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FORAGING RETURNS OF !KUNG ADULTS AND CHILDREN: WHY DIDN'T !KUNG CHILDREN FORAGE?

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Children of the hunting and gathering !Kung San seldom foraged, especially during the long dry season. In contrast, children of Hadza foragers in Tanzania often forage, in both wet and dry seasons. Because we have argued that the economic dependence of !Kung children has important consequences, we must try to understand why they did not forage. Experimental data on foraging by !Kung adults and children show that children would have had to walk far from dry season camps to acquire much food. Interviews suggest that !Kung children risk getting lost if they wander unsupervised into the bush. Thus, foraging without adult company was a poor option for !Kung children. Foraging with adults might have been a better strategy. We calculate the benefits to a !Kung mother if her oldest child accompanied her to the nut groves. Because of the high processing costs, a child's work time was most profitably spent at home cracking nuts.

MANY SCHOOLS OF anthropology attach importance to the subsistence infrastructure of a population. While the subsistence ecology of the !Kung of northwestern Botswana stood for two decades as one of the best described (Lee 1968, 1969, 1979) and as a landmark in quantitative anthropology, it may still be possible, even though the circumstances of !Kung lives have changed greatly, to supplement this earlier descriptive material. We present some figures on the rates at which !Kung women acquired food in 1988 in habitats and plant communities described by Lee in 1965 (Lee 1979). The data were gathered with a specific question in mind. We had argued that for the !Kung, the work involved in feeding children constrained women's lives and indirectly limited their fertility (Blurton Jones and Sibly 1978; see also Harpending 1994; Blurton Jones 1994). But we had seen children forage successfully among the Hadza hunter-gatherers of the wooded savanna of northern Tanzania (Blurton Jones, Hawkes, and O'Connell 1989). So it seemed essential to find out why !Kung children were not persuaded or permitted to forage and thus relieve their mothers of at least a part of their burden.[1]

Some general patterns in the cross-cultural variation in child work have been described, leading to the widely held view that while children in agricultural societies do much useful work, children in hunting and gathering societies do little or none (Barry, Child, and Bacon 1959). Thus we tend to take it for granted that children of hunters and gatherers do no work, gratefully receiving the sustenance, care, and attention often lavished on them by adults (see, e.g., Briggs 1970; Konner 1976). But this orthodoxy was strikingly challenged by the Hadza. This exception, even if only a single case, reminds us that explanation by categorization can never be satisfactory. What is it about hunter-gatherer life that leaves children in some populations doing no work? What is it about other populations that results in children foraging? Why do some hunter-gatherer children forage more and others less?

In fieldwork on the Hadza, we have approached the question of children's work and its relationship to fertility, child care, and the relations between the sexes from the perspective of behavioral ecology. This perspective (though far removed from Western culture's commonsense concepts of causes of behavior) has been highly productive in research on hunter-gatherer and other "traditional" societies (Smith and Winterhalder 1992). From this perspective we expect parents to allocate resources between care of offspring and the generation of more offspring so as to maximize the number of the parents' descendants in subsequent generations (see, e.g., Lessels 1991; Smith and Fretwell 1974). Thus we share with earlier perspectives the expectation that if children work, they are easier to feed and keep alive, and parents will divert more of the available resources away from child care and toward bearing more children. Furthermore, we expect that this potential advantage to the reproductive success of parents would mean that whenever children could feed themselves safely, they would be encouraged to do so. Thus when they do not work and are actively discouraged from trying, we must expect there to be some practical reason. Seen from the view of the child, in a context where even the leisurely !Kung are described as showing "some mild undernutrition" (Truswell and Hansen 1976:171) and where the fieldworker never sees a child refuse an offer of food, it would not be surprising if children helped themselves to any food that was available without too much effort or danger. On these grounds again, we should as well ask, Why don't they forage? as Why do they forage?

Many authors have claimed that where children can do useful work, fertility is higher, and where they cannot, it is lower (e.g., Caldwell 1982). Blurton Jones et al. (1992) and Blurton Jones, Hawkes, and Draper (1994) claimed that several reported differences in the reproduction and behavior of !Kung and Hadza adults can be predicted from the difference in apparent costs of diverting resources from feeding children toward bearing more children. If we are claiming to explain so much from children's foraging opportunities, we are obliged to show why Hadza children forage so frequently and why !Kung children forage so seldom. Until we do this, our particular behavioral ecological edifice for explaining differences between the Hadza and the !Kung is built on sand.

In this paper we report data gathered in mid dry season 1988 to examine the benefits that might arise from !Kung children foraging, first, unaccompanied by adults, and, second, in the company of adults. We aimed at a simple disproof of the hypothesis that the difference between the time !Kung and Hadza children spend foraging can be explained by the costs and benefits of foraging in their respective habitats. If we found that !Kung children could have obtained much food near camp, suffered minimal risks from the quest for food, or could have increased their food intake by accompanying mother on foraging trips, yet still did not forage, our hypothesis would have fallen into immediate trouble. We will show that it survives these initial tests.

Lee (1979:71) proposes a completely different view of !Kung children's foraging, which we discuss in some detail in Blurton Jones, Hawkes, and Draper (1994). He suggests that children forage when the producer:dependent ratio is low and that most of the time, in most camps, children represent an "unutilized reserve of labor power."

BACKGROUND: THE !KUNG AND THE HADZA

The !Kung, living in northwestern Botswana, have been the subjects of many cultural, archaeological, biological, and demographic studies (e.g., Lee 1979; Shostak 1981; Yellen 1977; Howell 1979). The Hadza of northern Tanzania have been described by Obst (1912); Woodburn (e.g., 1968a, 1968b, 1988); O'Connell, Hawkes, and Blurton Jones (1988, 1991, 1992); Hawkes, O'Connell, and Blurton Jones (1989, 1991); Blurton Jones, Hawkes, and O'Connell (1989); and Blurton Jones et al. (1992). The !Kung and Hadza live 2,500 km apart and are culturally distinct. Claims of links between Hadzane and Khoisan languages by Bleek (1931) and others are not uniformly accepted by modern linguists and are the subject of ongoing investigation (Sands, Maddieson, and Ladefoged 1993); Hadzane remains one of the few languages whose affinities are unknown. Nevertheless, there are many similarities between the two populations. People in both populations live, or until recently lived, in small, mobile bands composed of about fifty people, most related by kinship or marriage. Neither group kept domestic stock or raised crops; men hunted with bow and poison arrows, and women gathered, with occasional help from men. Many of the same plant and animal genera or species were exploited by each population. Both groups lived in dry savannah and made frequent moves, either in search of food and water or to resolve disputes. Both groups live at a very low population density (!Kung, 0.042–0.08/km^2; Hadza, 0.24–0.3/km^2 [Blurton Jones et al. 1992]) with usually a substantial distance between neighboring camps. In both, infants are carried by mother most of the day and suckled frequently. Diarrhea is a common cause of death of young children in both societies, and many adults and children contract malaria. Children interact with children of a wide range of ages, having rather few exact age mates in a camp. In both cases, the same species of predators are quite abundant in the bush, making foraging by children a potentially risky enterprise. The Hadza and !Kung (while they were living as mobile foragers) each depended on standing surface water in the rainy season, and both faced reduced numbers of watering places in the dry season.

While similar in the above respects, important differences also exist, and we argue that ecological differences account for differences in the returns on children's labor. Conditions are generally less harsh for the Hadza. Water sources are more numerous and near to food sources, the daily maximum temperatures are lower, resources such as baobab trees are much more abundant in Hadza country (up to 32 trees/km^2), but there are no mongongo nut trees. The completed fertility for the two populations is different: Hadza women average 6.2 births (Blurton Jones et al. 1992), whereas postreproductive !Kung women reported 4.7 births (Howell 1979). The average stature of !Kung men and women is 161 cm and 150 cm, respectively, and their respective average weight is 47.9 kg and 40.08 kg. The figures for Hadza are: men 161 cm, 54.3 kg; women 150 cm, 48 kg (Hiernaux and Hartono 1980). The greater robustness of the Hadza (especially the women, as discussed by Hiernaux and Hartono) seems to indicate more favorable conditions.

Since the 1970s, !Kung in the Dobe area have linked their fortunes more and more closely to Herero and Tswana herd owners who have settled the area. They rely less on bush foods, sometimes grow small gardens, and sometimes receive government food aid. Furthermore, the number of livestock in the area has increased steadily, and some are owned by !Kung. The degradation of the environment around contemporary settlements is striking, especially to those who had visited the area in the late sixties or early seventies. Solway and Lee (1990) suggest that the degradation extends far afield, which questions the relevance of research in the 1988 environment to understanding foraging in the 1950s and 1960s. This question took high priority in our data collection and is examined at length in the Appendix.

Since the sixties, the Hadza have been subjected to a series of attempts to make them settle and forsake the foraging lifestyle. These episodes were mostly short lived, and at no time have all Hadza left the bush. But on the other hand, there are probably no Hadza without experience of settlement life. Contemporary Hadza seem to switch easily and instantly between settlement and bush but require inducements such as plentiful free food to make them move to a settlement.

Foraging by Children

Since the comparison of Hadza and !Kung children's foraging motivated this fieldwork, we summarize the evidence for a difference in Table 1. The best

TABLE 1
Months with Data on Foraging by !Kung and Hadza Children

	J	F	M	A	M	J	J	A	S	O	N	D
!Kung	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3, 4	2, 3	2, 3	2, 3		
Hadza	5	8	5 8	5		5	5	5 6	5 6 7	5 6 7	5 7	5

Note: Numbers in body of table refer to notes 2–8 below. Rainy months are shaded.

1. !Kung rainfall data from Yellen and Lee 1976 (Figure 1.1); annual rainfall 239 mm, 597 mm, 378 mm (mean 405 mm); some falls in April and May. Hadza rain seasonality from Woodburn 1964 and personal observation. Rainfall is heaviest in December–January and May. Annual amounts are not well documented.
2. Draper 1976 (Table 9.1). Child out of camp in 8 of 76 spot observations of girls (7 gathering with women; 6 of these under 3 years old). Child out of camp in 18 of 93 spot observations of boys (6 were boys over 11 out with men; 7 were with women, mostly still carried by mother).
3. Draper and Cashdan 1988. Girls spent 0.6 minutes per 10-minute observation gathering or collecting water or processing food; boys spent 0.2 minutes.
4. Lee 1968, 1979 (Table 9.3). Children foraged on 4 out of 244 child-days.
5. From 1985–86 Hawkes and O'Connell spot observations and follows of adults. During June, nuclear families pursue honey almost daily. Hawkes, O'Connell, and Blurton Jones (1989) report children and women collecting berries during October, March, and April.
6. August–October 1986 (Blurton Jones, Hawkes, and O'Connell 1989). Children foraged or processed food in 50% of the one-hour follows. Children aged 5–10 brought home 729 kcal/day; aged 11–15 brought home 1,526 kcal/day. Baobab fruit and makalita roots. Berries ripened in mid-November.
7. September–November 1988 (Hawkes, O'Connell, and Blurton Jones n.d.). On 47% of days children aged 6 and over accompanied adults on day-long trips to forage on *Salvadora persica* and *Cordia gharaf* berries at distances up to 5 km from camp (31% of days in September, 52% in October, 42% in November). Berries were collected at a rate of 1,045 kcal/hr. in patch for *S. persica,* 2,089 kcal/hr. for *C. gharaf.*
8. January–March 1989 (fieldwork by Blurton Jones). Children foraged or processed food in 45% of one-hour follows. Children aged 5–10 brought home 660 kcal/day; aged 10–16 brought home 1,673 kcal/day. Makalita and panjuko roots, baobab fruit, nestling weaver birds. A few Cordia berries were ripe.

evidence that !Kung children seldom foraged is given by Draper's ten months of quantitative observations on children aged 2–14 (Draper 1976; Draper and Cashdan 1988). We must note that her observations on forager !Kung were from the /Du/da area, where there are fewer mongongo nuts (elsewhere the staple plant food), but her conclusion is supported by numerous comments in the ethnographies. The 1988 interviews with !Kung adults (Blurton Jones, Hawkes, and Draper 1994) confirmed this and other points with little prompting: !Kung children only foraged when food was so close that they could be kept in sight; usually food is far away from camps, which are near water. Adults said they scared children into staying in camp and away from going in search of food because the bush was dangerous. They said that taking children along on gathering trips "spoiled the work," explaining that children got tired and thirsty and held the adults back. !Kung children were more likely to forage in the rainy season, when temporary water could be found during a day's outing. Further, during the rainy season, entire camps relocated away from permanent water; children could then forage near home and not lack water. Nevertheless, during most of the year and in most localities, !Kung children did very little foraging and were dependent upon adults for their food until they were in their mid-teens.

Our field data on the Hadza (Table 1) are supported by most previous observers (the usual comment is, "women and children set off to gather berries, roots or baobab fruit" [Obst 1912]). More recently, Hadza informants in all Hadza regions reported that children forage successfully. Hadza children (and women) seem to have a particular food in mind each time they leave camp, and dominant foods differ with season, location, and year. We have data on Hadza children foraging with and without adult company and on several resources. Because of the many brief and highly variable seasons of the Hadza environment (for example, Salvadora berries ripened in September 1988, October 1982, and November 1986), complete information on Hadza foraging will take many years to accumulate, but it should be clear that Hadza children forage more than !Kung children.

Deriving Hypotheses about !Kung Children's Foraging

We have shown that observers and informants agree that !Kung children did little gathering work, and thus they were almost entirely dependent upon adults for food. Adults further assert that they actively dissuaded children from gathering (Blurton Jones, Hawkes, and Draper 1994). These data, do not, however, give the economic value, real or potential, of children's work. The question is, Would !Kung have been better off (in the calculus of costs and benefits) if children worked? Cost-benefit analyses rely on arguing that what individuals don't do gives worse outcomes than what they do do! The question, What would happen if they did something else? can best be answered by experiment.

We propose that alternatives to encouraging children to stay in camp, such as allowing them to forage without adults or inviting them to come to the nut grove, yielded too little gain in food to outweigh the costs entailed. Thus we must assess consequences of such alternative strategies. We consider (1) children foraging unaccompanied by adults, as Hadza children often do, and (2) children accompanying adults to the mongongo nut groves on trips similar in distance to the trips Hadza children take with adults to berry patches.

Differences between the flat, featureless, scrub-covered countryside in which the !Kung live and the undulating, landmarked country of the Hadza led us to expect that unaccompanied !Kung children may be unable to find their way home. In Blurton Jones, Hawkes, and Draper (1994), we report interviews of !Kung adults that showed the hazards of unaccompanied children getting lost in the bush. In a recent series of interviews with Hadza adults, very few expressed the view that children could get lost; most indignantly denied that this could happen. Lee (1979) and Yellen and Lee (1976) described the distribution of plant communities in the Dobe area as a series of parallel bands stretching east-west across the countryside (see Figure 1, below). The most productive habitats were far from permanent water, and even these became depleted as the dry season progressed. Thus we proposed that unaccompanied children in the Dobe area faced an unfavorable trade-off between the likely gains in food

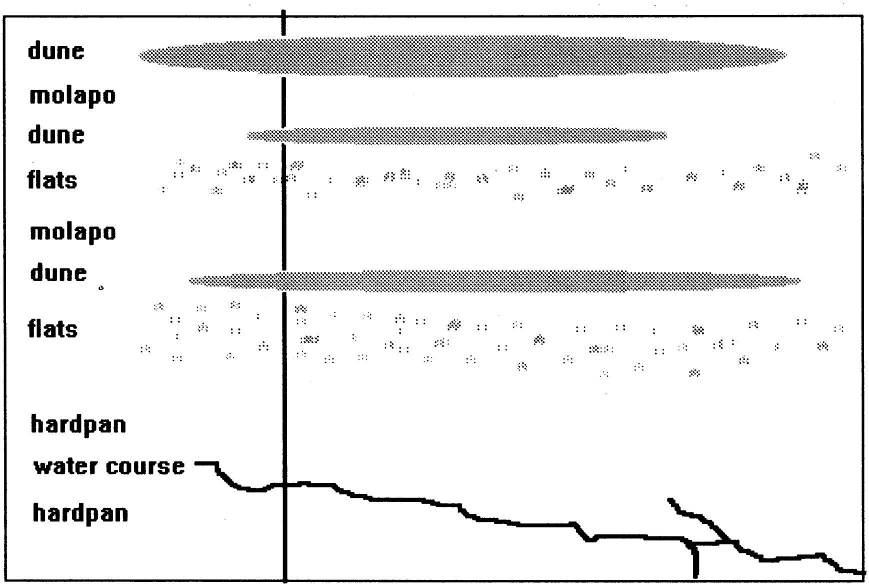

Figure 1. Schematic Map of the Dobe Area Illustrating Parallel Distribution of Habitats and Resources

Mongongo nuts grow on stabilized dunes ("dune"), Grewia berries on "flats." Molapo refers to low areas that hold water in the rainy season but are comprised of hard unproductive soil in the dry. "Hardpan" is the thin soil over the calcrete base of the valleys that sometimes channel substantial water during rain and underground water in the dry season. The nine permanent water sources in the Dobe area are found where the calcrete has been penetrated by human or other action.

intake and the costs arising from the distance they had to travel to get significant food returns. The farther they went, the longer they were exposed to the risk of losing their way, exhaustion and thirst, or encounters with dangerous animals. We proposed to measure food returns at different distances from the shallow "valley" that holds permanent water (Experiment 1). These measurements could disprove our hypothesis—food may be plentiful nearby.

We propose that children who forage in the company of adults have no risk of getting lost and negligible risk from predators. !Kung adults complained that children get tired and thirsty and slow their journeys, but Hadza children often go 5–6 km each way with adults. We measured the rate at which children and adults crack mongongo nuts so that we could investigate the economics of nut collecting and processing (Experiment 2). We compare the rate at which a woman and child would make food available for consumption if a child over age 8 accompanied its mother to the nut grove with the rate achieved if the child stayed home and cracked nuts from time to time. Processing mongongo nuts is quite time consuming, and they cannot be eaten until they are cracked. Lee reports that children over age 8 crack nuts for themselves and younger siblings. Since mongongo nuts are still used by !Kung, it was safe to assume that today's children would be as experienced and competent at this art as in bygone times.

The experienced ethnographer will doubt that a series of experiments conducted in one field season can inform us about longer term conditions. We went to great lengths to check the relevance of our measures to the context that interests us: the !Kung and their dry season habitat up to the early seventies as described by Lee and by Howell (1979). In addition to local and temporal variation, the environment may have been so modified by the increased population of livestock (Solway and Lee 1990) that our results would be misleading. We describe our efforts to deal with these issues of validity in the Appendix. Experiment 1 assumes that the experimental foraging returns reflect availability of food. To test this, we surveyed food available in a series of quadrats at different distances from the valley (see Appendix: Experiment 3).

EXPERIMENT 1: FORAGING EXCURSIONS

We did not want to find out where or how much !Kung are foraging nowadays but to measure what children and adults could have acquired if they had gone different distances from dry season camps. The distribution of the plant communities and habitats in the Dobe area is a series of bands, running roughly east to west and roughly parallel to two main valleys in which most of the nine permanent water sources are found (Figure 1). It seemed appropriate to sample this countryside with a north-south transect of the dune-molapo bands to the north and west of Dobe, using the road along the fenced border with Namibia. A valuable opportunity to control for effects of livestock was presented by this barrier. The border fence, which !Kung are allowed to cross, but beyond which Bantu and their livestock had been prohibited for some years, formed an immense experimental enclosure. Livestock have destroyed the habitat in the immediate area of the now-permanent settlements. These settlements are located at permanent water in the two main valleys, referred to by Lee as the !Kangwa valley and the /Xai/xai valley. These shallow valleys have a rocky floor beneath which water stays underground all year-round. But the water is only accessible where the rock is broken through by human or other agency. By making our observations near the valley but a little away from settlements, we hoped we were sampling habitat representative of dry season camp sites but outside the zone of destruction around contemporary settlements. We drove people by truck to various points, let them forage there, and recorded what they collected.

Draper spread the news that we would like to take women and children to the bush to observe them gathering food. The response was enthusiastic, a major problem being to share this privilege evenly among the !Kung settlements located at and near Dobe. In all, fifty adults and teenagers and fifty-one children and infants participated in our foraging excursions.

Between five and thirteen adult women and teenagers, plus children, were collected up each day for a trip by truck to the bush. We measured the distance along the border fence by the truck odometer. The location at which we stopped for people to forage was sometimes determined by their requests and sometimes by our wish to sample the environment. On most days we went to one location by popular request and one location of our choice. Each time we stopped, we asked people to gather, and we gave each person a plastic bag into which to put the food and bring it back to us to be identified and weighed. We sent people to forage on a specified side of the border. We were helped by our field assistant Timon Mbatara, who spoke English and !Kung in addition to his Herero mother tongue. After people had been foraging for forty minutes to an hour, we called them back by sounding the car horn and shouting. During these foraging sessions, people walked away from the car but did not get much more than half a mile away. After weighing, the food was given back to the person who collected it. People invariably took the food home with them.

Groups of people foraged for twenty-one sessions on the Botswana side and thirteen sessions on the Namibia side. Some sites were visited more than once (e.g., the farthest nut groves). The locations were reasonably well distributed by distance, between 1.5 km south and 17.5 km north of our point of origin at the watercourse, and by altitude, habitat, and soil type (dune, flats, molapo, and hardpan). Excursions to other locations, including a series around /Xai/xai, are described in the Appendix and suggest that our main transect represented a substantial portion of the environment.

The calorie value of each person's collection of food was calculated from its weight and the figures in Table 2. We have been unable to find a caloric value for tree resin (gum) collected and eaten by !Kung. Small amounts were collected during our excursions, especially where other foods were scarce.

The mean "on-site" returns at each distance (calorie value of the food collected per hour gathering at the experimental location) are shown in Table 3. The yields of each adult and teen are marked in Figure 2. (If !Kung children

TABLE 2
Calorie Values of Main Foods Taken in July–August 1988

Name	Kcalories per 100 gm eaten	Kcalories per gm collected
Mongongo nut	654	0.949
Marula nut	642	0.949 (1)
Tsin bean	544	3.808
!Gwa berry	293	1.46
N/n berry	227	1.13
Other berry	--	1.3 (2)
/Tan root	47	0.47
Water root	31	0.31
Sha root	79	0.79
Other root	63	0.63 (3)
Bitter melon	21	0.105 (4)

Note: Column 1 from Lee 1979 (Table D.1). Column 2 calculated from edible portion as fraction of amount collected (see Lee 1979:Chapters 6 and 7, Appendix D). Plant names as in Lee 1979.

1. We have no data on the edible amount of marula nuts per weight collected. It is probably less than for mongongo nuts, and processing time is probably longer; but we have conservatively estimated it as the same as for mongongo nuts.
2. Other berries are assumed to be halfway between the figures for !gwa and n/n. Few other berries were taken, so errors will not be large.
3. Other roots are assumed to be halfway between the figures for sha and /tan, assuming water root to have an unusually high water content. We have assumed that little root is discarded, which slightly inflates kcal/gm collected.
4. We used estimates of amounts of melon eaten by our experimental subjects; substantial rind is always discarded.

TABLE 3
"On-Site" Returns from Experimental Foraging Excursions

Km north from water course	Habitat	Botswana N	Botswana kcal/hr	Namibia N	Namibia kcal/hr
-1	Molapo	8	37.5	7	34.4
1	Molapo	9	54.7	7	5.8
2	Flats	5	131.0	5	115.4
3	Flats	13	295.9	9	353.3
4.1	Flats	12	346.3	8	0
5.7 - 5.9	Dune	22	330	8	253
7	Molapo	5	694.2	5	748.4
9 - 9.5	Flats	17	482	12	629.5
9.6 - 9.9	Flats	7	655.0	11	561
11	Flats	9	374.8	9	274.6
13.3 - 13.9	Dune	7	1596	13	3055
14.4	Flats	9	621.4	9	560.1
15.8	Dune	11	5219.9	0	-
17.2	Dune	7	4015	0	-
17.9	Dune	5	1962	5	722
18.6	Dune	11	1769.2	0	-
18.9	Flats	9	597.2	0	-

Note: Returns are expressed in mean kilocalories per hour per person. N = number of adults and late teens in sample.

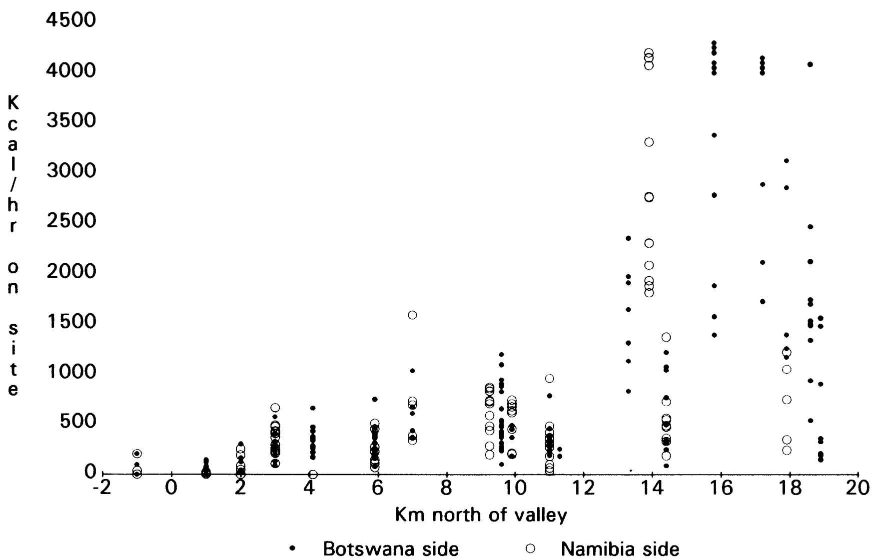

Figure 2. "On-site" Returns Obtained by Adults and Teenagers during Experimental Foraging Sessions

Each point is one person's haul at one location on one occasion. Values greater than 4,000 are rounded down to around 4,000–4,500 to aid scaling the diagram.

only forage a little in the wet season, their performance in the experiment might reflect lack of expertise, not an unbountiful environment, so we ignored our data on acquisition rates of !Kung children. This biases against showing the results that we expect.) These initial figures exclude processing time. They were converted to returns for hypothetical foraging trips in which people would have walked from the valley (at km zero) and subsequently spent time processing the food. To minimize the effect of journey time, we assumed maximum possible daylight trip durations (twelve hours), from which we subtracted journey time (round-trip distance ÷ 4 kph walking speed) to give time in patch during which resources were acquired at the rates we observed in each locality. We subtracted nothing for energy used in walking. We used Lee's (1979:198) data on processing mongongo nuts (and our data from Experiment 2, which closely match Lee's). This nut-processing time is extensive (0.833 hours per kg of mongongo nuts collected plus time for roasting the nuts) and is probably more for marula nuts. To judge from Lee's accounts, processing time is moderate for berries and fairly brief for roots. We treated time spent processing roots and berries as zero.

The results, foraging returns with travel and processing time included, are shown in Table 4 and Figure 3. These returns are measured in a way closely comparable to the return rates reported in Blurton Jones, Hawkes, and O'Connell (1989) for Hadza children (which were obtained from follows of spontaneous

TABLE 4
Kilocalories per Hour of Work, Including Travel and Processing Time

Km	Habitat	Kcal/hr on site	Total kcal collectible in daylight hours	Kcal/hr including travel and processing[1]
−1	Molapo	36	414	34
1	Molapo	33	379	32
2	Flats	123	1353	113
3	Flats	319	3349	279
4.1	Flats	346	3443	287
5.9	Dune	311	2815	189 (727)[2]
7	Molapo	721	6128	511
9.5	Flats	555	4024	335
11	Flats	350	2275	189
13	Dune	2325	12787	542
14.4	Flats	591	2837	236
17	Dune	2738	9583	462
18.9	Flats	597	1522	127

Note: Calculated from mean calories per hour "on-site" at each distance sampled.

1. Calculation of foraging returns (including time to walk to patch and return and processing time).
   Calculation for nuts (processing time 0.833 hours per kilogram plus 0.33 hours for roasting load of nuts; collecting time maximized by allowing 12-hour excursions):
   a. Calories per hour in patch
   b. Grams collected per hour
   c. Distance in kilometers (odometer or map)
   d. Time to patch and back at 4 kph [(c × 2) ÷ 4]
   e. Time in patch if all daylight hours are spent foraging (12 − d)
   f. Kilograms collected (e × b)
   g. Time to process this many kilograms of nuts (f × 0.833)
   h. Total time gathering and processing (12 + g) + 0.33 to roast whole load
   i. Calories obtained in the 12-hour excursion (a × e)
   j. Calories per hour (i ÷ h)
   Calculation for other foods (berries and roots; processing time ignored, but collecting time maximized by allowing 12-hour excursions):
   a. Calories per hour in patch
   c. Distance in kilometers (odometer or map)
   d. Time to walk to patch and back at 4 kph [(c × 2) ÷ 4]
   e. Time in patch if all daylight hours are spent foraging (12 − d)
   i. Calories obtained in the 12-hour excursion (a × e)
   j. Calories per hour (i ÷ h)
2. Intentionally inflated figure obtained by using the "on-site" returns recorded in the dunes at 13 and 17 kilometers.

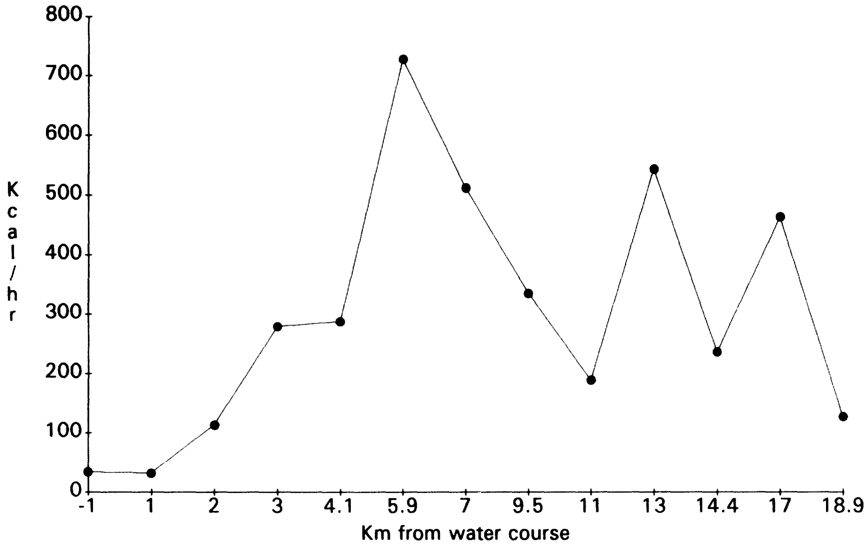

Figure 3. Returns in Calories Acquired per Hour of Foraging and Processing for Hypothetical Foraging Trips to Different Distances North of !Kangwa Valley

Data from Table 4.

foraging excursions). In Figure 3 we inflate one !Kung data point—returns for trips to the Dobe nut grove—by using in-patch rates from more distant groves, lest Dobe is more heavily depleted these days because so many people have donkeys to carry nuts. There is a clear trend for "on-site" returns to increase with distance from the valley. Many more calories were collected per hour from dunes (nut groves) than from flats. Returns including travel and processing time showed an increase in returns with distance for the first 7 km or so but declining returns as journeys of over 20 km round-trip are involved.

Conclusion from Experiment 1

Food was gathered at a greater rate at locations far from the valley, the only source of dry season water. There was no consistent difference between the Botswana side and the Namibia side of the border (see Appendix). The rate of return from foraging excursions near the valley was very low. When travel and processing time is included, the return rate nowhere exceeded 730 kcal/hr.

EXPERIMENT 2: PROCESSING MONGONGO NUTS

We want to know why !Kung children seldom accompanied adults to the nut groves from dry season camps. Would there have been a material advantage or disadvantage if children went to the nut groves? Would a woman make edible calories available to her children at a greater rate if she took her 8–year-old with her to the mongongo nut grove or left it home to crack nuts for itself and younger siblings?

The mongongo nut is well known to anthropologists as the staple plant food of the !Kung. Less celebrated is the cost of this food, especially its processing, described in detail by Lee (1979). The nut has an outer layer, edible early in the season, but the main nutritional benefit comes from the kernel; to reach this the nut must be cracked open. Lee (1979) reports that children over about 8 crack most of the nuts that they eat, and they have been observed gathering nuts during the rainy season when families were camped in nut groves. But accounts seem to agree that children did not accompany women to the nut groves during the dry season. Since we have observed Hadza children making trips of 5–6 km to berry groves accompanied by adults, we need to examine the possible consequences of !Kung children accompanying adults on trips to the nut grove during dry season. Experiment 1 gave data on children picking up nuts in the grove. In Experiment 2 we tried to measure how rapidly children, teenagers, and adults cracked mongongo nuts. We use the results and other figures from Lee (1979) to calculate the rate at which edible calories can be made available to children.

Procedures and Results

We timed thirty-one people cracking mongongo nuts: eight adults, six teens (estimated age 14–17), and seventeen children (aged 5–13, mostly 9–13). Nuts were collected, usually by our assistants, sometimes also by us. They were roasted by our !Kung assistants, as is usually done to prepare them for cracking (Lee 1979). We counted out 20 nuts and weighed them. They were then handed to the subject, who was seated with suitable rocks that had been selected by our !Kung assistants. The subject was timed cracking the nuts until he or she had finished. Two small boys were given only 5 nuts. One was stopped when it was clear that, even though encouraged by his mother, he could not safely crack any. The other took nearly eight minutes to crack his 5 nuts. Both of these subjects are omitted from the child figures discussed below. The discarded shell and nut flesh kept for consumption were weighed. Six adults cracked on average 314 nuts/hr.; the six teens, 241 nuts/hr.; and seventeen children, 120 nuts/hr. Boys and girls cracked at the same rate.

Two adults (an old, but active, man and N/isa Kxau, our energetic assistant in Experiment 3) were given 100 nuts to crack, and they worked much more slowly than the adults and teens given only 20 nuts (180/hr. versus 314/hr.). The rates for teens and adults given 20 nuts to crack are comfortably close to Lee's "200–300 nuts per hour" (Lee 1979:198), but the slower pace of the adults given 100 nuts to crack suggests that we should not expect anyone to process large numbers of nuts at the highest speed. Lee's instance (1979:198) of a woman cracking 558 nuts in 156 minutes is a rate of 215/hr. Below we use 200 nuts/hr., or 1.2 kg/hr. for adults.

Some of the children were not required to process the inner shell (it seemed to be difficult for them). A subsample was asked to do this. They processed only 100 nuts/hr. (631 g/hr., 599 kcal/hr.). We also doubt whether children would keep up the speed that we recorded for more than a few minutes at a time. A reasonable estimate for children's nut processing seems to be 500 g/hr. If the children are ranked by relative age, there appears to be a gradual increase with age to the teen rates above 1 kg/hr.

In the calculations reported below, we use the following values. Mother carries 12 kg of nuts home from the nut grove. One kg of unprocessed nuts yields 949 edible calories after processing. The round-trip to a nut grove takes three hours. Adults gather nuts at just under 10 kg per hour (12 kg in 1.25 hours), a much higher rate than we observed in 1988. Lee (1979:193) estimates that collectors can gather 20–30 fruits/minute, collecting "a few kilograms of whole fruits" "every 20 minutes or so" and adding these small loads to a central pile. He estimates that three to five such small loads make a full backload of "10–15 kg of whole fruits." Our calculations show that the rate at which nuts are picked up has little effect on the calories acquired per hour of food gathering and preparation. Nuts are normally roasted before cracking. We assume, based on our timed observations, that a 12 kg load takes 0.33 hours to roast. We assume that children do not have to roast their own nuts; they are roasted along with mother's. We assume that children pick up nuts at the adult rate.

Two Possible Nut-Harvesting Strategies

Would we expect an 8-year-old child, who can crack mongongo nuts at about 500 g/hr., to go to the grove to help mother gather nuts or stay home? A !Kung child who brought home about 2.5 kg of nuts (a little more than the load of berries we observed Hadza children carrying) and processed them itself would be almost self-sufficient in plant foods, and its mother could use her load to feed younger children. Children over 8 might be able to carry more than 2.5 kg, and below we explore the payoff from carrying loads up to 10 kg. But a child who stays home and cracks nuts saves its mother some time. Which strategy works out best? Do !Kung parents and children follow this strategy?

Within our paradigm, "best" refers to the reproductive-economic interests of individuals. Mother gains by maximizing the rate at which she makes food available for consumption by herself and her children. The child receives a reproductive-economic benefit from increasing its own food intake and (according to kin selection) from increasing the food intake of younger siblings and mother in so far as this enables mother to provide more sibs. The interests of mother and child do not completely coincide (Trivers 1974); the child's fitness benefit from aid to sibs will be less than mother's benefit. We might generally expect the child to work less than would maximize mother's gain, but in the present instance, more work may directly help the child as well as mother.

Thus we assess "team returns," the benefits in kilocalories made available for the children to eat, and the costs in time. We do not add together mother's work time and child's work time but compute the time that elapses to make food available: time spent on the journey, picking up nuts, roasting them, and cracking them. We call this "elapsed time"—the work time from mother setting off to the nut grove until the last nut is cracked and available to eat. We look to see which strategy makes food available to children most rapidly, measured as kilocalories per hour of elapsed time. Lee (1968, 1979) reports that women went to the groves roughly every two to three days, not daily. Our calculations fit well with these observations: no one could crack a full load of nuts on the same day as she gathered them. It takes another one to two days, unless people work very hard dawn to dusk, and we assume they have other worthwhile activities to pursue. Our models also show that increasing the weight of nuts mother brings home increases mother's kilocalories per hour very little once the loads pass 12–15 kg, close to Lee's reported normal loads of 10–15 kg (Lee 1979:193). This implies that the few kilograms a child adds may not be very useful—the nuts still have to be cracked.

Our calculations are illustrated in Table 5. A child who goes to the grove and carries back some nuts (a "carrier") increases the team's income—the total weight of nuts brought home. A child who stays home and cracks nuts (a "stay-at home") saves mother time and reduces the costs—the team's elapsed time. We used two very similar models to examine this trade-off. Our first model considers only the approximately five hours it would take for a child to go to the grove and back. We assume that carriers and stay-at-homes behave in the same way the rest of the time (and our conclusion is not affected by whether we assume children do any cracking during the time when mother and child are both at home). During the five hours, the carrier child brings home a specified weight of nuts. This weight is added to the weight mother brought home (always 12 kg in these calculations). The stay-at-home cracks nuts at its specified rate for zero to five hours. This saves mother some time, calculated as the grams the child cracks in an hour divided by the grams mother cracks in an hour, multiplied by the hours during which the child cracks. This saving is subtracted from the time mother needs to crack her load of nuts. (Following the ethnographies and our informants, we assume that mother leaves children at home with some uncracked nuts.) Returns, in kilocalories per hour, are calculated from mother load plus child load (converted to kilocalories), divided by elapsed time, the time mother takes on the trip plus the time she needs to crack (which is shorter if she had a stay-at-home helper, longer if there are more nuts).

It turns out that at the values tested (1–10 kg carried by a child; stay-at-home cracks for 0–5 hr. at 500 g/hr., 750 g/hr., or 1,000 g/hr.), the time saved by the stay-at-home increases the team return rate more than the extra calories brought home by the carrier. We calculated the hours of cracking needed for the stay-at-home to match the return rates achieved by a carrier who brings 1–10 kg home. A child who cracks at 500 g/hr. (our estimated rate for 8–10 year olds) must crack for 3.23 hours to match one who carries home 5 kg of nuts. Only if the carrier can bring home 10 kg does the child make better use of the 5 hours spent on the trip than a stay-at-home could.

As the child grows up, it can presumably carry heavier loads and could bring home more. Intuition would suggest that there should thus come an age when

TABLE 5
"Team Returns" from Mongongo Nuts

	Mother	Carrier	Team 1	Stay-at-home	Team 2
Child work hr		5		5	
Journey out	1.5	1.5	1.5	0	1.5
Collect	1.25	1.25	1.25	0	1.25
Load (kg)	12	5	17	0	12
Journey home	1.5	1.5	1.5	0	1.5
Roast nuts	0.33	0	0.33	0	0.33
Hr Child cracks		5 - 4.25=0.75		5	
C saves (1)		.42 x .75 =.31		.42 x 5 = 2.1	
M crack	10		14.2 -.31 = 13.89		10 - 2.1 = 7.9
Team time (2)			18.44		12.48
Kcal	11388	4745	16133	0	11388
Kcal/hr			875		912

Note: Calculations to see whether mother gets more help from taking her child to the nut grove or from leaving it at home. Team 1 comprises mother and a child who goes to the grove to carry nuts. Team 2 comprises mother and a child who stays home and cracks nuts for the same amount of time as the child in team 1 works. Both children crack at 500 gm/hr. Both mothers crack at 1,200 gm/hr. Team 2 gains the most kilocalories per hour of work.

1. Child saves. Time saved by child cracking nuts = child's cracking rate ÷ mother's cracking rate × hours for which child cracks; e.g., 500 ÷ 1,200 × 5 = .42 × 5 = 2.1 hours. This represents the time mother would have spent cracking the nuts that the child cracked.
2. Team time. This is the time from the beginning of the journey until the last nut is ready for eating. It is *not* mother's work time plus child's work time.

children begin to accompany mother to the grove. But our data on nut cracking by teenagers show us that as children age, they also get better at cracking nuts. The result is that children who crack at 750 g/hr. need only work 2 hours to match a child who carries 5 kg and for 3.33 hours to match a child who brings home 10 kg from its 5-hour trip to the grove. If they crack at 1,000 g/hr., they need work only 2.5 hours to match a 10 kg load. This leads to the surprising suggestion that there should never come a time when a child, even a teenager, accompanies mother to the nut grove. We are reminded of Lee's (1979:265) comment that "adolescent girls do not start regular subsistence work until marriage." After marriage, they presumably begin to have reproductive goals of their own, and they share their mother's goals less than when they were single.

The same conclusions arise from our second, basically similar model in which we calculate the consequences of children working from 5 to 15 hours on each load of nuts. We assess the whole period from mother departing until the last nut is cracked. (In this model it does not matter whether mother leaves nuts for children to use while she goes to the grove.) One child goes to the grove and brings back a load of nuts, which is added to the team load, but the duration of the trip uses up some of its total work time; the remainder is spent cracking nuts. The stay-at-home spends all its work time cracking. Cracking saves mother time, calculated as in the first model. The saving is subtracted from the time mother would need to crack the load of nuts. At long work durations and fast cracking rates, the mother's cracking time plus trip time is less than the child's work time. At this point, elapsed time must be set to the child's work time. At most values, this results in a lower return rate (because too much of the cracking is being done at the child's slow rate instead of at mother's faster rate). Thus there is an optimal duration of child work beyond which returns decline (Figure 4). This optimum is at a higher return rate and shorter duration for stay-at-homes than for carriers—8–10 hours in a two-day nut cycle, 4–5 hours per day.

As in the first model, it looks as if leaving the child home is the best strategy. This second model adds the conclusion that when the child stays at home, the team gets a greater increase in team returns from each added hour of child work than when the child goes to the grove. It also supports the suggestion that teenagers should stay home and that growing strength will not bring about a time when the child should switch to the carrier strategy. Conversely, both models suggest that if younger children crack nuts at a slower rate, but can carry, say, 5 kg of nuts, they would be expected to go to the grove. How would we explain why children aged 6–8 did not go to the grove? Our adult !Kung informants emphasized children's thirst and exhaustion. In the following we assume this exhaustion translates into slower walking and thus into a longer time for trips to the grove.

If the child slows mother down on her trips to the grove, we can calculate the consequences by adding to mother's travel time in the spreadsheet for

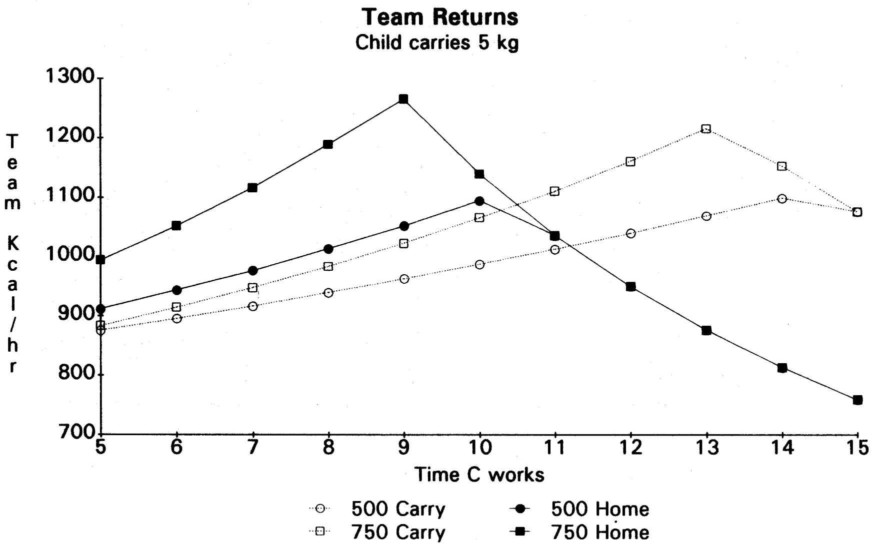

Figure 4. Kcal/hr. Made Available to Children

Kcal/hr. are plotted as a function of the hours which a child over 8 works at each of two strategies: accompanies mother to nut grove and carries 5 kg nuts home (dotted lines); stays home and cracks nuts for self and persuasive siblings (solid lines). A pair of lines is shown for children who crack nuts at 500 g/hr., and a pair for children who crack at 750 g/hr. (low teenage rate).

either model. Adding half an hour (a mere 15 minutes to each leg of the round-trip) lowers the team return rate by 25–30 kcal/hr. when the child goes to the grove. Adding an hour lowers the return rate by around 50 kcal/hr. Gains in team return per hour of child work fall further behind the rates achieved by leaving the child home. Even a child who can only crack at 400 or 300 g/hr. but can carry 5 or 2.5 kg does better to stay home if he slows mother down by about 20 minutes on the round-trip. Thus the informants may have pointed to exactly the aspect of nut economics which tips the balance in favor of leaving young children home.

We conclude that there is little support for the notion that !Kung mothers or children would have benefited from children accompanying adults to the nut grove. The reason has much to do with the relatively lengthy processing needed to make mongongo nuts edible.

DISCUSSION

The Validity of the Experiments

The Appendix deals with several important questions about validity. Livestock have destroyed bush foods around dry season camp sites, and Solway and Lee (1990:118) assert that the habitat has been degraded enough to "seriously undermine the foraging option." Could our data on food availability reflect availability in previous decades? Was local and annual variation so great that we could not generalize from our experiments? These are well-known limitations of short-run observations.

The ground near present-day settlements was almost bare, but we collected data away from settlements, sometimes near the valley, sometimes very far from it, and on each side of the border fence. We expected to find effects of livestock in our quadrats (Appendix: Experiment 3) and that these would diminish gradually to distances of 5–10 km from the valley. Similarly, we reasoned that foraging returns from the Namibian side of the border fence (where livestock were prohibited) would be much richer than on the Botswana side. We were wrong on both counts. The yields in Namibia were no higher than in Botswana. Quadrats with tracks of livestock did not consistently yield less food than quadrats without tracks. The negative effects of livestock were localized to the area within one kilometer or so of settlements. This outcome is surprising, but the evidence seems strong.

Returns from different localities support the general picture obtained from our main transect. Our simulation showed that variation in density of mongongo nuts lying on the ground would have little effect on the calories obtained per hour of gathering and processing nuts. The density of nuts on the ground affects the amount of time taken to collect a load, which is a small proportion of the total gathering and processing time. Travel and cracking comprise the main portion of the time required to move nuts from the grove to the mouths of a woman and her children. Our findings are, surprisingly, quite robust.

Children Foraging Unaccompanied by Adults

According to the literature, !Kung children seldom foraged. So first we asked, What would happen if !Kung children tried to forage without adult company from dry season camps in a habitat like that around the !Kangwa watercourse? We collected data on foraging by !Kung adults and children whom we took by car to a variety of locations. We showed that, just as our informants told us, more food is found far from watercourses. Our quadrat data closely matched the plant communities and soil types described by Lee (1979) and matched our foraging data. Our foragers had not ignored large and important sources of food. The soil types, drainage patterns, and underlying geology seem to be the reason for the distribution of food plants and the distance of the richer patches from permanent water.

We have already reported (Blurton Jones, Hawkes, and Draper 1994) the evidence that !Kung children who leave camp unaccompanied by adults run substantial risks of getting lost and, once lost, of dying of exposure. We assumed that the longer a child unaccompanied by adults spent out of camp and the further it went, the greater its risk of getting lost. Tracks recorded in our quadrats showed that risks of encounters with predators did not increase as a child went further from the watercourse (but chances of an encounter with a predator would increase with time spent out of camp). The data presented here on foraging returns and availability of food show that the gains from exposure to these risks would have been very small, unless children travelled far (8 km round-trips to productive berry flats and 12 km round-trips to nut groves). We conclude that foraging unaccompanied by adults was not likely to have been a rewarding activity for !Kung children.

The costs and the benefits from children's unaccompanied foraging seem much more favorable among the Hadza. Blurton Jones, Hawkes, and O'Connell (1989) report Hadza children aged 5–10 obtain 629 kcal/hr., and children aged 10–15 obtain 1,014 kcal/hr. by collecting and processing baobab fruit, mostly from within 200 m of camp. For !Kung to achieve similar return rates, they would have to travel as far as the Dobe nut grove, 5.5–6 km each way, much further than we have observed unaccompanied Hadza children travel. A recent series of interviews suggests that Hadza children suffer little risk of getting lost. In many hours of following Hadza children in the bush, we have seen none show any uncertainty about the route home (they guide us!), nor have we seen their parents panic like !Kung parents when the whereabouts of a child is unknown.

Children Foraging in the Company of Adults

Foraging in the company of adults may be an entirely different matter. The presence of adults must reduce the risks of children getting lost and preyed upon, and if Hadza children aged 7 can make their 10 km round-trips to berries, we cannot assume that !Kung children were incapable of a trip to the nut grove.

Why didn't !Kung children go to the nut groves with the women? We used data from experimental sessions in which children cracked mongongo nuts and data from Lee (1979) to calculate the consequences of two strategies for mother and children. We computed the calories brought home and the time taken to collect and process them to see which strategy would make edible calories available to a woman's children at the greatest rate. We used this measure because it can be expected to determine the growth and survivorship of children. Mongongo nuts cannot be eaten until they are cracked, and the cost of cracking them has a large influence on the return rate obtained from them. Our calculations showed that mother and child gain more per hour of child work if the child stays at home. Indeed, even if the unsupervised child cracks nuts for much less than the duration of the trip, the mother-child team do better if the child stays at home (see Figure 4). It seems reasonable to expect a child to crack nuts whenever it gets hungry and perhaps occasionally to crack some more when nagged by a younger sibling.

Surprisingly, younger children who are less efficient at cracking nuts would help mother more by going to carry nuts. But in the interviews, !Kung adults commented that if children go into the bush with adults, they get tired, thirsty, and "spoil the work" by pleading to be taken home. !Kung adults regard children as a liability on trips into the bush. We showed that even a slight increase in journey time imposed by a tired and thirsty child would tip the balance clearly in favor of leaving the child at home. Yet Hadza children accompany adults on trips to berry groves that were at least as distant and long lasting (10 hours) as !Kung trips to nut groves. Why don't they get tired? Would holding mothers back be such a penalty? Important differences in the environment may explain the situation. On the Hadza trips to berry groves, there is much shade, water is available along the way and near the berry groves, and the Salvadora and Cordia berries themselves contain much water. In contrast, on dry season journeys to nut groves in !Kung country, there is neither shade nor water. At the groves there is just enough shade to take a rest in but no water. All water must be carried. Daytime temperatures are very high (100 percent of days above 33°C in September and October, highs 33–45°C, i.e., 92–100°F [Lee 1979:104–6]; globe thermometer reading at Tsumkwe, 50 km west of Dobe, September–December 1981, mode 116–120°F [Blurton Jones, Hawkes, and O'Connell 1989]). Environmental physiology literature (e.g., Drinkwater et al. 1977; Drinkwater and Horvath 1979; Squire 1990) suggests that children are less capable of work in hot environments than adults. But the surprisingly complex economics of foraging may also play a significant role.

The Hadza child obtains very high returns in the berry groves (1,220–1,440 kcal/hr. [Hawkes, O'Connell, and Blurton Jones n.d.]). The processing costs are very low (the child can eat the berries as it picks them), and our second model, constructed to analyze mongongo nut strategies, shows that when processing costs are very small, accompanying mother to the grove should pay, even if the child walks more slowly than adults. The very limited processing of berries, e.g., mixing Salvadora berries with water and baobab pith, may be little affected by the quantity of berries (like roasting mongongo nuts, which seemed to take about the same time whatever the quantity of nuts). This further decreases the value of an assistant processor and increases the value of an assistant gatherer.

A final puzzle concerns times and locations (such as /Du/da, where most of Draper's data were gathered) where mongongo nuts are not widely available and women forage on a variety of berries (such as *Grewia retinervis*) and roots. Why don't children go with them? These are resources with low processing costs, like the distant berries that Hadza children exploit with adult company. Grewia berries are abundant all over the African savanna and have quite long seasons; they should have been an important resource for savanna foragers at many places and times. But we know too little about their economics (food value, processing times) to add an economic argument to our informants' opinion that children lack the stamina to aid their food quest.

Explaining the Difference between !Kung and Hadza Children's Foraging Opportunities

We suggest that important reasons for the difference in foraging opportunities for children in the two localities are the spatial distribution of water and food and the amount and nature of processing needed by the available foods. In the Dobe area, the richest food sources tend to be far from dry season water (as described by our !Kung informants, evidenced by our data, and implied by Lee [1979:175, 191–92, 203]). The Dobe area has only nine permanent water holes.

We have not counted the water holes in Hadza country but doubt that we ever would obtain a complete count. We already know many that we and our Hadza hosts use routinely. Most are far too small to support livestock or a large complex of camps, but there are some dozens close together all over our study area. If Hadza children should deplete their resources near camp, it would be easy to move to another water hole.

Our effort to model the economics of mongongo nuts is most notable for the complexity that it uncovers. In discussing !Kung and Hadza strategies for exploiting plant foods, we had to consider the degree to which individuals share reproductive interests, travel time and the costliness of the travel, acquisition time (e.g., simply picking food from ground or bush, roots in loose soil that are easily and quickly dug up versus roots that take long and heavy work), processing time, and the degree to which processing time depends on the amount of food being processed (e.g., cracking each nut versus roasting a pile of any size). We find that we lack sufficient information on these variables to attempt to calculate strategies for !Kung use of roots or for the use of Grewia berries by children in either population. An interesting elaboration of !Kung mongongo nut use is that women sometimes crack nuts in the grove before returning home. Our limited exploration of this issue suggests that it will not require us to change our conclusions about children's foraging. The detailed economics of food gathering and processing seem likely to account for the frequency and duration of !Kung women's foraging trips, the nonparticipation of children and teenagers, and several of the differences between !Kung and Hadza subsistence.

Appendix

Validity of the Experiments

Field experiments are unusual in anthropology, and it is important to discuss their validity. Much of our effort in the field was directed toward assessing validity—the relevance of our short series of experiments in one field season to the time and region that interests us. Since many authors have portrayed !Kung economics as relatively comfortable, and Solway and Lee (1990) described the recent environment as seriously degraded by livestock, we were especially alert for erroneously low estimates of the returns obtained from foraging. We surveyed a series of quadrats in the Dobe area (Experiment 3) and conducted foraging experiments in the /Xai/xai area (Experiment 4). We have already shown that foraging returns on the cattle-free Namibia side of the border fence were no different from those on the Botswana side and described how we collected no data from the obviously devastated country close to contemporary settlements.

Experiment 3: Quadrat Survey

We wanted to show whether our experimental foragers were neglecting any rich food sources (nowadays many !Kung own livestock or work for herd owners, and they sometimes receive food from government distributions, so perhaps our foragers were not really trying). We wanted to understand why more food was obtained further from the valley. Was it due to depletion by people or livestock (as indicated by presence of tracks in a quadrat), or to the location of different plant communities (dune, molapo, flats), or the seasonality of berries? As there were no permanent villages north of Dobe and no permanent water sources within almost 100 kilometers, we expected that signs of use by people and domestic stock would decrease as we drove north in search of foraging locations.

At each of twelve points along the Botswana side of the border, beginning 1.5 km north of the valley starting point and working north as far as 17.5 km, we surveyed three 15 m^2 quadrats. The distances were chosen to represent hardpan, molapo, flats, and dune habitats (Lee 1979:93, fig. 4.3). Once the truck was stopped at our chosen distance (by the reading on the odometer), the exact location of each quadrat was selected by throwing a colorfully flagged stick as far as possible east from the roadside. The fallen stick marked the southwest corner of the first quadrat. To locate the second quadrat, we hurled the stick east from the southeast corner of the first quadrat. The same procedure marked the corner of the third quadrat. The aim was to obviate any tendency to choose quadrats in a microhabitat that would support our expectations.

On finding the marker stick, one of the three !Kung men who helped us as trackers walked the area, reporting on all tracks seen in the approximate area of the quadrat. The tracks represent much of the passage through the quadrat in the roughly three months since the end of the rain. Many tracks were reported as "in the rains" and "since the rains," none from before the rainy season. Presumably the tracks of larger animals last longer than those of small animals, since small tracks may be filled more rapidly by windblown sand. We recorded whether human tracks were found and which species of wild animals, especially predators, and livestock had left their spoor since the rains. Then we marked the border of the quadrat with string, using a compass and tape to make the area as nearly square and oriented north-south as possible. Next N/isa Kxau (famed for her energy and hard work) collected all the plant foods that she could find in the quadrat. Her instruction was to get all the food of all kinds that she could find, however long it took her. These foods were then identified and weighed. Then she walked the quadrat with one observer and pointed out and identified all the berry bushes, fruiting and not fruiting. Her reputation as an efficient and energetic gatherer was confirmed whenever she participated in the experimental foraging excursions. The team was completed by our interpreter, Timon Mbatara.

The procedure in nut groves was slightly different. Individual trees were chosen by following a compass-determined path until we came under a tree. Tracks in the area covered by the tree were examined, and food found beneath the tree was collected. The areas were quite similar in size to our 15 m^2 quadrats. More than three trees were examined in each grove, but the figures in Table 6 (below) are prorated to represent three trees, roughly equivalent to the three quadrats reported for other locations.

Results

Food availability, habitat, and distance from the valley. Table 6 shows the total calorie value of the food found in each quadrat (except tree gum for which we have no calorie value). The pattern of availability of food followed the pattern of in-patch foraging returns. Available food increased with distance from the valley (correlation of .3452 between calories and kilometers, $p < .006$, $N = 53$) and was greater in nut groves (dunes) ($t = 3.0$, $p < .001$, $N = 53$) and less in molapos than on flats ($t = 3.4$, $p < .003$, $N = 27$).

Further statistical analysis showed that the location of different habitats accounted for the increase in food with distance from the valley. The correlation between distance and calories is reduced if examined within a habitat type. If dunes are removed from the sample, the correlation falls to .1193 (p = .277, N = 27). If dunes and molapos are removed and the quadrats from flats are examined alone, the correlation is -.0606 (p = .397). For dunes only, the correlation remains (r = .3474, p = .041, N = 26). Thus flats yielded the same amount of food wherever they were, and molapos yielded their small amount of food however far from the valley they were. But dunes (where the nut groves are found) yielded more food the further away we travelled north from Dobe grove. This situation may be evidence for human depletion of the Dobe grove. These results suggest that the reason foraging yields increase with distance from the valley is primarily the distribution of habitat types and, secondarily, the depletion of the nearest nut grove.

TABLE 6
Calories Obtained from Each Set of Three 15-Meter Quadrats

Km north from water course	Habitat	Total yield (Kcal)	Kcal from berries	Kcal from Roots	Kcal from nuts
1.5	Molapo	14	14	0	0
3.5	Flats	106	0	106	0
4.5	Flats	319	163	156	0
5.9	Dune	625	0	0	625
7.0	Molapo	17	0	17	0
9.0	Flats	406	406	0	0
9.5	Flats	1111	1111	0	0
11.0	Flats	467	329	138	0
13.0	Dune	4398	0	0	4398
14.4	Flats	118	118	0	0
16.0	Flats	146	133	13	0
17.5	Dune	3173	0	0	3173

Berry bushes. Table 6 shows the calories obtained from berries in each set of quadrats. We also tabulated the number of berry bushes and the yield of the dominant species of bush in kilocalories per bush for each quadrat. This showed a predominance of n/n bushes near the valley (just as Lee [1979:160] reported) and of !gwa between 9 km and 14.4 km (flats north of Dobe nut grove and Chipi grove). But the data show that n/n yielded almost no fruit at this time while !gwa were quite productive. The rank order of yield at the time of our observations (!gwa [19.75 cals/bush] > /tore [9.9 cals/bush] > kamako [0.04 cals/bush] > n/n [0.03 cals/bush] > zoma) resembles Lee's (1979:484) sequence of fruiting (latest fruiting to earliest: kamako > !gwa > /tore > n/n > zoma). N/n may have been a useable food source for children at the beginning of the dry season, but evidently they do not last long, unlike the faraway !gwa. Our data from /Xai/xai (Experiment 4) suggest that even !gwa near a valley may not be very productive later than July.

Depletion of resources by people. Nuts in the Dobe grove were strikingly sparse, and 1988 was a year of heavy rain after many very dry years. As Lee (1979:189–90) reported for other such years, the mongongo crop was poor. Although Lee (1969, 1979:175, and elsewhere) writes of depletion of groves close to camp, we are concerned that the sparseness we witnessed might result from the combination of a poor year with the greater ownership of donkeys by !Kung in 1988 compared to the 1960s. Donkeys are used to carry nuts, and their use might accelerate the depletion of the Dobe grove. Tracks of people were found under five of the ten trees examined in the Dobe nut grove, the nearest nut grove (and in only two other of the remaining forty-three quadrats). For this reason, we used the intentionally inflated figure for returns from trips to Dobe grove (727 kcal/hr.) so that the "on-site" returns (calorie value of food gathered per hour at the grove) are taken to be as high as for the more distant groves (see Table 4, above). The almost complete absence of tracks of people in quadrats elsewhere gives little support for the view that the low foraging returns near the valley were due to depletion. With the model of mongongo nut economics, it is easy to show that no matter how rapidly nuts are picked up (which depends on how densely the nuts lie on the ground; we tried values from 1 to 20 kg/hr.), the return rates cannot rise much above those we have discussed. Annual variation in the mongongo crop seems to be much less of a threat to our argument than intuition would have suggested.

Depletion of resources far afield by cattle. We recorded tracks of livestock in our survey quadrats and sought associations with amount of food yielded. Associations suffer problems of interpretation not applicable to the "experimental" test. For instance, cattle may be attracted by grass and leave their tracks where there is more grass. More grass may be found where there is less other vegetation. A stand of productive !gwa berry bushes leaves little but bare ground beneath and between the bushes. A t-test showed no difference between calories obtained from quadrats containing cattle tracks and those with no tracks. Analyses of variance examining distance and livestock gave no evidence for an effect of livestock. Quadrats with tracks still showed a correlation of calories and distance ($r = .4183$, $p = .008$, $N = 33$). So did quadrats with no tracks ($r = .3736$, $p = .052$, $N = 20$). When habitat types were included, there was a significant main effect of dunes and none of livestock. But when dunes were excluded from the data and a t-test performed to compare quadrats with cattle tracks with quadrats with none, a significant difference was found. Quadrats in flats and molapo with cattle tracks yielded less food than quadrats with no tracks. This is the only indication we could obtain that cattle might have affected food availability, and as mentioned above, this association could result from cattle seeking grass and thus avoiding large stands of berry bushes.

Several of our trips were to distances far out of reach of dry season day trips on foot, a result of our persistent, but unsuccessful, efforts to show that higher returns could be obtained in remote undisturbed habitat. We think it is impossible to argue that the low returns in some of the very remote sites we visited where there was no sign of livestock were, nonetheless, a result of recently increased numbers of livestock.

Predators. Tracks of predators were found in eleven out of fifty-three quadrats and were not associated with distance. If predators are a risk to children, they are a risk that is equally present near or far from valleys. The tracks, while representing an impressive array of wildlife, were an accumulation since the last rains about three months before data collection. In our thirty foraging and quadrat days walking about in the bush, often very far from settlements, we encountered only one puff adder and one leopard.

Conclusion from Experiment 3

The quadrat data revealed no massive food supply that our experimental foragers failed to exploit. Habitat type and berry season explain, but do not remove, the effect of distance. Richer habitats were farther from the valley, and later fruiting berries (lasting longer into the dry season) were also farther from the valley. Though we can thus offer some explanation for the distance of food, the decisions of foragers must take into account the distance at which the food actually can be found, regardless of the reason for its being so far away. According to our data, this inconvenient relationship between food-bearing habitats and permanent water is not a result of recently increased human use of the land.

Experiment 4: Foraging Experiments at /Xai/xai

Perhaps there is so much local variation in habitat that generalization is impossible. We conducted foraging experiments around /Xai/xai, included in Yellen and Lee's (1976) definition of the Dobe area and the site of much research by Wilmsen (1989 and earlier).

The permanent water at /Xai/xai is now a complex of wells clustered in the valley, which runs west to east through the village and then curves away to the southeast to Drotsky's Cave and beyond. To the west, the valley becomes wider and shallower, much as does the !Kangwa valley as it approaches the border near Dobe. Our foraging trips were aimed to locate high-yielding patches and to gain an impression of the area around /Xai/xai, not to provide a second transect. Some locations were selected by !Kung participants, others by us.

We list the results in note 2, giving direction and distance of the foraging locations from the valley and from the village, the number of people involved, the habitat, and the mean yields. Mean kilocalories per hour collected "on-site" were 719. This figure is not markedly different from that around Dobe (695 kcal/hr.). Returns calculated to include travel time are also similar to those around Dobe. As in the main transect near Dobe, the biggest yields were in a mongongo grove. The best berry yields were again far from the valley. The valley itself was almost completely lacking in bush foods (though not lacking grass). Thus our foraging excursions around /Xai/xai and elsewhere (N!oon!oodima and nut groves at Cheracheraha) gave similar returns to those presented for our main transect. It would be hard to argue that we collected data in an untypically poor part of the Dobe area.

However, Lee (1979:160) reports substantial berry groves just to the north of /Xai/xai, which had apparently disappeared by 1988: "At /Xai/xai vast groves of !gwa bushes (*Grewia retinervis*, B9) extend back from the pan for almost 1 km on the north side." This is an important observation. If these !gwa bushes near /Xai/xai were as productive as the !gwa bushes 9 km north of Dobe and those 5 km south and 14 km east of /Xai/

xai, we would have expected everyone, including children, to have exploited them, but our quadrat data show that the presence of berry bushes is no guarantee of berries in the dry season. In 1988 we saw dense stands of Grewia to the south and east of /Xai/xai, much nearer the valley than in the Dobe area. The valley had steeper banks, and berry bushes began within a few hundred yards of the bottom. But the returns obtained from foraging in these nearby berry bushes were very, very low. We do not know why; soil type or greater numbers of birds or insects near wet season water might be factors. Perhaps the season for fruiting is earlier near valleys, and thus by mid dry season, most fruit has gone. Thus if the berry groves close to /Xai/xai were as unproductive as the berry groves at Site A near the valley but far from the village (see note 2), they would not have lasted long and might have been little used by children.

Comparison with Lee's Early Data

While contemporary effects of cattle were not evident away from settlements, there could still have been a longer term degradation of the entire environment due to grazing and other overuse, as asserted by Solway and Lee (1990). Lee reported no data on acquisition rates or densities of foods, but in his 1979 Appendix D he reports that /tan roots "may weigh up to 10 kg, but the more typical sizes are 1 to 2 kg, and smaller specimens weigh as little as 30 g" (Lee 1979:485). Twenty /tan roots that our foragers acquired weighed 195–2,700 g, mean 1,025 g. The mean digging time was seven minutes, which at Lee's 47 cal/100 g gives 2,886 kcal/hr. upon encounter. Lee (1979:486) also comments that sha root "edible parts range in weight from 10 to 75 g, with an average weight of 44 g." The mean of 231 pieces we weighed individually was 64 g (14–97 g). These pieces are extracted in strings, and we calculated a return rate upon encounter of 3,043 kcal/hr. No wonder our foragers stopped even for a single plant. But these figures give no indication that roots were any smaller in 1988 than in the 1960s.

Lee (1979:484) illustrates the collection of !gwa and n/n berries (*Grewia retinervis* and *G. flava*), saying that "5 to 10 liters of the berry are typically gathered by a single person in a few hours." The berries "follow a ripening sequence that extends the Grewia season from December to July and beyond." So we were collecting data late in the berry season. In berry groves, our foragers collected 434 g/hr.; women of middle age and up collected 507 g/hr. Lee says a liter weighed 311 g. If "a few hours" is at least three, then 5 liters = 1,555 g in three hours, a rate of 518 g/hr. If a few hours means as much as five hours, then 10 liters = 3,100 g in five hours, which is 620 g/hr. These figures are in the high end of our range (166–861 g/hr.). They are low by Hadza standards (*Grewia bicolor* at 440–1,000 g/hr. [Hawkes, O'Connell, and Blurton Jones 1989]).

Hawkes and O'Connell (1982) calculated returns for a 6–hour mongongo nut trip using figures from Lee (1968, 1979) as 670 calories per hour, a little lower than the 727 that we calculate here for hypothetical trips to the Dobe nut grove. This close agreement suggests that returns for mongongo nuts have not significantly decreased over the intervening years.

Our impressions of conditions near settlements could have led us to the same extreme assertion that Solway and Lee (1990) make. But we see nothing in the above analyses to suggest that degradation affected the countryside as a whole. The degradation near water may, nonetheless, achieve the effect Solway and Lee (1990:118) claim: "inability of their land to support a foraging mode of production." But any who claim that change in the wider environment invalidates our experiments must present the data.

NOTES

1. We are grateful to the Office of the President, Republic of Botswana, for permission to do research in Botswana; to the National Science Foundation for support; to /"Ashe Kumsa, /Oma Bau, and !Xoma K'au for assistance in our quadrat survey; and to Timon Mbatara for interpreting and other assistance in the field. Hawkes and Blurton Jones would like to thank both Patricia Draper and Henry Harpending for their hospitality and advice in the field. Harpending and Draper were supported by a grant from the National Institute of Aging.

2. We report three ways to calculate kilocalories per hour: (a) kcal/hr. spent "on-site" where food was sought; (b) kcal/hr. spent on-site, plus time spent processing the food and time spent walking to site from the nearest point in the valley; (c) kcal/hr. spent on-site, plus time spent processing the food and time spent walking to site from the present-day village of /Xai/xai.

Site A: 0–2 km from valley, 16 km southeast of village, nine people, molapo-flats habitat, (a) 81 kcal/hr. on-site, equivalent to (b) 77 kcal/hr. including travel from valley and processing, (c) 27 kcal/hr. including travel from village and processing.

Site B: 2 km, 9 km southeast, eight people, mongongo nut grove, (a) 1,699 kcal/hr. on-site, equivalent to (b) 658 and (c) 550 kcal/hr.

Site C: 3.5 km, 12.4 km northwest, ten people, flats, (a) 1,136 kcal/hr. on-site, equivalent to (b) 970 and (c) 549 kcal/hr.

Site D: 4.25 km, 14 km east, nine people, flats, (a) 459 kcal/hr. on-site, equivalent to (b) 378 and (c) 191 kcal/hr.

Site E: 5.2 km, 5.2 south, five people, flats, (a) 541 kcal/hr. on-site, equivalent to (b) 424 and (c) 424 kcal/hr.

Site F: 6.2 km, 15.6 km northwest, seventeen people, flats, (a) 401 kcal/hr. on-site, equivalent to (b) 297 and (c) 140 kcal/hr.

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