness benefit from the food by each following its selfish interests alone" (1984: 2). He designates this transfer as passive sharing or tolerated theft, and he likens it (1987: 35) to Glynn Isaac's description of chimpanzee sharing as tolerated scrounging.

Day-to-day reversals of fortune in the acquisition of contested or *tolerated theft packets* mean that an individual who on one day procures portions (a *taker*, or T) will on another day cede them (that is, have a turn as a *giver*, or G). Self-interest, expressed as willingness to risk forceful acquisition of high-value food portions and as reluctance to hazard a defense of portions with limited value, impels everyone to engage in resource transfers when opportunities arise. In a small group with stable membership, the repetition of these purely selfish interactions could prime the evolution of reciprocal altruism in food exchange and perhaps other behavioral arenas (see Blurton Jones 1987: 33–34, 38). In the rather Hobbesian world of tolerated theft, an equilibrium of self-interest generates the reallocation that avoids costly or injurious squabbles over resources.

In a group engaged in regular transfers of food through tolerated theft, individuals may find it advantageous not only to be thieves but cheats as well. Scroungers might regularly seize the benefits but avoid the costs of securing tolerated theft packets. Blurton Jones analyzes this situation by noting that active (hominid, or human) foragers will occasionally miss opportunities to benefit from tolerated theft because they are away from camp, whereas a full-time scrounger is always present to secure a portion. If distributions flow equally to those present and portions are not saved for those absent, a scrounger's average share always will be greater than that of active contributors. Although everyone does better with greater numbers of foragers relative to scroungers, the equilibrium reached among self-interested individuals will be a mix of scroungers and foragers (or a group of individuals each mixing the two strategies).

Through repeated simulations using different group sizes and penalties for active foragers, Blurton Jones reaches these conclusions about such cheating: (1) Scroungers stand to benefit if they can convince other scroungers to become

foragers, thus "Even in this possibly primeval context, the gift of prestige to the active forager would be a self-serving deceit by the scrounger" (1987: 45); (2) "full-time scrounging is more likely to occur in larger groups and it is very unlikely indeed to occur in small groups" (1987: 45); (3) the self-interested decisions of active hunters to become scroungers strongly reduce the average harvest rate of a group, creating "a mechanism by which individuals maximizing their selfish interests come to under-produce" (1987: 47; see also Vickery et al. 1991: 856; Winterhalder 1993); and (4) the model predicts that particularly good hunters will have little incentive to leave or avoid groups with scroungers because offenders can follow, and "although good hunters will not receive the advantage that may appear due to them . . . an equal share of their own greater returns will be greater than an equal share of a poor hunter's lesser returns" (1987: 47). Scrounging recently has received extensive analysis within a game-theory framework (Caraco and Giraldeau, 1991; Giraldeau, Hogan, and Clinchy 1990; Vickery et al. 1991; see below), confirming in some cases and adding considerable detail to Blurton Jones's conclusions.

Kaplan and Hill (1985) provide the clearest ethnographic test of the tolerated theft hypothesis. The amount of each Aché resource distributed through exchange networks was regressed on packet size and on acquisition asynchrony (measured as the standard deviation of daily acquisition for the resource). Consistent with the tolerated theft prediction, both relationships are highly significant in predicting variability in sharing patterns: Larger packets, asynchronously acquired, are more often shared. However, Kaplan and Hill reject the tolerated theft hypothesis. They note that food often is saved for individuals absent at its distribution and consumption, and that distribution does not appear to correlate with differences in the presumed ability of men to defend larger shares. In effect, food distribution appears not to be a contest. Most importantly,

hunters eat from their own kills significantly less than other individuals. . . . According to [the tolerated theft] hypothesis . . . they should never give up so much food that its value is greater to them than it is to the thieves. However, this is exactly what occurs when hunters eat less from their own kills than other band members (pp. 230–231).

Unequal distribution—the hunter's lesser share—appears to rule out the tolerated theft hypothesis for the Aché; the Blurton Jones model cannot fully explain the pattern of sharing that occurs in this group. This is not necessarily a surprise, as the original model emphasized its possible importance in the origins of food sharing, not its potential for explanation of the well-developed practice of reciprocity that is observed ethnographically (Smith 1992: 53).

A MARGINAL EXCHANGE MODEL

Although discussions of exchange often assume that diminishing marginal value is associated with food packets of increasing size, there has been little explicit use of marginal analysis. I begin with a simple graphical model that entails the logic of tolerated theft, progressively adding considerations to increase realism. I then briefly extend the analysis to reciprocity.

RESULTS

The Base Model, One Resource

We start with two foragers. Occasionally one or the other happens upon and harvests their one resource. This resource occurs in packets that by their size encourage tolerated theft. Because such opportunities are rare and unpredictable, they are nearly always asynchronous. The two individuals then run into one another or meet at a temporary camp or home base. Marginal value diminishes with resource holdings, and we expect tolerated theft to generate transfers.

This situation is depicted in Figure 1A. G designates the forager who gives; T the one who takes. Other notational conventions are as follows: Q_T and V_T , the quantity and value of resource(s) held by the taker; Q_G and V_G , the quantity and value of resources held by the giver; Q_p and V_p , the size and value of the tolerated theft packet; Q_e and V_e , the quantity and value of resources held at equilibrium (after a tolerated theft transfer); Q_s and V_s , the quantity and value at the point of individual satiation. Note that $Q_{G(p)}$ assigns G the quantity of a packet.

FIGURE 1. Marginal analysis of transfer equilibria and value outcomes for a giver (G), who holds a large packet resource, and one or more takers (T): A) the base model; B) the taker has pre-existing resources (Q_T); C) both the giver and taker have pre-existing resources (Q_G and Q_T , respectively); and D) there is more than one taker ($n = 3$). See text for a full explanation.

When they meet, T has no food ($Q_T = 0$) and zero value ($V_T = 0$), but G pursued and has captured a resource packet [$Q_{G(p)}$] with value [$V_{G(p)}$]. Marginal units of the packet are more valuable to T than G. We can envision tolerated theft as a reallocation in which T acquires one portion of the packet for each that G cedes. The first portion transferred leaves a residual value imbalance (marginal portions remain more valuable to T than to G) as does the second through fifth. At Q_e transfers stabilize. With their marginal values equalized, the incentive for T to take is precisely balanced by that of G to resist giving.

We can make several observations about the tolerated theft equilibrium. G and T end with the same amount of food (Q_e). The packet has been equally divided [$Q_e = Q_p/2$]. The overall value loss suffered by G ($V_G - V_e$) is less than the gain to T ($V_e - V_T$). The *summed* value for the two individuals after tolerated theft ($2V_e$) is greater than before the transfer ($V_G + V_T$). This result occurs because for any decelerating (concave downward) curve the tangent at Q_e on the arc will always be above the intersection of Q_e with the chord [thus $V_e > ((V_G + V_T)/2) V_T/2$ or $2V_e > (V_G + V_T)$ or $V_e > (V_G + V_T)/2$]. The equilibrium at which marginal transfers cease leaves the participants with equal resources and equal allocations of the packet, but T gains considerably greater value than G relinquishes. By definition each portion given is one taken, and portions change possession only so long as they are of greater value to T than to G. The transfer itself enhances the value of the resource.

Summary. In the simplest, single-resource case, a tolerated theft equilibrium leaves participants with equal resource holdings but unequal gains and losses of resource value. As a result of a transfer, the giver cedes less (and perhaps much less) total resource value than the taker acquires. The transfer itself enhances the aggregate value to be derived from the resource. Repeated instances of tolerated theft with role reversal of givers and takers generate the value enhancement that is among the conditions for the evolution of reciprocal altruism.

Two Individuals, Multiple Resources

Even by the standards of highly simplified heuristic models, Figure 1A does not represent a plausible circumstance for foragers. The same conditions that make a packet subject to transfer through tolerated theft – rare, unpredictable, and asynchronous encounters – make it unlikely that a forager could rely solely on such a food resource. There must also be harvest of more reliable and regularly encountered items, presumably those occurring in smaller packets or with lower variance in procurement rates.

To add realism, I assume general *encounter-contingent* foraging multiple resources. This is the pattern of the classic diet breadth model, verified for a variety of human groups (see Alvard 1994; Kaplan and Hill 1992; Smith 1991; Winterhalder 1983) and non-human species investigated by evolutionary ecologists (Stephens and Krebs 1986). Included in the hypothetical diet is a variety of smaller, regularly encountered items and one tolerated theft packet that is larger and rarely and unpredictably encountered.

Assume that when the transfer occurs T already has acquired some small packet resources (Q_T) with value (V_T) (Figure 1B). G, however, has been preoccupied with pursuit and capture of a tolerated theft packet [$Q_{G(p)}$] with value [$V_{G(p)}$] and has no additional resources. In the transfer, T acquires one portion of the tolerated theft packet to add to its pre-existing catch (Q_T) for each that G cedes. At the marginal equilibrium, G and T hold the same amount of food [$(Q_{G(p)} + Q_T)/2 = Q_e$] but the packet (Q_p) has been unequally divided. T receives a share equal to $(Q_e - Q_T)$; G retains the larger portion, Q_e . T's overall gain in value is greater than G's loss.

Figure 1C depicts the case for which $Q_G > Q_T$ in non-packet resources, that is, the forager garnering the tolerated theft packet already has somewhat more resources than the one who takes portions of it. Again the distribution of the packet is unequal, but in this case G retains a smaller share than is obtained by T. Despite giving up a disproportionate quantity of the packet, G loses less value than T gains. At the transfer equilibrium, a forager may consume less of his or her tolerated theft packet than the individual who acquires portions.

Summary. The distribution of a packet through tolerated theft will vary as a function of the other resources (including endogenous reserves) held by the parties to the transfer. If giver and taker meet already in possession of modest but dissimilar quantities of non-packet resources (or afflicted by differing levels of hunger), then a tolerated theft packet will be unequally divided among them. If T has the non-packet resource advantage, then G will relinquish less than half of the packet (Figure 1B); if G has that advantage, he or she will relinquish more than half of the packet (Figure 1C). Only if initial holdings and reserves are precisely the same will the resource packet be equally allocated (see Figure 1A). Equal packet division is not necessarily entailed in the concept of tolerated theft and is unlikely in realistic conditions.

N Individuals, Multiple Resources

Figure 1D shows how the analysis can accommodate more than two individuals ($n = 4$ is depicted). G has only a tolerated theft packet [$Q_{G(p)}$]; the three remaining individuals each have (Q_T) non-packet resources. Tolerated theft occurs in three-portion units, one portion going to each of the three takers until equilibrium is reached at Q_e . G has relinquished more than half of the tolerated theft packet but retains twice as much as any one of the takers has received. G has suffered a value loss ($V_{G(p)} - V_e$) greater than the gain ($V_e - V_T$) to any individual T, but less than the gain to all Ts taken together [$3(V_e - V_T)$]. Thus, under tolerated theft a forager may cede greater value to a group of takers than he or she retains.

The value enhancement summed over the group as a whole will be greater than in the $n = 2$ case (Figure 1B). With each increase in n , more of the low-value portions relinquished by G concentrate on the highest marginal value increments to be gained by a T.

FIGURE 2. Marginal analysis of the situation in which transfer is indeterminate because the large packet resource saturates the utilities of the parties. See text for a full explanation.

Summary. Equilibrium allocation of a tolerated theft packet is a function of group size. As participants grow in numbers, G is forced to cede a larger proportion of the resource and its value. For this reason, we might expect that he or she will try to limit exposure to multiple claimants. Value enhancement increases with the size of the group.

Marginal Satiation

So far I have considered implications occurring only on the ascending segment of the value curve. Food, however, has special properties in the economy of foragers that may affect the form of this curve and the relation of the asymptote to equilibrium transfers. For nutritional health, food must be available in regular, short-

FIGURE 3. Marginal analysis of the situation in which the giver (G) exchanges food for not-in-kind utilities. See text for a full explanation.

term doses; a fairly narrow range of quantity represents the difference between adequate consumption and surfeit; variability in short-term acquisition rates may be large relative to consumption limits; and, food has value that can be consumed only once and if not consumed may quickly perish. There may be relatively few options for the individual to preserve, store, or convert any surplus food. These observations yield a value curve that is initially quite steep and may rather abruptly approach an asymptote at a level of resource holdings well below the quantity generated by the rare tolerated theft packet. Long-term survival suggests that most of the time members of a foraging group will acquire the small quantities that ensure adequate levels of food value (V_T).

Consider the resource transfer situation depicted in Figure 2. In this case, T will acquire only up to the point of value saturation (V_s), a quantity which G can cede without any loss of value. Transfers will stop at Q_s , leaving portions of the packet that neither T nor G has incentive to take or defend. Not only is distribution partly indeterminate, but in a strict sense there has been no tolerated theft because there is no cost to the finder. Two hominids can eat only so much spoiling wildebeest before it is apparent that the glut has made a contest over the balance superfluous. Of course, the likelihood of such a surplus and indeterminate transfer diminishes as group size increases.

As an example, a common raven that chances upon a largely intact moose carcass (Heinrich and Marzluff 1995: 342) may well experience value saturation. The raven making the discovery may suffer little or no cost in marginal value by attracting conspecifics to such a windfall, which most likely will soon be consumed by another species of predator or scavenger. It does however gain a survival advantage as such opportunities are shared through information exchange at communal roosts. If sharing of an abundant resource is costless for the finder in terms of marginal fitness or utility, then it does not represent an instance of tolerated theft (see above) or reciprocal altruism (Wilkinson 1987).

Summary. In the case of quite large packets and small groups, it is possible that a tolerated theft equilibrium constrains but does not specify a unique outcome to resource transfers. If the producer of the resource sates the value it can derive from the resource, then sharing the balance cannot be considered altruistic because it entails no cost.

Unbalanced Transfer

So far we have analyzed cases in which individuals switch between the roles of G and T in a series of symmetrical, in-kind transfers. Over the long-term, each procures tolerated theft packets in proportion to his or her frequency in the group, and all harvest the same average amount of non-packet resources. The quantities transferred and individual values gained or lost balance across group members. But it is possible that one individual is a more competent or more dedicated forager, disproportionately a G. Others may be slackers, or they may be less competent foragers or specialized in other tasks than the food quest. The respective

positions of G and T in Figures 1A–D and 2 may represent relatively permanent imbalances among individuals in a group.

Consider Figure 1B and the situation in which G cedes portions of tolerated theft packets more frequently than he or she has opportunity to claim them. Perhaps G is a better-than-average forager. Will G find it in his or her self-interest to leave the group (or otherwise avoid contact with other foragers) in order to avoid transfers unbalanced by quantity? Not necessarily. Even if suffering differential losses to tolerated theft, G may be better off in a group engaged in the practice than he or she would be alone. As a giver, a forager cedes a small marginal amount of value; as a taker — even a relatively infrequent taker — he or she stands to gain large marginal amounts of value. G will stay so long as the frequency-adjusted benefits and losses amount to a net gain greater than that which can be realized by leaving.

Summary. An individual may well find it advantageous to remain engaged in tolerated theft transfers even if it means fewer gains than losses. It is not necessary that there be balance in the quantity or value of the transferred resources.

Reciprocity and Exchange

Tolerated theft is initiated by simple, individual-level selection. Recurrent instances of tolerated theft in a small group generate an environment conducive to the concurrent evolution of exchange through the mechanism of reciprocal altruism. The latter is facilitated by the large value enhancement attendant on food transfer. In this new circumstance, foragers would have the opportunity of realizing exchange value (in kind, not in kind, immediate, or delayed) from any excess of food resources. Marginal analysis like that introduced above is equally suited to the analysis of reciprocity and exchange, with appropriate attention to the different circumstance.

Consider Figure 3. T regularly harvests small quantities of resources (Q_T), but G returns to camp with much greater amounts of food (Q_G), which may or may not include large packet items. We assume that G's extra holdings are sufficiently protected that G can seek advantage through not-in-kind exchange with T. The maximum value that T will assign a portion is the marginal value he or she stands to gain by possessing it. Likewise, G will exchange the quantity that maximizes his or her summed use and exchange value. To represent transfer of the first portion, we add the exchange value gained by T to G's marginal value curve (Figure 3) at the point ($Q_G - 1$). Second and subsequent portions are represented by stacking the summed gain by T onto the marginal curve for G at the appropriate point. G can maximize his or her total benefit by exchanging three portions.

This solution has a useful property. The maximum value that a resource holder can achieve through a not-in-kind exchange falls at the same point as the equilibrium for tolerated theft. The maximum added value in material goods

or debts of reciprocity that G can extract from the exchange is simply ($V_e - V_T$), identified earlier as representing the value T acquires from one episode of tolerated theft. We can dispense with calculating the exchange value “hump” of Figure 3 and, with appropriate attention to the difference in conditions, use Figures 1A–D and 2 to evaluate G’s possibilities for enhancing value through not-in-kind exchanges. For instance, the quantity of resources exchanged will depend on other resource holdings of the recipients (compare Figures 1A through 1C). G will exchange preferentially with individuals holding the fewest in-kind resources, as they should be willing to offer the greatest return of delayed or not-in-kind value. Other things being equal, the greater the number of individuals receiving portions, the greater the potential not-in-kind value that G can extract from the exchange (Figure 1D). G will seek to distribute portions widely through the group. If most individuals in the group have adequate food supplies (high V_T relative to V_s , Figure 2), even large food holdings by G will have little potential for extracting not-in-kind exchange value.

Summary. If it generates debts of reciprocity, the widest possible sharing or exchange within a social group may offer the greatest advantage to the self-interested giver. Wide distribution does not necessarily imply an ethic of selfless generosity as is sometimes concluded. Similarly, the advantages to wide distribution within a social group may override those of sharing preferentially only with kin in that group. This may account for the weak correlation observed between sharing and relatedness (i.e., Kaplan and Hill 1985). These observations also give us a testable difference between tolerated theft and reciprocity, which have been difficult to separate because they make overlapping predictions (i.e., Blurton Jones 1987: 50–51). Where the transfers result from tolerated theft, an individual may attempt to limit distribution by avoiding encounters in which portions of a resource are contested. In contrast, where reciprocity is a possibility, an individual may seek to broaden distribution among reciprocators so as to generate the greatest aggregate obligation of value.

ANALYTICAL ISSUES

Marginal analysis leads to several more general observations on the qualities and procurement of tolerated theft packets, and the testing of hypotheses about the origins of exchange.

How Large Is a Tolerated Theft Packet?

What are the qualities of a resource that make it a tolerated theft packet? The literature mentions large size and sudden (over)abundance for the individual, diminishing marginal returns, divisibility, and susceptibility to being taken. There must be unequal possession sufficient to entail a contest. But, how large is large

enough? And, does the method of procurement make a difference? Is a sizeable tree laden with ripe fruit as fitting as the wildebeest? Is the gazelle carcass chanced upon by a group of scavenging hominids a tolerated theft packet in the same sense as one slain by a lone hunter from among their ranks?

A tolerated theft packet can be any resource fully the object of a contest. The tolerated theft model requires an opposition of interests; both G and T must stand to lose or gain value from the portion being contested. This requires that possession be defined as the holding (and potential withholding) of value. Packets large in absolute size, however, may not fit this definition if they saturate the nutritional needs of those assembled. A tolerated theft packet must be large enough to be attractive to supplicants but small enough that the last portion transferred does not sate all present (Figure 2). If portions removed by takers leave undiminished the maximum value available to the giver, then there has been no theft of the evolutionary currency that matters. For hominids, ravens, or any other creature whose largest resource finds might temporarily exceed the requirements of those present, tolerated theft requires packets of *intermediate* size.

Likewise, we should not expect quite small food packets to be the object of tolerated theft. First, they may be eaten immediately and thus be unavailable when the forager encounters a conspecific. In fact, hand-to-mouth consumption may be advantageous to the individual in part because it forestalls transfers through tolerated theft. Second, because small packets are more regularly and continuously encountered, individuals who do accumulate and carry them to a camp or another rendezvous are more likely to return from foraging with comparable amounts. A forager can avoid and would have no incentive to allocate effort in order to accumulate an unusually large holding in small items (just as, correspondingly, he or she cannot avoid the surfeit entailed in the rare encounter with a large item worth harvesting). Finally, it is possible that the marginal value curve is concave upward for a short interval from the origin. Between the morsel too small to make a difference and the meal adequate to stave off disaster, there may be a limited range of *increasing* marginal returns to food quantity. In such a situation the holder of a small packet has the marginal advantage, preventing transfer to any individual who has less.

Priority of discovery or differential effort in the acquisition of a resource packet is what distinguishes givers from takers, and what justifies the very limited sense in which possession can be distinguished in this context. This suggests that a group of foragers jointly encountering a fruit tree or a partially scavenged wildebeest carcass does not generate the conditions for tolerated theft; neither does food consumed by the individuals equally involved in its cooperative foraging.

Summary. A resource is most likely to act as a tolerated theft packet if it is intermediate in size, divisible, characterized by diminishing marginal value, and procured initially by fewer individuals than consume or use it. Packet size is especially significant. It bears importantly on use of the model to identify the antecedents of tolerated theft in hominid prehistory, and to assess whether group consumption entails any cost to the individual who locates the packet.

Why Bother to Harvest Tolerated Theft Packets?

If its value is markedly diminished by tolerated theft, in what circumstances would a forager find it worthwhile to harvest a tolerated theft packet? We can look to encounter-contingent foraging theory (Stephens and Krebs 1986) for an answer.

The optimal forager takes a set of resource types that depends on their relative abundance (encounter rates) and their ranking, or net value per unit time for pursuit and handling. Rank typically is calculated using the *absolute* size of the resource (taken to be its value and usually measured in kcals for the edible portion). But the value that matters is the *realized* value of the resource to the individual procuring it. If the item is perishable before being fully consumed or if subject to tolerated theft, its realized value is diminished correspondingly and its ranking may be much lower than absolute size would suggest.

Three possibilities arise from this distinction: (1) A resource may, because of high absolute value and low pursuit and handling cost, remain in the optimal diet even if subject to tolerated theft. Despite uncompensated transfers, its realized value is great enough that it will always be optimal for the forager to pursue on encounter. (2) However, if the reduction in value due to tolerated theft is great enough, perhaps because of larger numbers of participants in tolerated theft (Figure 1D) or because the initial ranking of the resource is low within the optimal set, then tolerated theft might lower the forager's realized value sufficiently to eliminate the resource from the optimal diet. It will cease to be harvested. (3) It also is possible that a resource will only enter the forager's diet when its realized value to the forager can be enhanced through reciprocal exchange, either immediate or delayed (in-kind or not-in-kind). Despite ability to pursue and capture wildebeest, it may not be worthwhile to do so unless the forager can extract exchange value in addition to realized use value.

Summary. Irrespective of the degree of loss to tolerated theft, the self-interested forager will harvest a tolerated theft packet so long as his or her realized value puts that resource in the optimal, encounter-contingent diet. Tolerated theft, however, may reduce the realized value of a resource sufficiently that it is eliminated from the diet. Because realized value diminishes with increasing group size, foragers in larger groups are less likely to harvest the resource packets that generate tolerated theft. Conversely, reciprocity and exchange may enhance the realized value of a resource and thereby cause it to be added to the diet (an effect that increases with n). In either instance, distribution practices can affect resource choice independent of the ecological variables usually incorporated in foraging models. This makes it important to distinguish between absolute and realized value when constructing rankings of resource types.

Is Balanced Transfer an Empirical Benchmark?

Most anthropological applications of the tolerated theft concept have adopted a standard of balanced transfer, either as the starting point for elaborating hy-

potheses or a benchmark for falsifying them. Blurton Jones's (1987: 43) conclusions about scrounging are predicated on equal division. Kaplan and Hill (1985) presume that if transfer of foodstuffs is imbalanced, then not-in-kind utilities must be flowing opposite to food. Hawkes predicates her rejection of the tolerated theft and risk minimization hypotheses (Winterhalder 1986) on evidence of departure from precisely equal flows: "The economics of defense will lead to even sharing" (Hawkes 1992: 295). It is clear why this standard has been adopted: Equal flow by quantity has seemed theoretically definitive (Figure 1A), and deviations from equal flow provided a readily observable ethnographic measure.

Nonetheless, balanced flows are not necessarily an entailment of tolerated theft under realistic conditions (Figures 1B–1D) nor a requirement of reciprocity. In tolerated theft, the marginal unit transferred between two individuals will have equal value, and the participants will end with equal resource holdings and value (assessed as endogenous reserves plus exogenous supplies). But in reaching this equilibrium state, the packet may have been apportioned by dissimilar shares, and the total value of gains or losses to the participants may be quite unequal. Furthermore, if an ongoing imbalance of transfers is not high (or the frequency of unbalanced transfers is not too great) then an encounter-contingent forager still may find it in his or her interest to procure tolerated theft packets that nonetheless flow disproportionately into redistribution networks (through tolerated theft or exchange). Thus, self-interested hunters may in a variety of circumstances "eat less from their own kills than other band members" (Kaplan and Hill 1985: 231; see above). This will be true whether other band members are considered in the aggregate (hunter's share $< 1/2$) or individually (hunter's share $< 1/n$). Unbalanced flows within an exchange system, even if sustained or indeed permanent, cannot be taken as evidence against tolerated theft, reciprocity or risk-minimization hypotheses. Nor does imbalance alone imply compensating counter-flows of not-in-kind values.

Summary. In order to assess the conformity of resource transfers with hypotheses of tolerated theft or exchange, cost-benefit accounting must encompass concurrent information on (a) the extant resource holdings and needs of the participants and (b) the alternative foraging and transfer opportunities of the givers and takers. The empirical observation that a forager cedes to tolerated theft or reciprocity-based exchange more food than he or she receives is not in itself evidence against either hypothesis.

What Currency?

A partial accounting that ignores the complete array of food resources and foraging opportunities available to a participant in tolerated theft or a reciprocal interaction may be quite misleading. But even if comprehensive, a purely material accounting — measurement by resource quantity — may not reveal the costs and benefits that affect behavioral evolution. This is because the relationship of re-

source quantity to fitness or utility can be strongly non-linear and asymptotic. The forager who has just harvested a large packet may relinquish significant portions of it at little or even no cost in the currency that counts. Conversely, small portions may have great value to the recipients. Two examples from recent literature on information exchange and scrounging will serve to illustrate this point:

(1) Unrelated, same-age females of the greater spear-nosed bat roost in clusters with highly stable membership. Because several common mechanisms for the evolution of long-lasting social groups — kin selection, anti-predator defense, limited roosting sites, male tending, and so forth — can be eliminated in this case, McCracken and Bradbury (1981) suggest that it is cooperative behavior. The greater spear-nosed bat apparently uses central place roosting and low frequency vocalizations to monitor and share information about the location of temporary but unusually rich food sources, such as termite swarms. McCracken and Bradbury (1981: 31) further propose that reciprocity underlies the cooperation. There is debate, however, as to whether or not this behavior represents reciprocal altruism (discussion in Wilkinson 1988: 90–91), which must involve a cost to the donor (Wilkinson 1987). To resolve this issue, it will not be enough to document through field studies that advertising diminishes the quantity or quality of the resource potentially available to the finder. It must also be shown that the depletion affects the marginal fitness the finder can derive from it. Cost-benefit accounting by attention only to quantities of the resource may suggest altruism where it does not exist, or lead to over-estimates of its cost when it is present.

(2) A related instance arises in the analysis of social foraging. Vickery et al. (1991) use a game-theory analysis to model the conditions affecting an equilibrium distribution of foragers, scroungers, and opportunists in a population of social foragers. In their analysis costs and benefits are assessed in terms of resource items gained or lost. There is no allowance for marginal fitness. Thus even in instances in which a finder has an advantage, say by consuming items from a patch before one or more scroungers arrives, rewards and losses are treated in the model as if strictly linear.

A second analysis (Caraco and Giraldeau 1991), which assesses the equilibrium balance among producers and scroungers whose goal is risk minimization, also measures costs and benefits in terms of units of food. In this case elevated producer priority (measured in units of food items) generally diminishes the frequency of scrounging. It thus raises the average rate of food discovery by group members and lessens the chance of starvation by both producers and scroungers. However, it is possible that measurement by marginal fitness effects might lessen or reverse this effect. Producer priority allows the individual discovering the patch to feed at high marginal returns and to cede items to late-arriving scroungers at low marginal cost. Conversely, even though scroungers get fewer items, these few may have a high marginal value. Relative to food-item accounting, marginal appraisal of the fitness effects of scrounging will generate lower producer costs and higher scrounger benefits, perhaps shifting the equilibrium more toward scrounging. Even small differences between the currencies of quantity and

fitness could be important because producer priority dominated other variables in establishing equilibrium numbers of producers and scroungers in this model.

Summary. Evolutionary studies must be sensitive to the possibility that cost accounting in terms of the theoretically important currency — food value — will diverge significantly from observations or measurements that take account only of food quantity. This distinction may have a qualitative impact on the interpretation (Is the behavior altruistic or not?). Or it may, as in the second example, produce quantitative changes in the thresholds at which we should expect strategy shifts between options like producing and scrounging. In either case, overlooking marginal values could lead to mistaken assessments of the fit between observations and hypotheses derived from evolutionary ecology models. Scrounging is tolerated theft by another name and should be subject to the marginal value relationships observed in the models presented here.

CONCLUSION

Using marginal analysis, I show how variation in resource transfer (based in tolerated theft) and exchange (based in reciprocity) can be related to environmental conditions affecting encounter-contingent foraging behavior, to the qualities and marginal values of tolerated theft packets and other resources, and to the food needs and behavior of individuals in groups of various sizes. I thus attempt to advance what Blurton Jones (1987: 35) identified, in one of the original papers on tolerated theft, as the “long and difficult process” of using simplified models to make “assumptions and their significance more explicit.” I leave to others or another time elaborations that might include individual differences in resource holding potential or defense costs, interactions among individuals with dissimilar marginal value curves, or more explicit consideration of evolutionary mechanisms.

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