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Tolerated theft, suggestions about the ecology and evolution of sharing, hoarding and scrounging

Introduction

Sharing food and information about food have been held to be crucial features of human evolution (e.g. Isaac, 1978; Feinman, 1979; Kurland and Beckerman, 1985) and of human societies in general (Mauss, 1925). It is thus worth examining the ecological conditions which would favour such traits. Elucidating the costs and benefits that accrue to individuals from sharing or not sharing food may help us understand both the origins of sharing, and its contemporary variation between individuals, cultures and species.

The theory of food sharing presented here is based on the theory of contests over resources that has been developed in animal behavioural ecology. The concept of "sharing" is turned on its head and examined as "tolerated theft". A brief account of the theory was published previously (Blurton Jones, 1984). The theory begins from two principles:

1. that contests over resources tend to be won by the individual for whom the resource is most valuable;
2. that the curve of value of resource against amount of resource

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held is a diminishing returns curve for food, but may take other shapes for other resources.

I argue that theft will be tolerated when the resources follow a diminishing returns curve of benefit gained from the resource against amount of the resource held, and when the resource is found unpredictably, seldom and in large packages.

The model is particularly relevant to some issues in the hunter-gatherer literature. In this literature it is sometimes claimed that people cannot refuse to share nor avoid scroungers, that they resist accumulating wealth, that disruption and hostility is caused by wealth; some forager populations have leisurely work schedules and many men who do not hunt. Two implications will be discussed at some length. These are:

1. The conditions under which hoarding may become possible in a population of foraging theft tolerators. Testart (1982) and Woodburn (1982) argued that storage or delayed consumption is the basis for a major dichotomy among hunter-gatherer societies. The material conditions favouring hoarding are thus an important key to understanding variation in hunter-gatherer societies and indeed may be a neglected aspect of the study of the origin of agriculture.

2. Implications of the model about the easy work schedule of some foragers, specifically for the mixture of foragers and full-time scroungers that we expect in a group. The low work rates of some forager cultures provide a challenge to all the materialist approaches in anthropology that has yet to be satisfactorily met (Smith, 1987; Hawkes et al., 1985). Suggestions arise from the model about ecological reasons for "the Zen road to affluence" (Sahlins, 1972) that rely only on individual interests and not on long range benefits to the group.

Major theories about the origin and ecology of food sharing have been kin selection (Hamilton, 1964; Feinman, 1979), reciprocal altruism (Trivers, 1971), "tit for tat" (Axelrod and Hamilton, 1981) and variance reduction (Kaplan, 1983).

Several authors have emphasized the variance reduction benefit of sharing: levelling out day to day variation in the food supply, when catches/finds are large but rare (e.g. Woodburn, 1972). Woodburn and earlier authors have also pointed to the negligible cost of giving away portions of the enormous prey taken by some contemporary foragers. The variance hypothesis has been explicitly and systematically modelled by Winterhalder (1985) and data

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presented that demonstrates its effectiveness by Kaplan et al. (1983, 1984, 1985). Kaplan showed that sharing reduced day to day variance in food intake among Ache hunters, and that their pattern of sharing did not fit with expectations from kin selection. Reducing variation in food intake makes considerable intuitive sense and need not be restricted to meat caught rather than found. Obviously it is to the advantage of an individual to receive food from another when he cannot find any. But the evolutionary theorist must ask whether the individual who found the food and refused to share, while continuing to accept food from others, would do better than the others, with selfishness thus spreading through the population. We cannot take for granted the existence of a tendency to reciprocate in the way it is implicit in some early accounts of sharing. We must ask ourselves whether the variance reduction advantage that Woodburn and others describe (and that Kaplan [1983] demonstrated) relies on an existing tendency to reciprocity whose origin we cannot explain.

The theory of sharing presented here in no way denies the effect of sharing on variance of food intake. It attempts to tackle issues of the initial invasion of a population by "sharers". It fails to account for some observations that the variance reduction theory addresses but it directs attention to a wider range of behaviour and readily suggests links between behaviour and circumstances, thus offering to explain variation in sharing and related behaviour.

In the anthropological literature sharing has sometimes been linked to cooperative hunting. Permitting each other a share might be seen as a necessary inducement to combine in the hunt. The advantages of cooperative hunting might seem fairly clear; returns may be greater for all participants (though attempts to demonstrate this suggest that the matter is not so simple, e.g. Boorman and Levitt, 1980; Hill and Hawkes, 1983; Smith, 1981, 1985; but see Sibly, 1983, for reasons why we may expect this to be difficult). If sharing evolved as an inducement for cooperation we would be compelled to regard the origin of food sharing as dependent on hunting rather than scavenging. The model proposed here does not link the origin of sharing to hunting rather than to scavenging. It only links the origin to food that arrives in large packages.

The two other well known mechanisms for the evolution of sharing are kin selection (Hamilton, 1964), and reciprocal altruism (Trivers, 1971; see also Feinman, 1979). Boorman and Levitt (1973) argued that reciprocal altruism was frequency dependent and

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therefore difficult to get started. The possibility of kin selection does not absolve us from thinking about the actual costs and benefits of actual behaviour in real circumstances. Although kin selection is undoubtedly at work in any small, related population, I propose that "tolerated theft" is a simpler explanation for the evolution of food exchange and has the advantage that it draws attention to some ecological factors and thus to the variation of behaviour with circumstances. This model may also explain how exchange could begin and spread to a frequency where reciprocal altruism could take off.

Background to the approach

Behavioural ecologists tend increasingly to regard all species as opportunistic and efficient in adaptation (Krebs and Davies, 1981). Thus ecologists are little concerned about the developmental mechanisms that produce adaptive responses. These mechanisms may be strongly environment resistant genetic effects, or learning, imitation or conscious thought. To the behavioural ecologist those are questions of developmental and proximal causal mechanisms (motivations, in Harris's terminology [1968]) and are irrelevant to the task of assessing the costs and benefits of behaviour and calculating what would be an adaptive response to particular circumstances (long range "causes", in Harris's terminology). Thinking out the costs and benefits of a range of actions under specified circumstances allows us to predict the outcomes of the adaptive decisions of an opportunistic species.

The definition of adaptiveness as maximization of reproductive success has been much treated in the literature. For the purposes of this paper we need to remember that the behavioural ecologist's usage is closer to "selfish interest", and the economist Marshall's "men labor and save chiefly for the sake of their families and not for themselves" (Marshall, 1920, cited by Becker, 1976) than it is to the archaic biologism of "for the good of the species". Indeed in many places in this paper it would be possible to substitute without detriment the word "utility" for the word "fitness". Of course equally important is that thinking in terms of maximization of reproductive success gives us a way to assess the expected balance between differently measured outcomes like calories and injury.

Behavioural ecologists have changed the study of animal

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behaviour from being mostly inductive to being mostly deductive. They aim to derive testable hypotheses from a few first principles. Often the models are intentionally oversimplified at first. This is because great importance is given to trying to set out the assumptions and show how they are manipulated to reach predictions. This can be a long and difficult process. Thus while some of the ideas in this paper can be found already in the anthropological literature they have only very recently been made explicit. One of my aims is thus to try to make the assumptions and arguments more explicit. It is also worth noting that while in this paper some curves of value against amount of resource are given shapes familiar to any economist, their significance for determining the outcome of contests over resources seem not to have been stated explicitly by economists.

This approach adopts the target, not of being able to explain all observations that have already been made but of moving from the fewest possible first principles towards expectations about variation of behaviour with circumstances and thence to predictions about observables that can be tested.

The tolerated theft model of food sharing

Despite Isaac's (1978) deprecating (but very stimulating) comment about chimpanzee sharing as merely "tolerated scrounging" I propose that we turn the idea of sharing on its head and think more about "tolerated theft". It is important to remember that food, unlike other forms of help such as rescue, can be taken by force. But it is equally important to remember that contests over resources can often be resolved without fights and with a minimum of threat and display. The tolerated theft theory of sharing is not a theory of incessant squabbling!

I argue that the assumptions used by Parker (1974) to discuss fighting over resources and their subsequent tests and elaborations (e.g. Maynard-Smith and Parker, 1976; Parker and Rubenstein, 1981; Hammerstein and Parker, 1982) suggest a form of sharing, or tolerated theft, which could spread and remain in a population under particular conditions. According to Parker's "fitness budget" argument (1974), natural selection may be expected to have favoured individuals that fight only for a fitness gain. A fight may gain a fitness-enhancing resource but it may cost time, energy and

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fitness-decreasing injury. The greater the potential fitness benefit from the resource, the greater the costs that can be incurred while still coming out with a net gain in fitness at the end. Thus between otherwise matched contestants one would expect the fitness benefit of the resource to determine the outcome. The one to whose fitness the resource is most valuable should be expected to profit, and usually to win, even if that means bearing greater costs and fighting hardest or longest.

The literature on animal contests seems unanimous that the outcome of a contest will be determined by such an asymmetry in resource value, or, if resource value is equal, by asymmetry in strength and fighting ability (resource holding potential (RHP), Hammerstein and Parker, 1982). There has been relatively little exploration of the outcome when these two asymmetries are in opposite directions or of the way in which we should consider them to interact. For the purposes of this paper we will proceed simply to examine asymmetries in resource value. The model proceeds on the assumption that the contestants are of near enough equal RHP. It seems reasonable to assume that ability to inflict costly injury will be very high in creatures that are able to dismember and perhaps kill sizeable prey and thus that strength and fighting ability (RHP) will be roughly equal in both contestants (i.e. differences in overkill capacity are assumed to be unimportant). It is also important to realize that this animal literature has mostly considered contests in the framework of a "War of Attrition" game, judging this to be the most appropriate for the conditions under which animals contest resources.

In the case of a group of individuals that find food rather seldom but in large packages, a series of asymmetric contests can easily arise. They will arise if the fitness gained from food follows a diminishing returns curve (see below) and if food items are large enough. Consider an individual that acquires a large food item. Because this happens very seldom then most probably other individuals will have found nothing. Recall that food can be broken into pieces. Some portions represent a large fitness gain for the finder (e.g. Y1 on Figure 1B). Other portions represent a much smaller gain (portion 2 represents e.g. Y2 fitness units on Figure 1B). But for a latecomer, who found nothing that day, any one portion of size X that he can get will represent a gain of Y1 fitness units. Thus for a contest over portion 2 we have an asymmetry in resource value. Its value to the finder is only Y2 fitness units, to the

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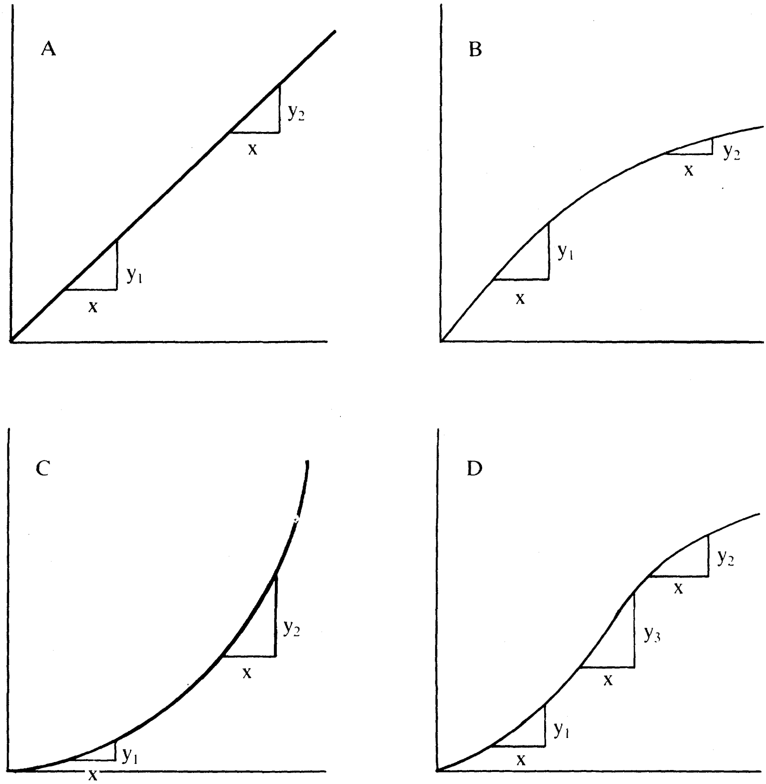
FIGURE 1
Curves of fitness benefit gained from a resource (Y-axis) against amount of resource held (X-axis)



latecomer it is worth more, Y1 fitness units. Thus the latecomer will be expected to win easily in a contest over portion 2. The finder should relinquish this portion without a fight.

For purposes of illustration one can think of this process either in temporal sequence or spatially. One can think of the two contestants positioned at opposite ends of a carcass (vultures may squabble with their neighbours, but what is the chance of defending the whole carcass?), portion 1 being a part near the finder, portion 2 being a part far from the finder. Or one can think of the finder having a headstart at the meal, becoming gradually satiated and then being joined by a hungry latecomer. But these figurative, or motivational,

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versions of the argument could be misleading. The argument does not depend on the end of the carcass being out of reach, nor on the finder having time to fill his belly before a latecomer arrives. And it is important to emphasize that it does not imply endless squabbles. Ability to assess the costs and benefits will be strongly favoured by natural selection (Parker and co-authors cited p. 35), and will be expected to be a well developed ability in many animals.

If we consider the process of tolerated theft continuing among a group of individuals who frequently meet there is another interesting outcome. An individual who is one day a finder will also often be a latecomer on other days. He will steal from the others who previously stole from him. Although all are merely following their selfish cost–benefit equations (fitness budgets) and avoiding costs of injury, the effect is a good deal of reciprocal transfer of resources. The amount occurring will presumably depend largely on the frequency of catches of large prey.

There are two interesting things about this. One is that the day to day variance in food intake will be greatly lowered, just as Kaplan (1983) has argued from other premises and has demonstrated to be the case for Ache foragers. The other is that if large prey is a frequent or relatively abundant part of the diet, the group consists of, in effect, good altruists and reciprocators. Thus, the condition that Boorman and Levitt (1973) argued was necessary for the evolution of reciprocal altruism (Trivers, 1971) is fulfilled: reciprocation is already occurring at a high frequency, just because the contestants do better to avoid injury.

Not only will reciprocation be at high frequency but it will also be hard to avoid. Cheating will be immediately dealt with, because the very condition that gives rise to the "sharing" is the condition that provokes contests and fights. Sharing happens because it avoids a costly fight, refusal to share provides a situation in which it is worthwhile for the latecomer to fight to gain a share, not because the system needs safeguards against cheaters but just because that is the condition under which attack offers a net gain.

A further interesting point is that the basic propositions about the contest imply that the "shares" be almost equal. The implication is not that they be exactly equal in amount of food but that the shares endow equal fitness value to the contestants, perhaps offset to the extent of differences in strength or fighting ability. There is, of course, no guarantee that the shares be adequate. This equality is predicted, not necessarily by endowing the individuals with a sense

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of fairness but by assuming each to be maximizing its fitness budget. Nor is there any implication that such selfish maximization must have an equable outcome under every circumstance. We will briefly discuss some such other circumstances (curves that are not diminishing returns curves) later in the paper.

Many hunter-gatherer societies have complex rules about sharing food. Yet this model predicts very even sharing of food. Despite the existence of many rules of sharing, it appears that equal sharing is the eventual consequence of these rules in most hunter-gatherer cultures (according to the literature review by Hayden, 1981). However, the only direct observation, quantified study of sharing in hunter-gatherer society is that by Kaplan (1983; Kaplan and Hill, 1985). Kaplan's study shows that the individual who catches an animal keeps less of the animal than was expected. Kaplan shows that successful hunters receive better treatment from others in many respects and he favours a trade or exchange theory of sharing.

It remains for me to argue that food can be a resource that follows a diminishing returns curve of fitness against amount. The concept of a dietary requirement is in essence an extreme form of a diminishing returns curve. We could set the model in the context of an individual attempting to fill his daily dietary requirement. A sizeable prey item would take it well beyond the requirement, many portions of the prey would be of no fitness benefit and would therefore not be worth defending. But daily dietary requirements may be neither realistic nor strictly relevant to such a model, especially for a creature that can provision mates and offspring. If we are concerned with fitness it is relevant that more offspring are likely to survive if well fed than if adequately fed, more offspring can be raised if more food is available for them. Fitness benefits of food therefore increase beyond an individual's "daily requirement". In addition, nutritionists seem unable (perhaps ultimately for this very reason) to agree on precise daily requirements (e.g. Durnin et al., 1973). However, it is very likely that fitness returns for food none the less follow a diminishing returns curve. At any one moment there is only a finite number of offspring to be fed, only so much increased probability of their mother becoming profitably pregnant and so on. If there *are* diminishing returns our propositions will hold. Only if the line is straight or concave will this condition for tolerated theft not be met.

Another important component of my argument is the size of the items of food. I took the example of large items, found unpre-

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dictably and seldom, and therefore on different occasions by different individuals. Let us consider the case where all the individuals are on average about equally satiated, i.e. they are all at about the same point on the X-axis of my graphs. Then a large item of food will have the effects described. There will be large differences in the value of portions of that item to the finder and to a latecomer. If the finder kept all the food he would move well up the X-axis and along the diminishing returns portion of the curve. But if food comes in small packages the finder who keeps the item will not move much further up the X-axis than the latecomer. The very small asymmetry that would result from keeping all of this small item may be negligible, and frequently overwhelmed by small differences in strength or fighting ability. Thus we might not expect theft of small items to be so often tolerated. We should expect more even contests, or more contests settled by individual differences in strength or fighting ability.

The argument about tolerated theft is simple and adds only the individual selection argument of avoidance of injury to the traditional anthropological view of sharing meat, but it seems to be both somewhat counter-intuitive and very productive. Several common-sense objections are often raised which, although the theory deals with them easily, raise other stimulating issues. Three interesting objections are as follows:

1. Storage and hoarding. The model may be fine for a situation where the food rots quickly and there is no technology for preserving the food. But once the technology was available surely an individual that kept and stored more of his find would do better. And if not, under what conditions would we expect hoarding to pay?

2. Scrounging. Would not the tolerated theft situation simply lead to all individuals becoming thieves and the gains from foraging getting so low that individuals all stopped foraging and became full-time scroungers?

3. Different resources and different curves. Food may follow a diminishing returns curve but what about resources that might give increasing returns, or straight line or sigmoid curves?

Storage and hoarding

If an individual could preserve food would it pay to defend more food so that it would have food for the next day?

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Under the conditions of the model there will still be an asymmetry in resource value on the second day. The value of the resource will increase by virtue of storage, but it will increase even more for the now starving latecomers. Only when the gains to contestants become nearly equal, for instance if the curve nears a straight line, will the condition for tolerated theft disappear. Thus knowledge of storage or preservation techniques seems unlikely to be the critical factor determining whether food is stored.

In animals storage of food is most often found in species which defend a territory during the season when food is stored. So what are the conditions under which hoarding is to be expected in a species that does not defend a territory? First, it seems clear that hoarding can begin under conditions of synchronized catches. If individuals make catches on the same day as each other then the conditions for theft disappear. We no longer have the situation in which one individual has an enormous package of food and another individual has none, which makes the enormous package not defendable. Each individual will be left with the beginning of a hoard and in a population of equally well endowed individuals. Supposing that they use up their hoards at about the same rate then conditions for theft still do not arise. Thus one obvious context in which hoarding meat can begin and will be expected is under conditions of a seasonal glut.

A second condition which would favour accumulation of resources, and yet allow them to be defendable, is when the curve of fitness value of the resource against amount of resource held follows an increasing returns curve (Figure 1C). In this case, an individual that has more of the resource will gain more from adding a unit of resource than will an individual that has less. It is possible that at some levels land and livestock perform this way but the only obvious example would seem to be financial capital.

Common sense, and the ethnographic record, suggest that hoarding pays when there is a season of scarcity such as a cold and snowbound winter. It is clear that the effect of such a seasonal scarcity on my model is to steepen and straighten the curve of fitness returns for food. But it is not clear whether this is a sufficient condition to make it profitable to defend the hoard. If other individuals do not have a hoard then the hoarders' hoard will be as valuable or more valuable to them and theft will be expected. In practice many of the environments with severe winters also have seasonal gluts such as a salmon run, caribou migration or pinyon nut

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season. Careful analysis of a large number of ethnographic cases might allow this issue to be resolved.

While predictions about hoarding meat may fit well with the hunter-gatherers of the Pacific north-west and Anaktuvuk Pass, I have no predictions about hoarding plant foods. I cannot say why the Shoshone should hoard whereas the !Kung (assuming the end of the !Kung dry season to be a season of scarcity) should not hoard. Further refinement of the hoarding model is obviously desirable.

There are several interesting anthropological implications about sharing and hoarding from the tolerated theft model. The difficulty of escaping the necessity of sharing and thus the difficulty of beginning to hoard and store food in a population of food-exchangers (forager thieves) is familiar in the field. It is commonly reported that accumulation of wealth (e.g. cattle, money, stored food) is resisted by hunter-gatherers becoming settled. Explanations have ranged from a tradition of fecklessness to the ease and reliability of foraging. The tolerated theft model emphasizes the potential for violence that arises from a minority of individuals beginning to accumulate wealth, a proposition remarked on and implied but not emphasized in the hunter-gatherer literature (e.g. Lee, 1969).

The model does imply that hoarding is not dependent on knowledge of techniques of food preservation. This is consonant with the ethnographic data. !Kung know how to dry and preserve meat but they often do not do this. Indeed my model might predict that they are more likely to preserve meat in the wet season (when in small groups and despite greater abundance in that season) than in the larger dry season groups, when any prey species will be shared, leaving little that cannot be quickly eaten up. Of course in the unlikely event that two or more large catches were made on one day, one might see meat being dried in a dry season camp.

Another form of sharply synchronized glut (besides a salmon run or a confined and intense ungulate migration) is an agricultural harvest (so long as many people planted a crop). It should be easy for agriculturalists to hoard their harvest (unless their crops yield asynchronously) so long as all of the population are farmers. A harvest from agricultural crops can be regarded as a synchronized "catch" and would clearly be defendable. But the model may predict that non-synchronized crops (not non-seasonal) might be hard to defend and worth raiding. This should provide easily falsifiable predictions. One such prediction might be that nowhere in

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simple societies do individuals plant briefly high-yielding crops at different times of year from their neighbours.

Moore (1984, and pers. comm.) pointed out that one implication of compulsory food sharing is that it will be extremely difficult for theft tolerating foragers to begin to farm. An individual who begins to farm in a population of theft-tolerant thieves will lose his harvest. The model would suggest that farming and hoarding can only begin if tolerated theft conditions have disappeared (unless the remaining share of the harvest is more valuable to the first individual who plants a crop than are the gains of foraging). Agriculture might begin in a society that already hoards much more easily than it would begin in a theft tolerant society. High dependence on a synchronized, seasonal plant food (which does not present the conditions for tolerated theft) might be one such context. A harvest that coincides with some other synchronous glut might also be defendable. But a culture that no longer catches large prey might have also lost the context for tolerated theft. These theoretical issues should be explored at greater length and more rigorously before attempting to match them to the ethnographic or archaeological data.

Scrounging

Will some individuals give up hunting and be pure scroungers? Models have been devised to account for the mix of foragers and scroungers in animal groups (e.g. Barnard and Sibly, 1981; Barnard, 1984). These contrast pure foragers and pure scroungers but the present discussion is concerned with pure scroungers and forager-scroungers.

The tolerated theft model implies that food will be shared roughly equally. If we take this conclusion as our starting point a number of arguments can be made about scrounging. If an active forager sometimes misses the opportunity to scrounge a share from other foragers, then full-time scrounging becomes a more attractive proposition and an interesting mixed strategy can easily result. An example of such a situation is as follows. It is, like all models, rather simplified; real life may combine features of several possible models.

To begin with let us suppose that:

1. Each active forager misses the chance to take a share of the

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catches of 25% of the other active foragers. Perhaps the forager is still out foraging when those 25% come home with their catches.

2. Full-time scroungers have the chance to take a share of 100% of the catches.

3. Any catch must be shared equally among all those present (other models of sharing might predict a different distribution).

4. A missed opportunity to join a share-out cannot be compensated by scrounging smaller portions from the recipients of the original shares (an assumption that follows from the tolerated theft model since they are unlikely after a share-out to have such large amounts that the entire package is not worth defending).

Since foragers miss some of the share-outs, e.g. each forager is only there for 75%, we reduce the amount of food that they join in sharing in proportion to this. Each forager gets 75% of the total catch, divided among the number of people who are in camp when the average forager is in camp (all the scroungers, plus the 75% of foragers who are already at home).

The share that a scrounger gets is the total catch divided among: all the scroungers plus the 75% of foragers who are present at each share-out.

These calculations are presented in Table 1, for a group of ten individuals, using estimates of hunters' returns within the range reported by Lee (1979). It can be seen from Table 1 that under these conditions foragers always do worse than scroungers. We can also

TABLE 1

Returns for foraging and scrounging when foragers miss 25% of opportunities for theft, in a group of ten individuals (total catch is based on returns of 2000g of food per forager day)

Scroungers (n)	*Foragers (n)*	*Total catch*	*Each scrounger's share*	*Each forager's share*
9	1	2000	205.1	153.8
8	2	4000	421.0	315.7
7	3	6000	648.6	486.5
6	4	8000	888.9	666.7
5	5	10,000	1142.8	857.1
4	6	12,000	1411.7	1058.8
3	7	14,000	1696.9	1272.7
2	8	16,000	2000.0	1500.0
1	9	18,000	2322.6	1741.9
0	10	20,000	—	2000.0

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see that the bigger the proportion of foragers there is in the group, the better everyone does. But if we consider the outcome for an individual deciding whether to become a forager (and as a result change the composition of the group), we see that only at a quite low frequency of foragers is there a gain for a scrounger in becoming a forager (row 3 to row 4). At high frequencies of foragers we see that there is a gain for a forager in becoming a scrounger (row 5 to row 4). Consequently there is an equilibrium mixture of forager-thieves and full-time scroungers.

We can also see from Table 1 that the gains from remaining one of a reduced number of scroungers are much greater than the gains from switching to foraging. Thus there is great advantage in persuading another individual to become a forager, much more than there is advantage for that other individual. Even in this possibly primaeval context, the gift of prestige to the active forager would be a self-serving deceit by the scrounger. The model describes a mixed strategy, with an equilibrium point above which it pays a forager-thief to become a pure scrounger, and below which it pays a pure scrounger to become a forager-thief, but would pay him even better to *remain a scrounger while persuading another individual to resume foraging*. We thus have the prospect of defining a situation in which there is strong selection pressure for persuasion. At low frequencies of foragers there is an advantage in being persuaded but at all frequencies there is more advantage in joining the persuaders.

The calculations were repeated for differently sized groups of individuals and for different proportions of missed opportunities to join in a share-out. The results of these calculations are shown in Figure 2. The equilibrium point occurs at different proportions of foragers and scroungers depending upon the size of the group and the proportion of share-outs missed by the forager. These repeated calculations show that in largish groups full-time scrounging begins to pay even when there are very small losses of opportunity to join in a share-out. But in small groups (five or fewer foragers) it only pays to become a scrounger in the very unlikely event that nearly half the share-outs are missed by foragers. Thus this model of scrounging predicts that full-time scrounging is more likely to occur in larger groups and it is very unlikely indeed to occur in small groups.

The tolerated theft model thus can imply that some individuals will give up foraging. To this extent it could explain the low "productivity" of forager cultures. How many give up and become

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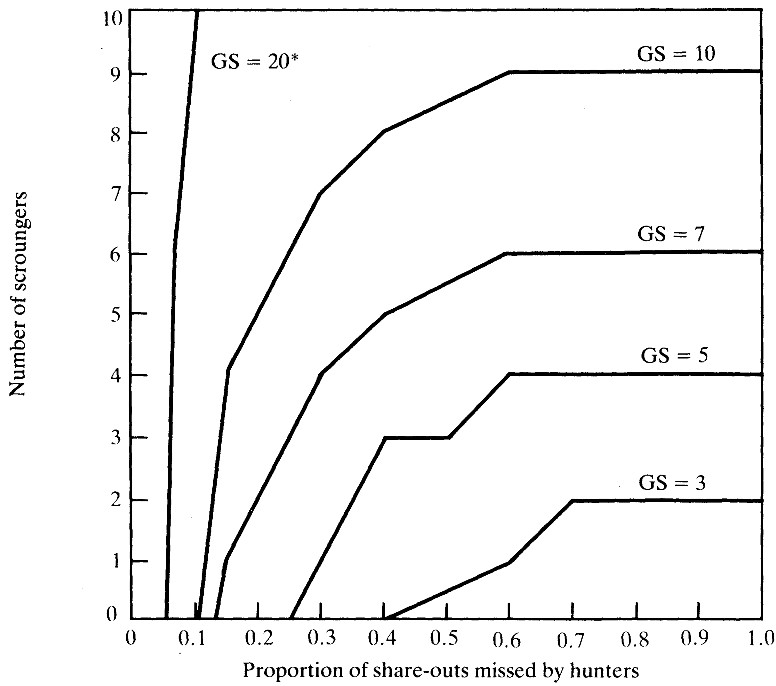
FIGURE 2
Results of repeated calculation of scrounger model



* GS = group size. In a large group, even missing quite a small proportion of share-outs leads to many individuals becoming full-time scroungers. In small groups all forage unless a very high proportion of share-outs is missed. For a group of ten individuals, when 0.15 (15%) of share-outs are missed, four individuals will be scroungers. When 0.3 (30%) of share-outs are missed then seven will be scroungers.

full-time scroungers will depend on size of group and on other costs of foraging, such as missing share-outs, risks of being in the bush, reproductive costs of leaving wife and offspring unattended, etc. The same arguments should apply to individual mixed strategies, in which individuals forage more or less often according to these same considerations. It could be that individuals are able to assess the probable pay-offs each morning, in accordance with the number of individuals who have gone hunting or who say they are going and decide whether to go hunting or to stay in camp.

One may wonder whether tolerated theft penalizes good hunters to the extent that they should attempt to leave the group. Kaplan (1983) and Vehrencamp (1983) consider this issue more exten-

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sively, using other models with many interesting consequences. Scroungers are presumably always at liberty to follow the successful hunter. In the tolerated theft model, although good hunters will not receive the advantage that may appear due to them, they will none the less gain from their efforts. They are likely to gain more from their efforts than from the efforts of less good hunters — an equal share of their own greater returns will be greater than an equal share of a poor hunter's lesser returns. Under most conditions poor hunters will be the ones to opt first for a pure scrounging strategy, or a less active mixed hunting–resting strategy. Good hunters should persist despite the drain of "spongers". We should expect that "Some people like to hunt, other people just like to eat", as a !Kung informant said to Konner and Blurton Jones.

Alternative explanations in the literature for the low work rates of some foragers are (1) they conserve resources ("prudent predators"); (2) the population is kept at a level that requires high work rates only in times of exceptional scarcity; (3) "the Zen road to affluence", the claim that forager behaviour is guided by an ideology that values leisure and security, avoiding over-production with its attendant over-reproduction. Thus the most significant aspect of the tolerated theft-scrounging model for anthropological theory is that it gives one possible, indeed plausible, answer to the challenge: how can individual economic or reproductive interests lead to low work rates and the toleration of scroungers? This may provide a route to an ecological explanation of the influential concept of the "Zen road to affluence" (Sahlins, 1972), an explanation which does not rely on the unrealistic "prudent predator" proposition. We have here a mechanism by which individuals maximizing their selfish interests come to under-produce. Thus there is no need to postulate long range planning, adaptation to a seldom observed "worst year", a group survival strategy such as altruistic restraint to conserve the environment, or a non-materialist cause for lowered work rates.

The differences between this model and one that views behaviour as maximizing the benefit and endurance of the group are striking. If foragers forage for the group, they should all forage, unless alternative explanations 1, 2 or 3 operate. When one pays attention to the interests of the individual, the "under-producing" societies become easier to understand than if one attends only to the group outcome. Such an explanation may also enable us to understand why the members of such societies profess to believe not that eating

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is bad but that generosity is good, and that eager and successful hunting is good.

Different resources, different curves

Parker's "fitness budget" argument of contests over resources, from which I derived tolerated theft, can be applied to other curves of resource value against amount of resource (Blurton Jones, 1986). If contests are won by the individual that will gain most from the contested resource we can conclude that: in Figure 1B the individual that has most will relinquish a contested item to an individual that has less (the tolerated theft model). In Figure 1C the individual that has most will be able to defend an added item from an individual that has less (Y1 < Y2). In Figure 1D the outcome will depend on the exact positions, compare Y1, Y2, Y3. In Figure 1A, wherever an individual lies on the X-axis he stands to gain the same amount from an added item. For such a resource, contests will not be predictably resolved by asymmetry in resource value.

Outcomes of repeated contests may lead to even distribution of resources (curve 1B), accumulation of resources by few individuals (curve 1C), and a population of resource holders alongside a population of non-holders (curve 1D). Repeated contests over a resource that follows curve 1A must lead to allocation of resources according to differences in strength and fighting ability. These being relatively constant features of an individual the result will be a ranking of individuals. The most interesting feature of these outcomes is the difference between the rank order arising from curve A (or as argued in the section on tolerated theft, a rank order arising from contests over food that is found in small packages) and the "stratification" arising from curves C and D. The latter may be more important in human society and its evolution than the rank order. Rank orders are common in animal societies but would appear likely to have a different ecological basis from stratification in human society.

The increasing returns curve will lead to individuals that have more, being able to acquire and defend more. This curve is in effect a curve which demonstrates economies of scale. Among many good theories about stratification is the view that it arises particularly when there are economies of scale in some subsistence activities (Garfinkel, 1981). If this is correct then the difference between

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stratification of human societies and the dominance hierarchies of non-human primates may be at least as profound as anthropologists have always felt. One can argue that monkey hierarchies can be explained adequately by the straight line curve (or by the use of food that comes in small packages). A straight line curve will lead to less easily resolved contests. Differences in strength and fighting ability will be the only sources of asymmetry, and if present are most likely to determine the outcome. Differences in strength and fighting ability do not change rapidly and so the outcome will be a ranking of individuals according to their ability to win resources from each other. A sigmoid curve may lead to a population of owners and a population of "dispossessed". Arguments for these conclusions and possible examples of resources that follow each curve, are described in Blurton Jones (1986). This "ecological determinist" view may be contrasted with the view that a common primate tendency toward rank ordering displays itself in our species in social inequality or class systems. However, I do not claim that my argument necessarily applies to phenomena such as leadership in small experimental or informal groups. It might be worth examining the extent to which it applies to the groups of nursery school children in which rank orders have so often been described.

I have discussed no applications of the tolerated theft model within stratified societies. There are some important inconsistencies. I have described a condition in which it pays the poor to threaten the rich, and in which it does not pay the rich to resist. In the increasing returns curve we have a condition where this is reversed. But in real societies factors such as control of access to weaponry may be just as important a factor as the resource value curves. None the less, aspects of the resource value curve idea are implicit in the anthropological literature. An incomplete irrigation system is not much use. The whole intact system gives enormous returns. It seems clear that the principles of this "fitness budget" approach to conflict over resources offer an explanation for an encouragingly wide range of social phenomena.

Discussion

I have taken a robust finding of Parker and others about contests over resources and tried to show how we could relate it to actual ecological circumstances. My main aim was to argue that the models

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could account for a form of passive reciprocal exchange of food, "tolerated theft". The proposed mechanism might increase exchange of food to a frequency at which reciprocal altruism could begin to evolve. The circumstances under which this would operate are: food is found in large packages, infrequently, by different individuals on different occasions and the individuals find each other with the food. These circumstances could have been present over long stretches of the evolutionary history of our species, they could arise from scavenging as much as from hunting large animals and they are present in many contemporary and recent hunter-gatherer societies. The model implies that gathering plant food would be a highly unlikely origin for sharing, unless plant foods that could fulfil the required conditions were involved (e.g. truly enormous tubers that were very hard to find).

A number of alternative models of evolution of altruism already exist and were mentioned in the Introduction. I claim that my model has the advantage that it draws attention more directly to circumstances than do the other models. Alternative theories of the origin of food sharing give little lead into the examination of the circumstances that favour sharing. When so much variation exists in contemporary societies it seems more hopeful to attend to environmental or materialistic differences than to hope that a model unlinked to the environment can explain both origins and variation. Kin selection, as it is normally used, is one of these alternative theories. All higher primate groups consist of closely related individuals and kin selection seems to be the key to understanding many features of their social behaviour. But kin selection unlinked to environmental variation cannot tell us why some species or cultures habitually share food and others do not, or why some are conspicuously hierarchical and others are more variable in this. Kin selection theory really gives us only a coefficient by which to adjust measurable costs and benefits. Thus it is not in conflict with, nor a substitute for, other theories that attend to the costs and benefits.

It seems to be difficult to choose between tolerated theft (injury avoidance) and variance reduction as prime movers for evolution of food sharing. An important consequence of real life food sharing is the reduced day to day variance in an individual's food intake, as demonstrated from data on the Ache by Kaplan (1983 and subsequently). The same consequence follows from the tolerated theft model, and the same circumstances lead to advantages from both tolerated theft and variance reduction. One potential disag-

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reement concerns whether, if variance reduction were the only advantage, the system could be exploited by individuals who decided to receive but not give. This is exactly the same question as arises with reciprocal altruism. Why could not an individual raise his mean intake and keep his variance low by defending his own catches and stealing from others? The tolerated theft model overcomes this problem.

The use of a central site is better explained by variance reduction benefits. The tolerated theft model leads to variance reduction and I do not wish to under-rate the importance of variance reduction. Given that cheating is impossible because of the costs and benefits of contests, then if variance reduction is advantageous we should expect individuals to do whatever achieves this. I have assumed that variance reduction had to be a by-product of a process that can evolve by selection acting on individuals.

If we remove the variance reduction advantage from consideration we get a scenario in which an individual that makes a catch will do better to avoid others and hide his catch (if he can hide it from other species as well!), and an individual that makes no catch will do well to follow other individuals. The implications of this unlikely model may be worth pursuing.

Besides continuing to try to pin down the rationale of each model we may be able to derive contrasting predictions from reciprocal altruism, tolerated theft, kin selection, etc. to test against real data. Thus tolerated theft may predict more even sharing than reciprocal altruism in which individuals may be expected to favour good reciprocators. Kaplan (1983) usefully contrasts variance reduction with kin selection predictions. Many other topics deserve further exploration, including the economics of alliances of thieves or owners.

It has been my aim in this paper to outline the model and illustrate some of its implications, not to relate the model in detail to the ethnographic literature. But the model, the discussion of hoarding, and the analysis of scrounging impinge on existing data or theory at several points and these deserve emphasis; the model makes us less puzzled by:

1. the undercurrent of potential hostility associated with sharing;
2. the near impossibility of avoiding scroungers;
3. the challenge to find materialist explanations for the "Zen road to affluence";
4. the difficulty of persuading hunter-gatherers to hoard;
5. the possible association of hoarding and seasonal gluts;

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6. the self-serving nature of some ideology; and
7. differences between primate rank orders and human social stratification.

Closer examination of these issues would be rewarding. For example, the model may help make more explicit the links between seasonality and hoarding discussed by Testart (1982), who argues that hoarding is the key distinction between types of hunter-gatherer social organization. The model suggests we look again at sharing in simple societies. Is it really so altruistic? Or really so reciprocal? Although hunter-gatherers all appear to support the sharing ethic, is there really an undercurrent of threat, appeasement and personal power behind it?

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