Risk and Uncertainty in Tribal and Peasant Economies

EDITED BY

Elizabeth Cashdan

Westview Press
BOULDER, SAN FRANCISCO, & LONDON

A Westview Special Study

This Westview softcover edition is printed on acid-free paper and bound in library-quality, coated covers that carry the highest rating of the National Association of State Textbook Administrators, in consultation with the Association of American Publishers and the Book Manufacturers' Institute.

Published in 1990 in the United States of America by Westview Press, Inc., 5500 Central Avenue, Boulder, Colorado 80301, and in the United Kingdom by Westview Press, Inc., 13 Brunswick Centre, London WC1N 1AF, England

Library of Congress Cataloging-in-Publication Data
Risk and uncertainty in tribal and peasant economies / edited by Elizabeth Cashdan.
p. cm.
Bibliography: p.
ISBN 0-8133-7821-4
1. Economic anthropology. 2. Risk management—Cross-cultural studies. 3. Risk perception—Cross-cultural studies. 4. Scarcity—Social aspects—Cross-cultural studies. I. Cashdan, Elizabeth A.
GN448.2.R57 1990
306.3—dc20

89-35018
CIP

Printed and bound in the United States of America

The paper used in this publication meets the requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48-1984.

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Why Do Men Hunt? Benefits for Risky Choices

Kristen Hawkes

The character of male foraging strategies among modern humans and ancestral hominids has been debated ever since Darwin (1871). How much women and children depend on food procured by men, whether and how much men hunt, and what this might entail for selection constraints and social organizations have been matters of dispute (e.g., Dart 1953; Washburn and Lancaster 1968; Lee 1968; Ember 1978; Hill 1981; Zihlman and Tanner 1978; Binford 1985). While it has been reported that males sometimes forage to earn sexual favors (Siskind 1973), the common assumption has been that whether they hunt, gather, or scavenge, and whether they provide most of the food or a minor fraction, the primary goal of men's foraging is to provision themselves and their families (Isaac 1978; Symons 1979; Lovejoy 1981; Lancaster and Lancaster 1983; Hamilton 1984). Recent observations of resource acquisition and consumption among the foraging Ache of Eastern Paraguay appear to be inconsistent with this picture. Neither Ache hunters themselves, nor their wives, nor their children consume a special share of the game men kill. Instead meat is evenly distributed to all in the foraging party (Kaplan et al. 1984; Kaplan and Hill 1985a). Wide distribution of game animals is common among hunters (Sahlins 1972; Kaplan and Hill 1985a). The suspicion which it raises, that men may not be hunting primarily to provision their families, is strengthened for the Ache by a second and separate result. Ache men could earn a much higher mean rate of energy gain if instead of hunting they gathered palm starch (Hill et al. 1987; Kaplan et al. this volume).

The purpose of this paper is to explore the possibility that men choose to hunt not for the average daily income they earn hunting, but because the maximum a hunter might capture on any day is very high. Under some circumstances the occasional jackpots, much larger than a hunter and his family could consume, may confer greater reproductive benefit than a higher daily mean with no bonanzas. After a brief description of the Ache and recent research among them, some general differences between the potential costs and benefits of high-variance foraging incomes for the two sexes are outlined. Game theory (Maynard Smith 1982) is then used to model the relative reproductive benefits which might be gained by men from this variance maximizing, risk-prone strategy and the benefits available for an alternative strategy which earns a steady, low-variance, daily income. The model shows that even if women could have significantly more children if they married men who pursued the low-risk course, it might not be in the interest of men to make that choice. Conflicts of interest between the sexes and among members of the same sex which are likely to play a major role in the sexual division of labor underlie this result.

THE ACHE

The Ache are indigenous inhabitants of Eastern Paraguay. Their traditional range is a forested, well-watered region cross-cut by many rivers and streams, with annual temperatures ranging from July lows of 0C to January highs of 38C (see Hill et al. 1984 for further ecological description). The first modern ethnographer to study these foragers, Pierre Clastres (1972), reported on the remnants of two ethnolinguistic populations of Ache living on a Paraguayan ranch. He did not study the Northern Ache, who remained full time hunter-gatherers, beyond unarmed contact with outsiders, until the 1970s. In 1972 the Northern Ache began to settle at mission-sponsored colonies (Hill 1983). Chupa Pou was established by the Catholic Church in 1978 as an agricultural settlement for the Ache (Hill 1983, Hawkes et al. 1987) and that year the last uncontacted group joined its residents. In 1980 members of the Utah Ache Project began systematic study of the foraging patterns of the Ache who spend part of their time at Chupa Pou and part of their time away from the settlement hunting and gathering, moving camp almost daily through the surrounding forest which is their traditional range.

Members of the Ache project have collected quantitative data on food acquisition (Hawkes et al. 1982; Hill and Hawkes 1983), diet (Hill et al. 1984) sharing (Kaplan et al. 1984; Kaplan and Hill 1985b), time allocation (Hill et al. 1985; Hurtado et al. 1985), and reproductive strategies (Kaplan and Hill 1985b; Hill and Kaplan 1988a, 1988b) during foraging periods when people were exploiting traditional resources and were dependent on their own daily acquisition of forest animals and plants. Guided by the theoretical perspective of behavioral ecology, we assumed that individuals would generally act to maximize their probable inclusive fitness. We expected that certain variables would have strong effects on reproductive success and sought to discover whether behavior was adjusted to those variables in the manner predicted by theory (Maynard Smith 1978). Employing optimal foraging models (Charnov and Orians 1973; Smith 1983) we assumed that efficient foraging, i.e., resource procurement patterns which earned the most food in a given amount of time, would enhance fitness by producing more food to eat or to give away for other favors (Hawkes at al. 1985). Individuals who adopted less efficent strategies would have less to eat and to give away, so less efficient males would have fewer mating opportunities and less well fed families, less efficient females would have fewer children and their children would have lower survivorship. Individuals would, we assumed, adjust their behavior to be as successful as they could. Results were encouraging. Most of the resource choices Ache foragers made and some striking adjustments in foraging behavior under different conditions were those we expected if foragers indeed were maximizing their net rate of nutritional benefit and that benefit could be measured reasonably well in calories (Hawkes et al. 1982; Hill and Hawkes 1983; Hill et al. 1987).

Some features of the sharing pattern were very surprising (Kaplan et al. 1984; Kaplan and Hill 1985a). The amount of sharing was remarkable even though hunters are known for their "sharing ethic" (Sahlins 1972): about three-quarters of the food Ache foragers consume is acquired by someone outside their nuclear family. Yet there were marked differences in the extent to which different categories of resources were shared. Those which came in larger packages, with greater daily acquisition variance across adults of the same sex were more widely shared. Vegetable and insect resources generally came in small packages, with low daily variance, and these were differentially shared with close kin. On the other hand, meat and the honey of *Apis melifera*, both large package, high-variance resources, were shared with no consumption advantage to the acquirer or his family (Kaplan 1983; Kaplan et al. 1984; Kaplan and Hill 1985a).

The absence of a bias in the distribution of meat and honey, leaving no special portion to the acquirer or his family, was quite unanticipated. We had expected kinship distance to make a difference due to kin selection (Hawkes 1983). Yet the fact that large package, high-variance resources were more widely shared is consistent with at least two models constructed on the assumption that individuals are likely to behave in ways which usually increase their own reproductive success: tolerated theft (Blurton Jones 1984) and reciprocal altruism (Trivers 1971; Kaplan and Hill 1985b). In both models sharing, without regard to kinship, can reduce the variance and, over time, raise the average consumption of sharers. This happens when resources are acquired unpredictably, in amounts large enough that the hunter gets diminishing value from consuming the whole thing. Tolerated theft predicts no consistent bias in the "sharing" pattern, and no larger share retained by the hunter. Reciprocal altruism predicts more shared with those more likely to give in future (Trivers 1985). Since there is a significant and consistent difference in the success rates of different hunters (Kaplan and Hill 1985a, 1985b), reciprocal altruism would predict correlated differences in benefits given to them or their families. Yet there are no correlated consumption benefits. In spite of this, better hunters tend to spend more time hunting (Hawkes and Hill 1983; Hawkes at al. 1985), compounding their differential contribution to everyone's nutrition. And they do benefit: better hunters have higher reproductive success (Kaplan and Hill 1985b). Hunters are gaining some other kind of reproductive advantage for their foraging (Hill and Kaplan 1988a, 1988b). To understand their strategies, benefits other than energy gain require attention.

The need to consider other costs and benefits was clear for other reasons as well. Male and female foraging strategies are quite unlike each other. Accounting for women's foraging patterns required explicit attention to the difference between food as an end in itself and as a means to gain fitness. Not surprisingly, trade-offs between food acquisition and childcare played a major role in shaping women's foraging (Hurtado 1985; Hurtado et al. 1985). Much of the food an Ache woman acquires comes in small packages with low daily acquisition variance and is consumed by her family. She is the primary caretaker of her children. Thus the reproductive costs posed by foraging interference in attentive maternal monitoring and the reproductive benefits of added nutrients can vary enormously for similar food procurement activities depending on the number and age of a woman's children. Different trade-offs for different women emphasized the importance of the distinction between maximizing foraging efficiency and maximizing reproductive success.

Detailed examination of women's time allocation led to the suspicion that the walking and carrying women do as they move children and household goods almost daily from one camp to another was not really a cost of their foraging. Women stop frequently, about each quarter hour spent walking. On about a third of these stops they forage. Whether they forage or not they spend about a half an hour resting. The regularity of the stops combined with the fact that women pass opportunities to forage as they walk suggest that this travel is primarily to move camp following the hunters (Hurtado et al. 1985). Focusing on the rare days when camp was not moved allowed women's foraging returns to be calculated without confounding this cost (although these days are atypical and may be associated with fruiting seasons when gathering returns are unusually high). The results showed that not only were women's foraging returns higher than men's on those days, they were higher on those days than men earned on "normal days" (Hill et al. 1987). Since the array of resources men know how to take and the acquisition strategies they can perform include all those taken and used by women plus others as well, this was a startling result. It stimulated a calculation of the net energy gain men might earn if, instead of hunting, they pounded palm starch. The calculation suggested that men might double the hourly rate they earn from hunting; and that they could do so without depleting the abundant palm population in this region (Hill et al. 1987). We could only conclude that Ache men are choosing not to maximize their mean net rate of energy gain.

Before pursuing alternative reasons for men's hunting some qualifications are in order. Other interpretations of both the Ache sharing pattern and the mean energetic return rates of Ache hunting and gathering are possible. It may be that despite appearances to the contrary neither the sharing pattern nor the estimated potential energetic returns for palm starch are serious violations of the assumption that men pursue foraging strategies which most efficiently provision their families.

For example, it could be that the parties monitored were composed of relatively close kin and a lack of a sharing bias within these parties does not mean a lack of bias over the Ache population or even within the subset of individuals studied if records extended over a longer time. The wives and children of better hunters almost always camp with their husband/fathers, so while they consume only the averages that all get from the company of successful hunters, they get higher averages almost all the time. More successful hunters may thus occasionally raise the consumption of other companions to regularly raise the consumption of their own families. Still, the fact that hunters eat significantly less of the game they kill themselves than do others (Kaplan et al. 1984) contributes to the suspicion that familial consumption is not the main goal of a man's hunting. Since others gain by the company of better hunters we might expect those hunters to extract some sort of compensation, compensation which would contribute to the reasons for hunting (Hill and Kaplan 1985b; Hill and Kaplan 1988a, 1988b).

Another possibility follows from the importance of new technology. The surprising result that palm starch exploitation would give a significantly higher mean rate of energy gain than hunting may depend on the use of steel axes. Without them the time required to cut down and open palms might reduce average returns below those for hunting. Since the wide availability of steel axes may be quite recent, associated with the establishment of mission settlements (Hill 1983), exploitation strategies may have yet to catch up with this technological change. But Ache men are quick to adjust their hunting to take advantage of other technological changes. They target a different set of prey when hunting with shotguns and so maximize the higher return rates they earn with firearms (Hill and Hawkes 1983). The most important qualification has to do with the index used to measure return rates. It is very likely that energy is a poor relative measure of the nutritional value of the resources men take. These are largely game animals, their nutritional constituents are fat and protein, rather than carbohydrates (honey is a major exception). The difference in nutritional value between a calorie of fat or protein and one of carbohydrate for human consumers, especially pregnant women and growing children, may be substantial (Hill et al. 1987; Hill 1988; Kaplan et al. this volume). It could be that a more accurate measure of nutritional benefit which accomodates the higher value of a calorie of meat would show that Ache men actually are pursuing the strategy which gives them the maximum mean rate of nutritional gain. This important possibility is not explored here (see Hill 1988, Kaplan et al. this volume), because there is another difference between hunting and gathering which may also have profound effects on foraging strategies.

HIGH AND LOW RISK STRATEGIES

In addition to the major difference in the nutritional constituents, there is the notable difference in the size and predictability of the resource packages procured by hunting and gathering. Because the resources men take come so unpredictably in such large units there is great variation in daily income between hunters on any given day, and for any hunter from one day to the next (hence the applicability of tolerated theft and reciprocity to the wide sharing of these foods). Figure 7.1 shows the distribution of daily income per man in Calories over 430 man-days (all foraging days monitored in 1981–82 excluding the first and last day of foraging trips and 6 days of heavy rain). The mean is 9634 Cal/man-day but the median is only 4663. The risk of failing to capture anything at all on a given day is substantial (103 of 430 or 24% of days). Yet it is also possible to acquire totals which are many times larger than the maximum amount to be gained from a full day's bout of diligent gathering. The difference is illustrated by comparing this distribution to the daily income of women on the 7 unusual woman-days when women spent more than 5 hours pounding palm starch. For those days the mean income per gatherer was 10,356 Calories with a standard deviation of only 1891 (Kaplan et al. this volume). Men, because they are stronger, can earn higher return rates pounding palms than can women. Still, the women may have extended their palm pounding on these days in this atypical way (Hurtado et al. 1985) because conditions allowed unusually high return rates. If the daily mean and variance for those seven woman-days is an approximation to the returns men might get from pounding

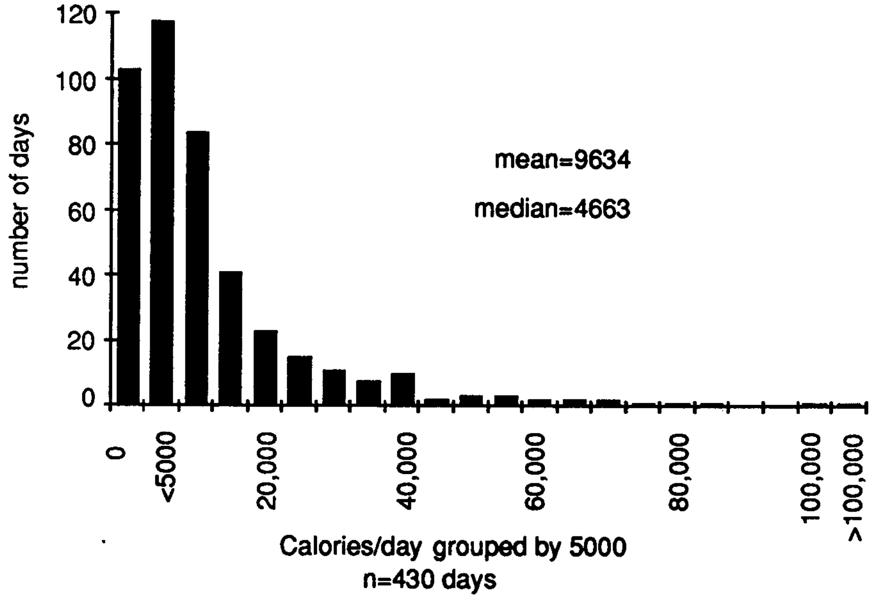

Figure 7.1: Calories Acquired Per Man Per Day
Man-days of income are grouped into categories by increments of 5000 Calories with zero days distinguished. Categories are thus: zero, > 0 but < 5000; > 5000 but $< 10,000$; $> 10,000$ but $< 15,000$; etc., with a final residual category $> 100,000$. The y-axis shows the number of man-days in each category. The sample of 430 man-days includes all foraging days monitored in 1981–1982 excluding the first and last day of foraging trips and six days of heavy rain.

palms day after day, a gathering man would almost never bring in less than 6600 Calories (the mean minus two standard deviations) or more than 14100 Calories (the mean plus two standard deviations). A hunting man, however, tops 15000 Calories about once every five days (84 of the 430 days). If we assume (following Kaplan et al. this volume) possible consumption totals of 5000 Cal/day for adults and 2500 a day for children, a gathering man would never bring in more than a family of four could eat. A hunter, though he would fail on most days to feed a family, would bring in amounts larger than a family could possibly consume more often than once a week. If estimates for the amount a man might acquire gathering are more generous, say 2630 Calories/hour (Hill et al. 1987), seven hours of food acquisition would bring in an average of 18,410 Calories. A gathering man could feed more people each day, but assuming the same small variance, his maximum income would be well below that of a hunter. He would almost never bring in more than 22200 Calories (the mean plus two standard deviations), while a hunter would bring in more than that just less than once a week (51 of the 430 days).

The variance in gathering return rates is extremely low. There are daily differences in women's gathering income (Hurtado et al. 1985) but these are directly related to daily differences in time spent gathering not to encounter luck. Women raise the minimum thay can expect to earn by choosing to gather, but they also sharply reduce the maximum they can ever expect to acquire on a foraging day. Men, on the other hand, earn lower mean returns by following the strategy which sometimes gives them very high daily totals.

Why choose the risky alternative? Some recent research has focused on how probabilistic variation in rewards affects foraging strategies (Stephens and Krebs 1986; Stephens this volume). A forager maximizes the chance of capturing a reward above some threshhold by preferring risky (high-variance) alternatives under some circumstances, certain (low-variance) alternatives under others. If the threshhold the forager tries to stay above is higher than the central tendency of the distribution of probable rewards, then more of a large variance distribution is above that threshhold. If the threshhold is lower than the central tendency of the distribution, then more of a small variance distribution is above the threshold. So a forager increases the chance of avoiding a shortfall by being risk prone when the expected reward is not enough, and being risk averse when the average is ample. Figure 7.2 illustrates this graphically. Daily income distributions A and B have the same means but A has a small variance, B a large one. A forager maximizing the chance of earning above r on any given day will choose distribution A over B since more of distribution A falls above this threshold. On the other hand a forager maximizing the chance of earnings above v will choose distribution B because more of distribution B falls above v. Distribution C, like the daily capture totals of Ache hunters, is far from normal. But like B, more of it falls below the threshold r and more of it falls above the threshold v than the low variance distribution. If men were to maximize their chances of capturing a very large daily food package, the risky alternative could be the optimal choice.

In experiments and models of foraging to avoid a shortfall when rewards are unpredictable, foragers try to stay above the minimum required for daily survival. (Caraco 1981; Stephens and Charnov 1982). A daily total which exceeds the consumption capacity of a whole family clearly cannot be a threshold in this sense. The broad distribution of these resources means that other members of the foraging party consume extra food. The forager who brings in intermittent bonanzas might earn special treatment from his companions to encourage his continued proximity and the occasional

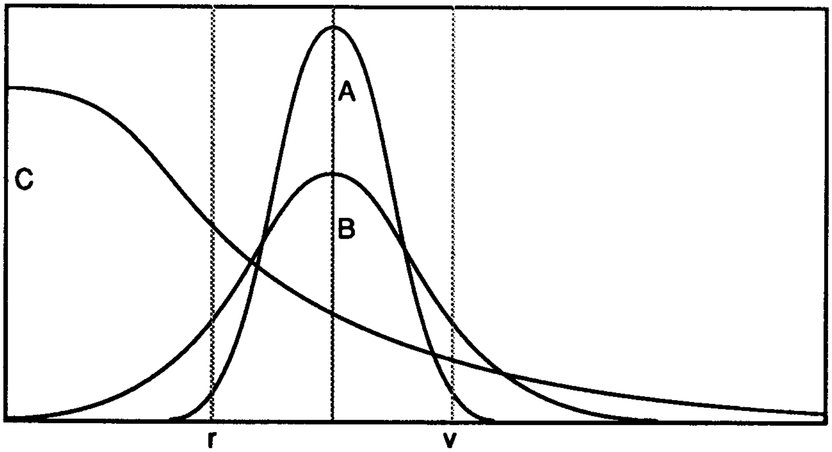

Figure 7.2: Frequency Distributions and Risk
These are hypothetical frequency distributions of daily incomes. The distribution labeled A has a low variance, B has the same mean but a higher variance. A forager choosing between strategies which give these two known distributions of daily income will maximize the chance of scoring above r by choosing distribution A, but maximize the chance of scoring above v by choosing distribution B. See text.

bonanzas that flow to them from his high-risk foraging strategy. If those incentives were crucial fitness benefits, then a failure to acquire sufficient food to elicit them would amount to a shortfall. The conceptual elements of this hypothesis are outlined below, beginning with a consideration of the different costs and benefits to males and females of high-variance foraging incomes. Then a game theory model is used to clarify more formally the circumstances under which a high variance but lower average gain acquisition strategy would persist. Possible ranges of value for the variables in the model are estimated from relevant Ache data to determine whether the circumstances required by the model are likely to hold.

MALE AND FEMALE COSTS AND BENEFITS FOR RISKY INCOME

The reproductive costs and benefits of similar foraging strategies can be quite different for the two sexes. If hunting is an energy expensive, sometimes dangerous activity requiring periods of concentration, the reproductive costs to women if they were to hunt would be notably higher than to men (Hurtado 1985). For women the reduced fecundability from the energy drain, the expenditure of resources which might go for a growing pregnancy or for lactation (Bentley 1985; Graham 1985; Ellison et al. 1986; Frisch 1984), the incompatability of hunting with tending infants and small children (Brown 1970; Murdock and Provost 1973; Hurtado 1985) may be considerable. Men have no comparable costs because lower energy expenditure, higher body fat, increased attention to infants cannot give them the same reproductive benefit.

The reproductive costs to male and female foragers for strategies which result in frequent daily failures would differ as well. Both might have reduced health and vigor but, in addition, a woman's fecundability, pregnancy and/or lactation and especially the health of her growing children might be compromised by frequent consumption shortfalls. Lower mean consumption rates, other things equal, might exact higher costs from women for the same reasons (Frisch 1984; Hamilton et al. 1984).

The difference in benefits gained from occasional bonanzas are of special interest here. For a female the potential reproductive benefits to be earned from a day's income larger than she and her family could consume themselves would be the general goodwill of other members of the band who ate from her prey. It would be in the interest of others to extend better treatment to her to induce her to continue to bring in the large packages which contribute to their consumption. A male would also benefit from companions' goodwill. He would gain additional benefits if the good will of reproductive females included mating access and the goodwill of males included reduced antagonism toward his mating attempts.

This is a fundamental assymetry between the sexes: Since the reproductive success of a male depends directly on the number of his mates, and since a male may impregnate one female without precluding his nearly contemporaneous impregnation of another, it will generally be in the interest of men to increase their mating opportunities (Trivers 1972). Neither of these things applies to females, although extra matings can confer reproductive benefits on a female by distributing the possibility of paternity in such a way as to elicit differential treatment for her offspring (Hrdy 1981; Smuts 1985; and see below).

Other things equal, men have less to gain from avoiding days in which they get small amounts of food than do women, and they have more to gain from occasionally feasting others than women do. Males should be more readily drawn to risky strategies than females are. Men should be more likely to hunt than women. What then might be the conditions under which they would actually do better by increasing the daily variance in their foraging returns?

THE MODEL

Imagine two strategies which a man might adopt. With one he feeds himself a bit and then procures a steady daily income for his wife and children. With the other he feeds himself a bit and then seeks resources which he often fails to capture but which give him occasional bonanzas big enough to feed more than a family. Because of the size and asynchrony of these jackpots, others could readily claim the extra which would be of little direct nutritional value to the hunter himself since he would be replete on consumption of only a portion of it (Blurton Jones 1984; Kaplan and Hill 1985b). Men who adopt the low variance provisioning strategy, which earns a steady daily income for a wife and children, never earn enough excess for others to claim without dispute. Because of this their presence in a band is of no advantage to any but their wives and children. On the other hand, those who adopt the high-variance, "showoff" strategy, which results in intermittent bonanzas, are desirable band companions for all because of the occasional feasts they provide. Since their average returns are low and the bonanzas they bring in are unpredictable, others cannot use them as a source of dependable support. But by not supporting a few they become sources of unpredictable benefits to many.

The value of the occasional large packages brought by the showoffs leads other adults to act toward them in ways which increase the chances that they will remain with the group and continue to supply extra food to all. Women extend them sexual favors, increasing the likelihood of their continued proximity and so of occasional treats for themselves and their children. Men tolerate this pattern of infidelity because of periodic food contributions. At least they tolerate it more than they would tolerate their wife's infidelity with a male who feeds only his own family. All adults may defer more to the showoffs' children than to the children of men who feed only their own families. The stronger the effect of this deference on the survivorship of the showoffs' children the greater the gains—other things equal—to women for having children fathered by showoffs. The mean daily income of a showoff might be well below that of the provisioners. The mean amount of his income consumable by him or a hypothetical family would be lower. Women married to provisioners would receive a regular dependable daily food supply. They could work less themselves, and so raise their fertility, and increase the survivorship of their children through a combination of more food each day and more uninterrupted maternal monitoring. Under these circumstances the preferred arrangement for a woman would be marriage to a provisioner, and thus an assured daily income from him which allowed her to have more surviving children, while other men in the band behaved as showoffs so that she and her children could take frequent additional shares from them. To the extent that band members gave special protection to the children of showoffs, a woman would do best if she could have the regular income of a provisioner with the paternity of all her children assigned to showoffs. The preferred arrangement for a man would depend on (1) how many additional children a woman could raise with the regular daily income of a provisioning husband, (2) how much paternity a provisioner would expect to lose to showoffs, and (3) how large an effect the differential treatment of showoffs' children had on child survivorship. The ideal arrangment for one woman conflicts with the interests of other women, and while a woman may wish to have a provisioning husband it may not suit a man's interest to be one.

Casting this model formally clarifies the relationships among variables which would lead the showoff strategy to persist even if the wives of provisioners could raise more children. Game theory provides tools to specify the conditions under which these alternative strategies would be stable (Maynard Smith 1982).

The Algebra

Define the following strategies:

W = the strategy of women who are Wives of provisioning men

U = the strategy of the other women, those Unmarried

P = the strategy of men who Provision a family

S = the strategy of men who Showoff by targeting high-variance resources

with the following payoff variables:

r = the increase in reproductive success of a wife due to the dependable income of a provisioning husband

m = the maximum fraction of children born to a provisioner's wife who can be fathered by showoffs; the maximum reduction in paternity a provisioner will tolerate

i = the factor by which a child's survivorship increases if he has a showoff father

c = the children a woman can have without the post conception help or influence of men

Assume a 50:50 sex ratio and no polygyny. If f is the relative frequency of showoffs in the population so that $1 - f$ is the relative frequency of provisioners, these are also the relative frequencies of the alternative female strategies: $1 - f$ is the fraction of women who are wives of provisioners, f the fraction of the other women, those without provisioning husbands.

There are three key variables in this model. The first is r, the factor by which a woman's reproductive success is increased by regular daily investment from a provisioning husband. This variable is here conceived as a multiplier on the number of children a woman could raise without that investment. The variable r is allowed values greater than or equal to 1 (if it falls to 1 a woman gains nothing from a provisioning husband). The second is m, the maximum fraction of the children born to the wife of a provisioner who could be fathered by showoffs. It is an index of the degree to which women use sexual favors and provisioners use tolerance of their wives' infidelity to induce showoffs to remain and continue the bonanzas. The third is i, which takes values greater than or equal to 1, the factor by which the survivorship increases for the children of showoffs due to any differential treatment from other band members. If it is greater than 1 it is an inducement for showoffs to continue the bonanzas. For exposition the variable c is included: the children a woman can raise without any post conception help or influence of men. In this model it is assumed that women can successfully raise some children by themselves.

The payoff to W, a woman married to a provisioner, is calculated as follows. The number of children she can have without regard to fathers (c) is multiplied times the help of her steady husband (cr). This help affects all of her children equally, either through her distributions of the income she gets from her husband, or through the increased attention she can devote to monitoring them because of his dependable contribution. Some of these children may have showoff fathers. The fraction of her children who have showoff fathers will depend on the relative frequency of showoffs in the population (f) and the maximum fraction of paternity a provisioner's wife can give to showoffs (m). The more showoffs there are, the more sexual encounters wives will have with them, but the value of m sets the limit on how much wives can give away without losing their provisioners. The fraction of paternity actually given to showoffs by provisioners' wives will be the product of the maximum allowed and the relative frequency of showoffs in the population (mf). The children fathered by showoffs (mf) receive special treatment from other band members which increases their survivorship by the factor i. Those fathered by her provisioning husband ($1 - mf$) do not. Thus:

$$W = cr(1 - mf + mfi)$$

If U is the payoff to a woman not married to a provisioner, her children are all fathered by showoffs, all have increased survivorship (i) due to special treatment. Thus:

$$U = ci$$

The payoff to P, a man who provisions his wife and her children, equals the children of his wife but only those not due to showoffs. Thus

$$P = cr(1 - mf)$$

The payoff to S, a man who plays showoff, includes children of women playing both U and W. One showoff's fraction of the children of women doing U is the relative frequency of those women (f), times the children of each (ci), divided by the relative frequency of men doing S. One showoff's fraction of the children of women doing W is the showoffs' children of each of these women ($crmfi$) multiplied by the relative frequency of those women $(1 - f)$, divided by the relative frequency of showoffs. Thus:

$$S = \frac{fci}{f} + \frac{(crmfi)(1 - f)}{f}$$

Cancelling the c's throughout will make no difference in the relative payoffs of these strategies and will simplify evaluation.

W will be favored over U whenever $W > U$, that is, whenever:

$$r(1 - mf + mfi) > i$$

P will be favored over S whenever $P > S$, whenever:

$$r(1 - mf) > i + (1 - f)rmi$$

If many men are provisioners, so that f, the proportion of showoffs, approaches zero,then $1 - f$ approaches one. Thus showoffs will not be able to invade a population of provisioners if

$$r(1 - mi) > i$$

If many men are showoffs, so that the proportion of showoffs approaches one, then $1 - f$ approaches zero. Thus provisioners will not be able to invade a population of showoffs if

$$r(1 - m) < i$$

If S is stable, it will also invade when rare because the payoff to showoffs goes up as the relative frequency of showoffs goes down.

W will always be favored at lower values of r than will P, as long as m is greater than zero because $W = P + rmfi$.

Some data for the Ache are available which can be used to suggest provisional ranges of value for i, the factor by which survival increases for the children of men pursuing the risky, showoff strategy, for m, the maximum paternity which could be gained by showoffs from provisioners' wives, and, less certainly, for r, the increase in reproductive success that a wife would get from a hypothetical provisioning husband. From the perspective of this model, hunting, which increases the size and unpredictability of the resources a forager acquires even at the expense of his average daily income, is a showoff strategy.

ESTIMATES FOR MODEL VARIABLES

The Effect of Father's Hunting on Child Survivorship

Hill and Kaplan (1988b) report that for a sample of 238 Ache children who survived to the age of two years, those whose fathers died had significantly higher mortality before the age of 15 than those whose fathers lived and remained married to their mothers (43.3% vs. 19.3%, $p < .001$) . These data show that fathers make a major difference in offspring survivorship: in this sample, survivorship more than doubles if fathers are around.

Elsewhere, Kaplan and Hill (1985b) report the differences in survivorship for the children of 28 Ache men distinguished by their hunting skills. Using age-matched pairs they compared the mean survivorship (to the present, i.e. young children who may not survive to maturity are included) of the children of good and poor hunters, and found .74 and .63 respectively, $p = .05$. Again, since all members of the band gain consumption benefits from a hunter's success, the higher survivorship of the children of good hunters does not come from differential consumption. But, as in the model, other band members may extend differential treatment to the children of better hunters to increase the chances that those hunters remain in the band. This "better treatment" may be primarily lower likelihood that these children will be victims of infanticide, although less extreme but important factors could include deference to illness (Kaplan and Hill 1985b; Hill and Kaplan 1988a, 1988b). The data show that not only the children of the wives of better hunters but also the "illegitimate" children these hunters father show differential survival, suggesting (as the model assumes) that mothers could gain survivorship advantages for children of showoffs even when they were married to hypothetical provisioning husbands.

No Ache man plays the provisioning strategy of the model, but the data show two things relevant to estimating i, the increase in survival gained by children of showoffs. First, fathers make a marked difference in the survivorship of all their offspring. And second, hunting success is related to the difference that fathers make. On these grounds we might estimate that the increased survival for children of showoffs (i) would be greater than 1.17, since 1.17 is the ratio of the current survivorship of the children of good to poor hunters (Kaplan and Hill 1985b). The maximum might be about 2 because the survivorship to maturity of children whose fathers remain with the family is more than twice the survivorship of those whose fathers die; and all these men are pursuing the risky, showoff strategy of hunting.

Paternity

The Ache distinguish three different kinds of "fathers" (Kaplan and Hill 1985b): the man married to the mother when a child is born, a man who was the mother's lover around the time of her pregnancy, and the one of the preceding men the mother claims actually impregnated her. Ache women report a mean of 2.1 men as possible fathers for a sample of 66 children (Kaplan and Hill 1985b). For a sample of 28 men, better hunters are named more often by women listing their lovers ($p < .05$), and are assigned more "possible" children than poorer hunters ($p = .05$)(Kaplan and Hill 1985b). Informant reports may well be biased. Moreover, since all men hunt, no firm inferences about paternity for showoffs versus hypothetical provisioners can be made. But the data indicate first, that a significant amount of paternity is assigned to men who are not husbands of the child-bearer, and second, that hunting success makes a difference in how much paternity men earn from other men's wives. Even poor hunters earn some. If a hypothetical provisioner tolerated losing the fraction of paternity a hunting Ache husband tolerates losing, that might be half of his wife's children. The mean number of men named as possible fathers is about 2 and, if each of those named had an equal chance of fathering, the average probability would be .5 that someone besides the husband fathered each child. Hypothetical provisioners, however, unlike Ache men, would not earn paternity through women other than their wives. Paternity loss of .5 might therefore be the most a provisioner would ever tolerate. The other end of the range of values for m would be greater than zero, showoffs earning some paternity from provisioners wives, so the range might be estimated as .1 – .5. The paternity actually lost by provisioners would then be a function of this value, m, and f, the relative frequency of showoffs in the population.

Number of Additional Children with a Provisioning Husband

Gathered products are much less widely shared by the Ache than are products of the hunt (Kaplan et al. 1984). The more weaned dependents a woman has the more she gathers if she is not nursing (Hurtado et al. 1985). But when she is nursing an infant, an Ache woman spends less time gathering and is less efficient at it than non-nursing women, whether or not she has additional dependents (Hurtado et al. 1985). These patterns suggest that women reduce the provisioning they would otherwise do for their older children when they have infants. A provisioning husband would allow a woman to attend to an infant without the same depression on older children's consumption. Reduced work effort for the wife of a provisioner might also raise her fecundability, as well as minimize interruptions in her child monitoring which may have especially significant effects on child welfare in this environment (Hurtado et al. 1985, Kaplan and Dove 1987). A man's hunting success does not increase the number of children his wife bears. As noted above, good and poor hunters differ in the survivorship of their children, and in the number of "possible" children assigned to them, but they do not differ in the number of children their wives bear ($p = .6$, Kaplan and Hill 1985a). If hourly energetic return rates were high enough that a provisioning husband earned a daily income which could feed his family well with no subsistence work from his wife, perhaps this could at a maximum double the number of children she could raise ($r_{\max} = 2$). At the other extreme we might estimate a minimum increase in reproductive success of about one child. Average completed family size for Ache women ($n = 37$ post menopausal women) is 6.75 (Hill and Kaplan 1988b). Thus the minimum relative reproductive success of provisioners wives would be 7.75/6.75: $r_{\min} = 1.15$.

USING THE ESTIMATES

The relative payoff for a provisioning man would be greatest when the number of additional children his wife can have is at its maximum value ($r = 2$), and both the survival advantage to children of showoffs and the maximum fraction of paternity a provisioner can lose to showoffs take their minimum values ($i = 1.17$ and $m = .1$). With the values set at the extreme to favor provisioning $r(1-m) > i$, provisioners do better. P is stable. At the other end of the range of values, where $r = 1.15$, $m = .5$, and $i = 2$, $r(1-mi) > i$ and showing off is stable.

The three variables r, m, and i define a three dimensional space. Their estimated ranges define a cube. *Through most of the space in that cube showing off is the stable strategy.* Even when r takes its maximum value, which is one face of the cube, that is, when a provisioning husband can make the maximum difference in the number of children his wife can have, showing off is the ESS as long as $i(1+2m) > 2$. The same is true for the face of the cube defined by the minimum value of m, where provisioners lose the least paternity to showoffs. On most of that plane showing off is the ESS.

The conflicts of interest between and among men and women produce an important instability in this game. Wives of provisioners do better than provisioners because they get additional payoffs through showoffs, while the other women do worse than showoffs because they do not get payoffs comparable to those showoffs get through provisioners' wives. This means that there are values of r, m, and i at which showing off is the ESS for men but marrying provisioners would give women higher payoffs. Sometimes women would do better to marry provisioners even though it is not in any man's interest to be one. Consider parts of the space in which the ESS for men is a mixed strategy. For example if r is at its maximum and i is at its minimum (provisioners adding the most and showoffs the least to numbers and survivorship of children) values of m below .36 make provisioning stable, values above .42 make showing off stable. Between these values the ESS for men is a mixed strategy, with some of the men provisioning and others showing off ($S = P$ when $0 < f < 1$). Whenever it is in the interest of any men to provision it is in the interest of women to marry a provisioner. Women might thus confront the following trade-off: if having a provisioning husband is advantageous and provisioners are scarce, decreases in the paternity allowed to showoffs would draw more men into provisioning. While the wives of provisioners do better the higher the value of m and the higher the frequency of showoffs, it would be in the interest of any woman without a provisioning husband to lower m and acquire one. Paradoxically wives would want to give less fidelity than other women were willing to offer. Provisioning men of course do better the more fidelity they can get.

In this game if women can adjust m, it would be in the interest of any without provisioning husbands to lower m whenever $r > i$. Here it is assumed that the minimum value m can take is .1: women can never guarantee a prospective husband higher than 90% confidence of paternity. This may not be an unrealistic limit, again using the Ache case for empirical guidance, where forced copulations occur. Other factors may complicate adjustments of m. The conflict of interest among women over the value of this variable might play a role. As noted above, however, even when m takes its minimum value, showing off is the ESS for men in most of the space defined by admissible values of r and i.

DISCUSSION

This model captures some important features of the Ache pattern. It shows that even if a hypothetical provisioning strategy gave men a much higher mean return rate, enough to allow wives of provisioners to have twice as many children, it would not necessarily be in the interest of men to be provisioners. We knew from the sharing pattern that some benefits, other than those of provisioning themselves and their families, must underlie Ache men's hunting (Kaplan and Hill 1985a, 1985b; Hill and Kaplan 1988a, 1988b). This model shows that the wide sharing could be less a consequence of the problem of risk created by hunting, than a cause of the pursuit of high-risk strategies. The bias against hunters eating their own game, and the absence of a tendency for hunters to hide catches for their families, are consistent with the model's assumption that the benefits to the hunter come from other people eating what he acquires. Extra-marital sexual relationships and flagrant sexual joking are prevalent among the Ache. As noted above it is also the case that the number and productivity of a man's extra-marital relationships are related to his hunting success, but there is no correlation between the number of children born to his wife and his success as a hunter.

It is appropriate to consider whether a model like this one is likely to have general applicability. Some relevant data are available for !Kung hunter-gatherers of the Kalahari of Southern Africa. Lee argued in 1968 that return rates for the Dobe !Kung and by extension low latitude foragers generally are higher for gathering than hunting. Hawkes and O'Connell objected (1981) that this is not so for the !Kung on the basis of figures Lee himself reports, if processing costs, which are very high for mongongo nuts are included. Mean return/hunter/day = 7230 (Lee 1979:262) (or 7900 ibid:268) divided by 8 hrs hunting plus the 1.12 hr Lee estimated for processing (which seems improbably high) is about 800 Cal/hr or more. While 11400 calories of mongongo nuts, which take 6 hrs to collect, take 11 hrs to process, for a return rate of 670 Cal/hr. But the mean returns for hunters are strongly skewed by the very high success of one hunter. He was the only one reported to hunt with dogs and the four warthogs they killed "provided 65 percent of all the meat in the camp" (Lee 1079:266–267). That hunter earned 28,200 Cal/day. The next highest hunter earned only 6,600 Cal/day during the period covered by Lee's work diaries (Lee 1979:268). If the best hunter is excluded, the mean for all other hunters (and 4 men did not even try) was about 250 Cal per day. The personal mean return rate for the second highest hunter is just over that for exploiting mongongo nuts (724 Cal/hr); all other men would earn much higher mean return rates by collecting plant resources than they did by hunting during the three week period of Lee's record keeping.

These figures suggest that, as for the Ache, !Kung men's foraging may not be aimed toward provisioning. The low calorie consumption (Truswell and Hansen 1976; Wilmsen 1982; Lee 1979) and the constraints on birth spacing posed by women's work (Blurton Jones and Sibly 1978; Blurton Jones 1987a, 1987b) indicate that a gathering husband might significantly increase the number of children a !Kung woman could raise. The value of r, the relative reproductive success for wives of provisioners, might be quite high for this case.

The frequency of extra-marital sexual relationships reported in Shostak's biography of a !Kung woman (1981) suggest that the value of m, the maximum fraction of the children of the wife of a provisioner fathered by showoffs, might be high as well for this population. There is no indication, however, that a man's hunting skills affect his desirability as a lover. In contrast to the implications of Shostak's account, Howell (1979) reports very little "extra-marital" paternity.

Pennington and Harpending (1988) report substantial effects on !Kung children's survivorship due to loss of their fathers. Such loss was more often due to death than divorce. They interpret these data as an indication of the importance of paternal care for offspring survivorship. However their data show no reduction in survival for the offspring of men who have married more than once. Loss of a mother had no effect on child survivorship. This pattern parallels that of the Ache where loss of a father has a much stronger effect on offspring survival than loss of a mother has (Hill and Kaplan 1988b). Rather than indicating that paternal care is more important than maternal care, this may indicate that fathers substantially affect their offsprings' survival through other avenues than provisioning. Children may be treated differently by others in a camp depending on whether their fathers are around. Although assessment must be very inconclusive, the third variable, the increased survival for children of showoffs (i) may be significant in this case.

These data and interpretations suggest that for the !Kung, as for the Ache, hunting is not primarily a strategy by which men provision their families. However, the payoffs to successful hunters are less obvious for the !Kung than in the case of the Ache. It is relevant that !Kung men in some seasons do not hunt nearly as much as the Ache (Lee 1979; Hill et al. 1985; Hawkes 1987). For example, four men did not hunt at all during the period of Lee's work diaries. !Kung men also sometimes spend whole days gathering (Lee 1979; Yellen 1977; Shostak 1981) a pattern not observed among the Ache (Hill et al. 1985). If hunting earns low returns for most men, lower extra-marital paternity and little differential treatment for the children of hunters might be expected to follow. With fewer rewards given to encourage hunting, there would be less of it. This poses questions about why !Kung men don't do more gathering.

The !Kung data suggest that the Ache pattern of lower mean caloric rates for hunting than for gathering, with men hunting nevertheless, may not be uncommon. Hill 1988 enumerates some additional ethnographic examples in which men choose to hunt when they could earn higher mean energetic return rates from gathering. The nutritional difference between plant and animal matter may be large enough that appropriate adjustments in measuring returns will raise the mean income for hunting above that for gathering in some cases. This corrective will not have such an effect in the case of the !Kung where the major gathererd staple, mongongo nuts, is high in fats and proteins.

The model and interpretation presented here show that high variance in daily income from hunting may be important enough to make it the best strategy for men sometimes, even if mean rates are lower than alternative low-risk options. The fundamentally different ways the two sexes earn reproductive gains not only makes hunting higher cost for women, it also makes it higher benefit for men. Hunting may be the optimal male strategy even where men could feed their families better and allow their wives to raise more children by gathering instead.

A major virtue of the model is the attention it focuses on possible conflicts of interest within and between the sexes. Game theory models often show how individuals acting in their own interest may come to adopt strategies in which all do worse than they might if only they acted "for the good of the group" (Maynard Smith and Price 1973). In this case, though women would often do better if they could have provisioning husbands, men would not do better by more gathering because of favors their wives extend to hunters. Any Ache woman would do best if she had a gathering husband while other men hunted, and if all her children were fathered by hunters.

The survival advantage for children of showoffs, and the paternity showoffs get from wives of provisioners, might be expected to vary with the likelihood that showoffs would bring in large bags of game. Others would do more to induce hunting the more food they could expect from it. Variation within the Ache case fits this pattern, and, as suggested above, variation between ethnographic cases might do so as well. Note that high-variance returns, among hunters on any given day and across days for any given hunter, are crucial to the model. If hunters' successes were synchronized, band members would gain little from more than one or two hunters in a band. On their successful days others would reach repletion from their income with little room to consume game taken at the same time by additional hunters. If some hunters scored almost every day those men might acquire the number of dependents their predictable returns could support, leaving little for others to feast on, and so little reason for others to encourage their hunting. Under such low daily variation hunting would no longer be showing off. However, where hunting continued to be a high-risk strategy, with unsynchronized daily income among hunters, a decline in the frequency or size of hunters' bonanzas would be expected to lead to a decline in the rewards for hunting given by companions. The survival advantage to children of hunters and the fatherhood hunters could gain through the wives of gatherers would decline. With this the proportion of provisioners would increase. Since each woman with a provisioning husband would have more children, this could mean that the total number of children would increase. The model shows how declining hunting success could lead to increasing population growth. Implications for paleolithic demography and population growth at the mesolithic transition may be worth pursuit (see Harris 1977; Cohen 1977). Paradoxically, the model shows how a population may have rates of growth lower than those which might be supported by its resource base, not because individuals in those populations are depressing their fertility to conserve resources (e.g. Harris 1977) but because by maximizing their own relative reproductive success individuals prevent the stability of strategies which, if widely maintained, would give "everyone" more surviving offspring.

Conflicts of interest among individuals, as modern behavioral ecology attests, have profound implications for social behavior. For modern humans and our hominid ancestors foraging strategies may be shaped not only by the food income they earn (measured as mean rates of gain) and the opportunity costs they exact (e.g., incompatability with predator avoidance, or with child care) but also by the benefits beyond familial consumption which could be earned by foragers with varying distributions of daily foraging income. While men may sometimes hunt to provision themselves and their close kin, other potential benefits could flow to them for pursuing high-risk strategies which result in unpredictable but occasionally large daily incomes. If these high total days represent frequent consumption gains to potential companions so that companions provide mating access and differential treatment of offspring to encourage their continuation, men might serve their reproductive interests better by choosing not to provision their families. If so, describing the differentiation of resource acquisition patterns along sex lines as a "sexual division of labor," which implies deployment of a work force to serve the production goals of a family or a larger group, may obscure the extent to which individuals pursue tasks to serve their own ends. These strategies could play a role at least as important as mean rates of gain and child care requirements in patterns of resource procurement and the way they vary over time and space.

ACKNOWLEDGMENTS

I thank N. Blurton Jones, M. Borgerhoff Mulder, R. Boyd, E. Cashdan, E. Charnov, P. Draper, K. Hill, A. M. Hurtado, H. Kaplan, D. Metcalfe, J. F. O'Connell, A. Rogers, and E. A. Smith for generous advice.