

TABLE 6
Sexual Division of Labor among Hiwi Hunter-Gatherers:
Mean Number of Calories Acquired per Person-Day*

WOMEN

SEASON	MEN	NONNURSING AND POSTREPRODUCTIVE	p =	NURSING AND PREGNANT	p =	SEASONS
LATE WET	mean = 3505 SE = 502 n = 395	mean = 3382 SE = 296 n = 192	>.05	mean = 2960 SE = 281 n = 123	>.05	roots
EARLY DRY	mean = 2893 SE = 401 n = 502	mean = 1171 SE = 150 n = 184	<.05	mean = 820 SE = 80 n = 107	<.05	
LATE DRY	mean = 2887 SE = 371 n = 614	mean = 724 SE = 117 n = 241	<.05	mean = 502 SE = 101 n = 129	<.05	
EARLY WET	mean = 3288 SE = 559 n = 221	mean = 626 SE = 144 n = 95	<.05	mean = 420 SE = 200 n = 50	<.05	mango/chiga

*p values are the results of two-tailed t-tests comparing men's mean kilocalories acquired per person-day to those acquired by women of different reproductive statuses.

TABLE 7
Mean Differences in Calories Acquired per Day among Hiwi Adults

	ROOTS			MANGO/CHIGA	
SEASONS	LATE WET	EARLY DRY	LATE DRY	EARLY WET	
	<i>MEN</i>				
	mean = 3505 SE = 502 n = 395	mean = 2893 SE = 401 n = 502	mean = 2887 SE = 371 n = 614	mean = 3288 SE = 559 n = 221	
LATE WET		-612	-618	-217	
EARLY DRY			-6	395	
LATE DRY				401	
	<i>POSTREPRODUCTIVE AND NONNURSING WOMEN</i>				
	mean = 3382 SE = 296 n = 192	mean = 1171 SE = 150 n = 184	mean = 724 SE = 117 n = 241	mean = 626 SE = 144 n = 95	
LATE WET		-2211	-2658	-2756	
EARLY DRY			-447	545	
LATE DRY				-98	
	<i>NURSING AND PREGNANT WOMEN</i>				
	mean = 2960 SE = 281 n = 123	mean = 820 SE = 80 n = 107	mean = 502 SE = 101 n = 129	mean = 420 SE = 200 n = 50	
LATE WET		-2140	-2458	-2540	
EARLY DRY			-318	-400	
LATE DRY				-82	

ANOVA
p(2-tailed) = .6890

ANOVA
p(2-tailed) = .0215

ANOVA
p(2-tailed) = .0012

this season. Hiwi men acquired 65 percent of the total kilograms of mango brought to camp. The average man acquired 602 mango calories per person-day, while the average woman acquired only 378. During the remainder of the year, however, the sexual division of labor is marked: men rarely dug roots ($n = 2$ man-days) or gathered other plant foods ($n = 9$ man-days). Although Hiwi women often accompanied their husbands on hunting and fishing expeditions, they rarely engaged in hunting or fishing and only acquired 12 kilograms of meat (mainly fish and land turtles) over the entire sample period.

Foraging Effort

Figure 5 shows the mean number of hours spent foraging per day across seasons by men and by women of different reproductive statuses. In this section "work," "work effort," "work output," and "foraging" are invariably used to mean time spent hunting/fishing and/or gathering.

The first striking feature of time allocation among the Hiwi is the relatively few hours that they spent out of camp foraging per day (<3 hours in any season) when compared to the economic behaviors of other populations (Minge-Klevana 1980; but see Hames 1989:64). We have made eight hours the maximum value on the y axis to illustrate this point. Second, changes in foraging effort across the year by either sex were slight and within one hour's range. Lastly, the differences between the sexes in time spent foraging are not very high in absolute terms mainly because the Hiwi spent few hours per day foraging. The highest mean difference between men and women in number of hours spent working per day is only 1.3 hours (compare nursing women to men in Table 8).

Sex Differences. Despite these low absolute differences in work effort, Figure 5 and Table 8 show some significant trends in work effort differences between men and women. First, in the late wet (root) interval, *all women, regardless of reproductive status, spent significantly more hours per day foraging than did men.* This difference extends into the early dry season when some roots continued to be acquired by the women. However, only postreproductive and nonnursing women spent significantly longer hours foraging than did the men in the early dry season. Second, during the early wet (mango) season, all women, regardless of reproductive status, spent significantly fewer hours foraging than did men. Statistical analyses suggest that in the late dry season, men and women spent similar amounts of time hunting and gathering (Table 8).

Seasonal Differences. Another way to study the sexual division of labor is to look at the temporal distribution of foraging effort from the point of view of each sex. Table 9 describes this distribution and the significance levels of behavioral differences between seasons. One-way ANOVAs were used to analyze this normally distributed data set. The table includes the mean number of hours spent foraging per person-day for each season across the top rows corresponding to each sex and reproductive status and the difference in the

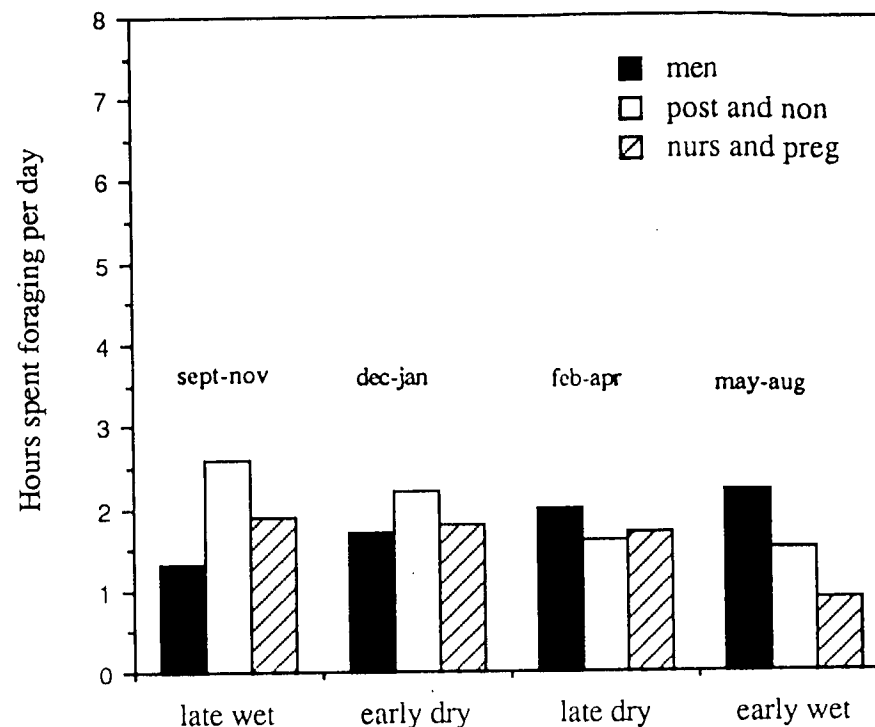


Figure 5. Mean Number of Hours Spent Foraging per Day by Hiwi Men and Women of Different Reproductive Statuses across Seasons

mean number of hours spent foraging per person-day between pairs of seasons in the boxes beneath.

Hiwi men spent fewer hours foraging per day in the late wet (root) season than in any other season of the year (Table 8). The primary foraging activities of Hiwi men during this season were hunting and some fishing; they rarely foraged for plant foods. It is interesting that even though Hiwi men significantly reduced foraging effort during the root season, they continued to produce as many calories derived from meat as in other seasons of the year.

Men's fluctuations in time spent foraging appear to have been due to *increases and decreases in time spent gathering rather than to changes in time spent hunting.* Men allocated the extra time they spent foraging in the late dry season to honey and egg gathering (0.7 hours increment per day from the late wet season mean) and to fruit gathering in the early wet season (0.9 hours increment per day from the late wet season mean; $n = 483$ and 180 man-days respectively) (see Table 9). The men did not increase time spent hunting or fishing during these seasons. Our sample also included two old men who showed the same change in time spent foraging that we report for men twenty to fifty-five years of age. During the root seasons (late wet and early dry), these men spent a mean of 0.2 and 0.6 hours foraging per day, while during the late dry and early

TABLE 8
Sexual Division of Labor among Hiwi Hunter-Gatherers:
Mean Daily Number of Hours Spent Foraging

WOMEN			
SEASONS	MEN	NURSING AND PREGNANT	NONNURSING AND POSTREPRODUCTIVE
LATE WET roots	mean = 1.3 SE = 0.9 n = 372	mean = 1.9* SE = 0.3 n = 138	mean = 2.6* SE = 0.2 n = 192
EARLY DRY	mean = 1.7 SE = 0.13 n = 421	mean = 1.8 SE = 0.24 n = 135	mean = 2.2* SE = 0.34 n = 184
LATE DRY	mean = 2.0 SE = 0.11 n = 483	mean = 1.7 SE = 0.23 n = 154	mean = 1.6 SE = 0.18 n = 241
EARLY WET mango/chiga	mean = 2.2 SE = 0.24 n = 180	mean = 0.91* SE = 0.4 n = 62	mean = 1.5* SE = 0.3 n = 95
Unpaired T-test, 2-tailed comparison between men and women * = <.05			

TABLE 9
Mean Differences in Hours Spent Foraging per Day among Hiwi Adults

SEASONS	ROOT		MANGO/CHIGA		
	LATE WET	EARLY DRY	LATE DRY	EARLY WET	
	<i>MEN</i>				ANOVA F-test = 7.892 p = .0001
	mean = 1.3 SE = 0.9 n = 372	mean = 1.7 SE = 0.13 n = 421	mean = 2 SE = 0.11 n = 483	mean = 2.2 SE = 0.24 n = 180	
LATE WET		0.4	0.7	0.9	
EARLY DRY			0.3	0.5	
LATE DRY				0.2	
	<i>POSTREPRODUCTIVE AND NONNURSING WOMEN</i>				ANOVA F-test = 5.038 p = .0018
	mean = 2.6 SE = 0.2 n = 192	mean = 2.2 SE = 0.34 n = 184	mean = 1.6 SE = 0.18 n = 241	mean = 1.5 SE = 0.3 n = 95	
LATE WET		-0.4	-0.18	-1.1	
EARLY DRY			-0.6	-0.7	
LATE DRY				-0.1	
	<i>NURSING AND PREGNANT WOMEN</i>				ANOVA F-test = 1.55 p = .2006
	mean = 1.9 SE = 0.3 n = 138	mean = 1.8 SE = 0.24 n = 107	mean = 1.7 SE = 0.23 n = 154	mean = .91 SE = 0.4 n = 62	
LATE WET		-0.1	-0.2	-1	
EARLY DRY			-0.1	-0.9	
LATE DRY				-0.8	

wet, they spent 1.8 and 1.5 hours foraging per day ($n = 56, 52, 40,$ and 16 person-days respectively).

Among the women who are less constrained by reproduction (nonnursing and postreproductive women), the seasonality of time allocation, on the other hand, appears to have been the exact opposite of that described for Hiwi men. Postreproductive and nonnursing women spent more hours per day foraging during the late wet (root) season than at any other season of the year ($p = .0018$, two-tailed). Among the women who are directly constrained by reproduction (nursing and pregnant women), work effort levels showed no statistically significant changes throughout the year ($p = .2006$, two-tailed), even though in the early wet season they allocated fewer hours to food acquisition relative to other seasons (<1 hour per day).

In summary, caloric consumption among Hiwi foragers is the outcome of within-sex and between-sex differences in decisions concerning what foods to acquire and how long to forage. The wet season diet shows a more even mix of vegetable and meat resources due to an increase in the amount of time that men allocated to gathering plant foods in the mango/chiga (early wet) season and an increase in the amount of time that women spent digging roots in the late wet season. Men produced more food than women in all seasons except the late wet (root) season. Men foraged less during the late wet season, but their total caloric acquisition did not vary throughout the year. Women worked more than men during the late wet (root) season but less than men in the early wet season. Women also provided more food energy during the late wet (root) season when they foraged longer. Nursing and pregnant women worked less and acquired less food than women who were not pregnant or lactating. They also appeared to have maintained a less seasonally variable foraging pattern than other adults.

BODY WEIGHT AND FERTILITY CONSEQUENCES OF DIFFERENCES IN FORAGING EFFORT ACROSS SEASONS

Body Weight

Figures 6a and b and Table 10 show weight changes among Hiwi men and among women of different reproductive statuses. The same definitions and criteria used above apply in our analyses of nutritional status. Pregnant women, however, are excluded from the analyses of seasonal fluctuations in women's weights.

Paired *t*-tests show that the men reached their highest weights in the late wet season ($p = <.05$, two-tailed) (Table 10). Between the late dry and late wet season, men gained 3.3 percent of their yearly mean body weight (57.8 kilograms). Figure 6a shows that Hiwi men began to gain weight in the second half of the late dry season and continued to gain weight during the early wet (mango/chiga) season. Men started to lose weight in the early dry season and reached their lowest weights at the beginning of the late dry season. Men's highest body weights coincided with the time of the year when caloric con-

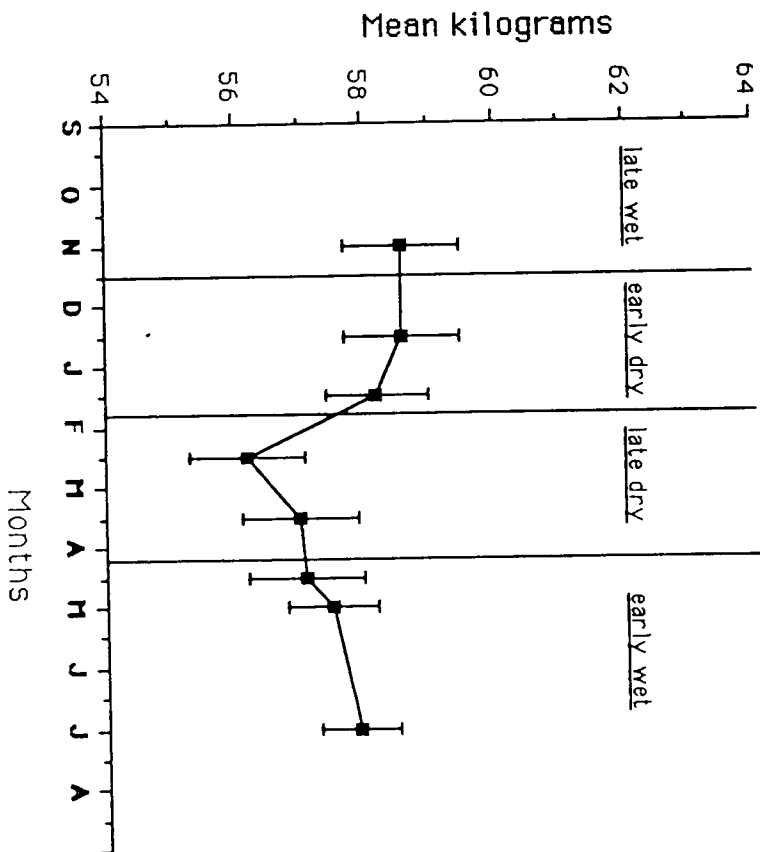


Figure 6a. Mean Body Weight of Hiwi Men across Months and Grouped by Season

sumption may have been the highest (the late wet, root season) and when the men spent fewest hours foraging. Weight loss occurred primarily during the dry season months when the men increased time spent foraging and food consumption appears to decrease. These analyses suggest that the dry season is characterized by a less favorable energy balance for Hiwi men than the wet season.

Postreproductive and nonnursing women, in contrast, attained their highest body weights in the early wet (mango/chiga) season (see Figure 6b). Between the late dry and the early wet season, these women gained 3.7 percent of their yearly mean body weight (48.2 kilograms). By the end of the late wet season, these women had lost weight, and they maintained a constant level until the beginning of the late dry season. As was the case for the men, postreproductive and nonnursing women also lost weight in the late dry season. The results show that postreproductive and nonnursing women attained their highest body weights during the season of the year when they allocated fewer hours to foraging (the early wet season). This is also the season of the year when the Hiwi men did more than half the plant food gathering. Interestingly, Hiwi men and women each appear to have gained weight during the periods

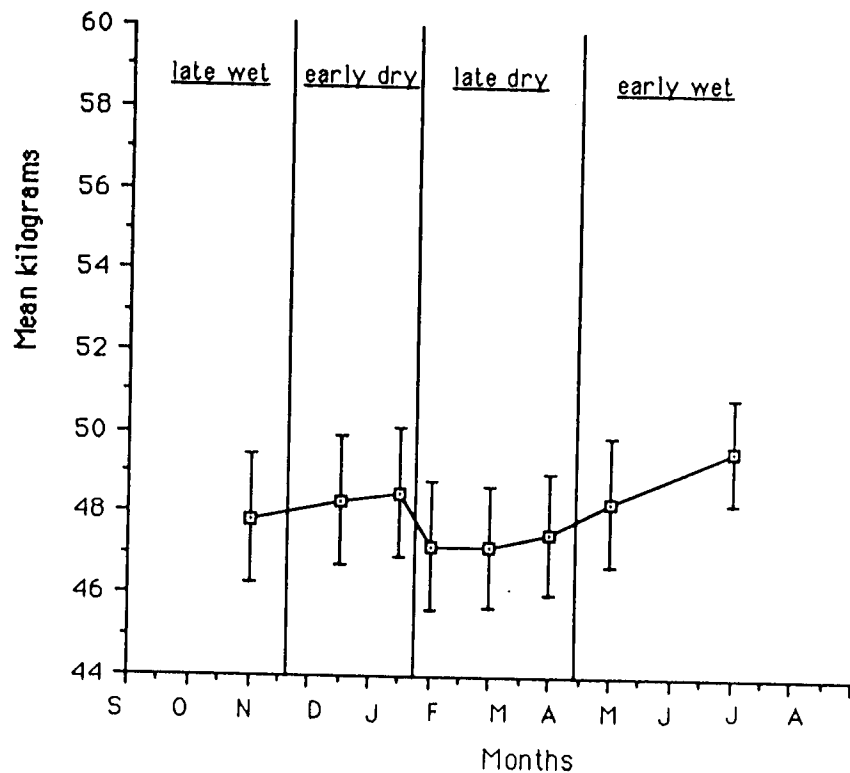


Figure 6b. Mean Body Weight of Hiwi Postreproductive and Nonnursing Women across Months and Grouped by Season

of the year when the other sex did most of the wild plant food acquisition. Postreproductive and nonnursing women lost weight during the period that appears to be the most plentiful time of the year (the late wet, root season). This is probably due to the increase in time they spent foraging as well as to an increase in the energetic costs associated with root collecting: digging tubers is more energy expensive than gathering fruits.

Although our sample is quite small, the data suggest that nursing women showed patterns of weight change that are similar to those of other Hiwi women. Nursing women also attained their highest body weights in the early wet (mango/chiga) season. Between the early dry and late wet seasons, these women gained 5.1 percent of their yearly mean body weight (48.7 kilograms). By the end of the late wet season, nursing mothers had lost weight, and they reached their lowest weights during the first month of the early dry season.

Thus men achieved peak weights during the late wet (root) season, but all women lost weight during this time. Women in contrast achieved peak weights during the early wet (mango/chiga) season. All adults except lactating women showed their lowest body weights in the late dry season.

TABLE 10
Mean Weight Differences (in Kilograms) across Seasons
Paired T-Tests
MEN

SEASONS	LATE WET	EARLY DRY	LATE DRY	EARLY WET
	mean = 58.7 SE = 1.0 n = 18	mean = 58.1 SE = 0.6 n = 26	mean = 56.8 SE = 0.5 n = 24	mean = 57.7 SE = .5 n = 24
LATE WET		-0.6 n = 18 p = .0027	-1.9 n = 17 p = .0001	-1 n = 18 p = .0639
EARLY DRY			-1.3 n = 22 p = .0001	-1.5 n = 23 p = .142
LATE DRY				0.9 n = 24 p = .7749

POSTREPRODUCTIVE AND NONNURSING WOMEN

SEASONS	LATE WET	EARLY DRY	LATE DRY	EARLY WET
	mean = 47.9 SE = 1.6 n = 12	mean = 48.3 SE = 1.5 n = 13	mean = 47.4 SE = 1.5 n = 14	mean = 49.2 SE = 1.4 n = 15
LATE WET		0.4 n = 9 p = .2665	-0.5 n = 10 p = .1698	1.3 n = 11 p = .8404
EARLY DRY			-0.9 n = 12 p = .1017	0.9 n = 12 p = .0402
LATE DRY				1.8 n = 13 p = .0006

NURSING WOMEN

SEASONS	LATE WET	EARLY DRY	LATE DRY	EARLY WET
	mean = 49.3 SE = 1.2 n = 3	mean = 47.5 SE = 1.8 n = 4	mean = 48.1 SE = 2.1 n = 5	mean = 50 SE = 1.8 n = 5
LATE WET		-1.8 n = 2 p = .4472	0.04 n = 2 p = .8764	0.7 n = 2 p = .9646
EARLY DRY			2.2 n = 3 p = .4559	2.5 n = 3 p = .0334
LATE DRY				1.9 n = 4 p = .5426

n = number of individuals.

Multiple measurements were made on most individuals in each season.

Fertility

Through reproductive interviews with women and direct observation, we are able to estimate female fertility rates by season. All Hiwi women accurately and consistently identified the season of birth for their children by reporting the resources that were eaten, the rainfall patterns, and the level of flooding at the time each child was born. For individuals born after 1968, the exact birth date is usually known. Because some seasons have more months than others, we standardized female fertility data by calculating the monthly rate of conceptions reported per season. Pregnancies were tabulated by calculating nine months back from the reported month of birth. Consequently, our sample represents only conceptions that terminated in live births. In this sample, we only included data on individuals born between approximately 1950 and 1988.

Hiwi women showed fewer conceptions per month during the early dry season than in other seasons of the year (Figure 7) (chi-square = 28.9, $p = .001$, $n = 122$ births reported by 24 women). This finding is not surprising, as birth seasonality has been found in almost every human population where it has been carefully investigated (Leslie and Fry 1989). However, because we also monitored food intake, work effort, and weight changes across the year, we are able to explore the possibility that one or more of these factors account for some of the observed seasonal variation in fertility.

Studies of the physiological mechanisms of fertility variation have often suggested that food intake and work effort play an important role in affecting the probability of conception. Two common proposals are either that current nutritional intake/energy balance affects fertility or that ongoing changes in nutritional intake/energy balance might affect fertility (see Ellison 1989 for a review). We therefore performed two sets of simple regressions with mean monthly fertility rate as the dependent variable. In the first set of three regressions, the independent variables used were mean daily caloric intake, hours worked, or body weight, all calculated by season for reproductive-age women (those at risk of pregnancy). In the second set, the *change* in each parameter (the value recorded in the current season minus the value from the previous season) was used as an independent variable. This allowed us to determine whether periods of gaining or losing weight, increasing or decreasing food intake, or changing work effort were correlated with variations in fertility rates.

Interestingly, female work effort, caloric consumption, and weight in a given season showed little or no association with fertility in that season. Differences in female weight and work effort between a season and the previous season also failed to correlate strongly with fertility rates. However, the difference in mean daily caloric consumption between a season and the previous season was a good predictor of the fertility rate (F-test = 10.5, $r^2 = .84$, $p = .0837$) but was not statistically significant with only four data points (the mean monthly fertility rate for each of the four seasons). This test, however, is not the best measure of changes in nutritional status or overall energy balance, since only food intake (not energy expenditure) is incorporated into the independent

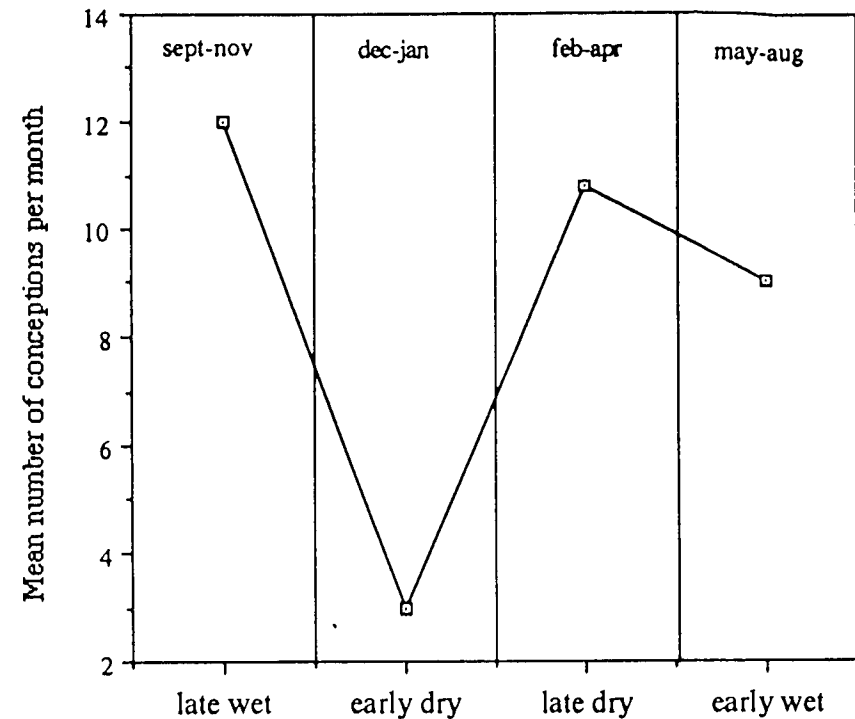


Figure 7. Mean Number of Pregnancies Reported by Hiwi Women per Month and Grouped by Season

variable. We therefore decided to test for the effects of changes in *net* caloric intake by subtracting energy expenditure from energy intake.

Although work effort by women showed only small seasonal differences in absolute terms, the relative changes were enormous, with the high work season representing almost double the amount of work effort as the low work season. In order to calculate net caloric intake, we estimated women's energy output using the mean number of hours that women spent foraging in each season, the mean female body weight of women at risk of pregnancy, and the energy expenditure values reported in the literature for activities that are analogous to the foraging activities of Hiwi females.⁸ Net energy intake by reproductive-age women was then defined as mean daily caloric intake minus mean daily caloric expenditure. Change in net energy intake was simply the measure of the difference between the net energy intake in one season and the net energy intake of the previous season. It should be noted that this procedure simply combines two of the variables from the first set of regressions (caloric intake and hours worked per day) into a single independent variable.

The analyses show that among women at risk of pregnancy (nursing and nonnursing women), the difference in net caloric intake between a season and

the previous season is a strong predictor of seasonal fertility rates among the Hiwi (Figure 8; F-test = 498.929, $r^2 = .996$, $p = .002$). Because we only have four data points (corresponding to the four seasons), because the measurements of all variables are quite crude, and because there is no reason to expect a linear relationship between the two variables tested, the strength of the correlation should be interpreted with caution. Nevertheless, the results are striking enough to encourage further investigation into the association between net caloric intake and fertility among women in natural fertility populations (see Bentley 1985). Interestingly, our results are consistent with research findings showing that in a sample of Western women, a *change* in nutritional status is a more important determinant of female fecundability than is nutritional status per se (Pirke, Broocks, and Tuschl 1988). It is important to note, however, that this test is designed to examine the determinants of seasonal variation in fertility, which may not be the same factors primarily responsible for fertility differences between individual women or between populations of women.

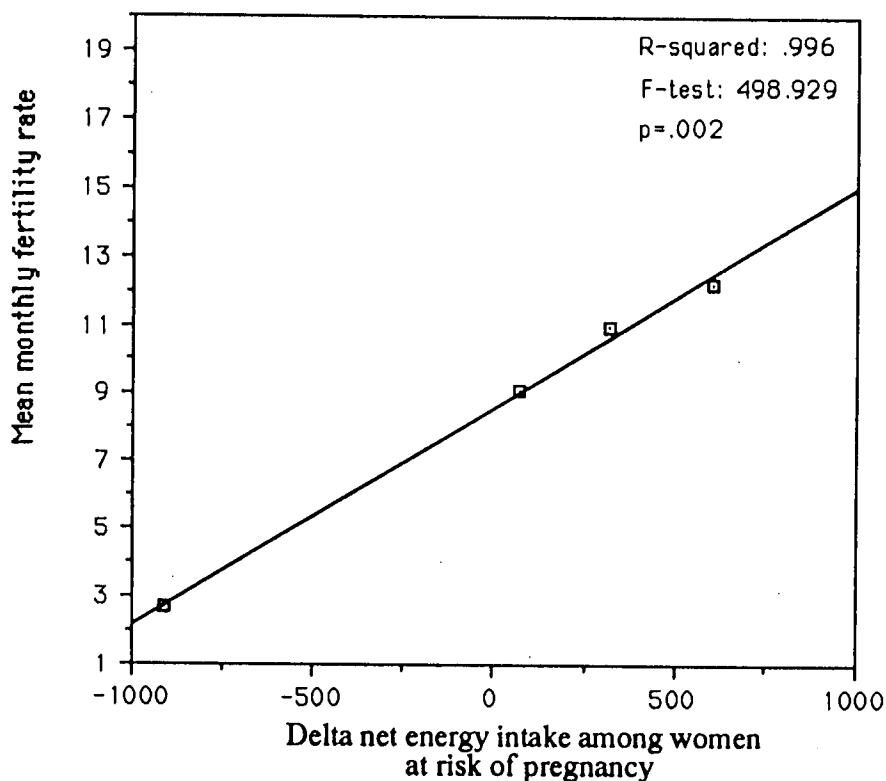


Figure 8. Relationship between Seasonal Changes in Net Energy Intake and Mean Monthly Fertility Rate among Hiwi Women at Risk of Pregnancy

DISCUSSION

Seasonal fluctuations in food consumption and in the sexual division of labor among the Hiwi took place within a hunting and gathering context during our sample period; the diet at their permanent central-place settlement was derived almost exclusively from wild foods. Preliminary analyses suggest that bush camps were characterized by an even greater dependence on foraged wild resources. We previously arrived at the same conclusion based on a smaller sample of two months of observations (see Hurtado and Hill 1987) and are now confident that until recently the Hiwi have been dependent on hunting and gathering for much of their subsistence.

Substantial amounts of meat from various sources were consumed at the Hiwi settlement throughout the year. Wild plant foods, in contrast, were sometimes scarce. The Hiwi may have been particularly carbohydrate stressed during certain months of the dry season when no vegetable foods are available or easily exploited. Over a year's time span, then, animal flesh appears to have been the "reliable" food, while vegetable foods were the more "variable" staple. This finding runs contrary to the commonly accepted generalization that the main, and more dependable, food staple among low-latitude hunter-gatherers is wild plants (Lee 1968; Eaton, Shostak, and Konner 1988:32).

One earlier study on the Hiwi allows us to compare our observations with those made during a different set of years. Arcand (1976) has published two weeks of quantitative data on the diet of a nomadic band of Colombian Hiwi that he observed in the late 1960s. His tables show that in February (late dry season), the Hiwi consumed a mean of 539 grams of meat, 357 grams of vegetables (roots), and 0 grams of fruits per person per day. Our February observations show a mean daily per capita consumption of about 900 grams of meat, 110 grams of roots, and 225 grams of fruits. In August, Arcand's observations show a mean daily per capita consumption of 521 grams of meat, 0 grams of roots, and 400 grams of fruits. Our July sample (we have no August data) shows a mean daily per capita consumption of about 850 grams of meat, 10 grams of roots, and 280 grams of fruits. Thus, the total amount of vegetables in both samples is about the same, but the component species differ. Meat consumption was consistently higher during our period of observation, but the major wild game species (capybara and fish) appear to be the same in both studies.⁹ These two studies done fifteen years apart and on groups who live over 200 kilometers distant from each other do not allow us to conclude that year-to-year variation (or regional variation) is unimportant; however, they both conform to the patterns we document here.

SEX DIFFERENCES IN FOOD CHOICE

Both food availability and the foraging choices that the sexes make across seasons are important contributing factors to fluctuations in food consumption in the Hiwi diet. This is particularly interesting since differences in which

resources each sex chooses to exploit during the year result in variation in the character of the sexual division of labor. An increase in time spent gathering plant foods by men during the mango/chiga season and by women during the root season defines the sexual division of labor for each season and results in a more "balanced" diet during the wet season and possibly a more plentiful diet during the late wet season. The increased presence of carbohydrate in the diet at these times may be due to an increase in the caloric return rates associated with plant food gathering relative to overall foraging returns (Hawkes, Hill, and O'Connell 1982; Hill 1988), but the decision concerning which sex exploits plant resources seems less straightforward. Specifically, two main questions arise: (1) Why don't women hunt? and (2) Why do men, and not women, collect most of the mangos, and why don't men collect any other plant resources in significant amounts?

As is the case with many other groups of hunter-gatherers, the Hiwi data raise the important question of why women don't hunt as much as men (Hurtado 1985; Hurtado et al. 1985). This issue becomes clear when the caloric return rates from hunting and gathering are compared. In our sample, men obtained a mean of 2,593 calories/hour of hunting out of camp (search plus pursuit time). Hiwi women's food collecting across all seasons produced a mean of only 848 calories/hour of gathering away from camp. Preliminary data also suggest that processing time is much greater per calorie of vegetable food acquired than it is for game resources. Thus, the differential in hourly rates of edible food production from hunting and from gathering is even greater than the above measurements imply. If people wish to acquire as much food energy for their effort as they can, Hiwi women should hunt. In addition, meat has a higher content of proteins and lipids, both of which seem to be desirable (Hill 1988).

In other publications we have argued that the fitness costs to children and mothers associated with hunting and fishing may be an important determinant of female subsistence strategies. Specifically, we hypothesize that by hunting, women would drastically increase offspring mortality and decrease their own fertility. Since informants suggest that Hiwi mothers want as many children as possible, and want them to survive, they may not be willing to hunt if the increased food thereby obtained does not offset their losses in fertility and child survivorship. The decision not to hunt may therefore be adaptive in a strict biological sense if it results in more surviving offspring than could be produced by participation in hunting. Further refinements of this hypothesis are discussed in greater detail elsewhere (Hurtado 1985; Hurtado et al. 1985; Hurtado and Hill 1990).

The reasons why Hiwi men generally avoid plant gathering but do collect mangos when they are available may provide important insights into the sexual division of labor. From a simple energy maximizing viewpoint, the behavior of Hiwi men seems puzzling. During the early wet season, men acquired a mean of 2,919 calories per hour spent hunting. Although some mangos were encountered and collected while hunting, the vast majority were collected on special purpose trips for which the stated goal was to collect mangos, and no

other foraging took place. On mango-collecting expeditions, men acquired a mean of only 1,007 calories per hour, including travel time to and from the mango groves. Why should a man sacrifice almost 2,000 calories per hour to collect mangos rather than hunt?

One possible answer to the above question is that Hiwi men strongly desire some carbohydrate in their diet and are willing to sacrifice higher amounts of meat in order to obtain it. In a previous publication (Hill 1988), we have discussed the reverse case in which Hiwi men were observed to sacrifice higher amounts of food energy in the form of carbohydrates (roots) in order to acquire meat. Given that informants often stated the desire to complement the major macronutrients of their diet (carbohydrates, lipids, proteins) with those that were missing, and that observations suggest they often sacrificed higher caloric amounts of one macronutrient for lower amounts of another, we have begun to modify some simple maximization models to incorporate macronutrient complementarity (Hill 1988; Kaplan and Hill 1990).

If the desire for carbohydrate in the diet is a major factor in Hiwi men's foraging decisions, we must explain why the women do not collect more mangos. Our current hypothesis concerning this issue is based on our impression that mangos have a unique pattern of spatial distribution, and this spatial distribution has important implications for the costs of foraging to Hiwi women. Mangos are an attractive resource, but one that is potentially dangerous for women unaccompanied by men to collect. Mangos appear to be distributed in large groves, or patches, which may contain several million easily acquired calories in an area of about 5,000 m². Because of their size, caloric density, and ease of exploitation, these patches may be much more attractive than any other food patches in the Hiwi area, a situation which probably explains why local criollo populations exploit the mango groves but do not "forage" for many of the area's other resources. While following men collecting mangos, we encountered enemy Hiwi bands and Venezuelan criollos several times. Both groups are known to sexually harass unaccompanied Hiwi women, and both groups occasionally kill Hiwi foragers—men, women, or children. Thus women, who generally forage in small, single-sex groups, may avoid foraging for mangos unless their husbands or male kin accompany them.

Another cost to women associated with collecting mangos is the spatial distribution of this food resource. Animal behavior studies have demonstrated that foragers increase the size of the load they bring back to camp as the distance between the nest and the foraging site increases (Orians and Pearson 1979). In the Hiwi case, mango collecting may only be profitable for individuals who can bring very large loads to camp and whose effort is not greater than the benefits that can be accrued from carrying the nutritious package. For women, the costs of walking long distances with huge loads of mangos, in addition to their small children, may be sufficiently high to offset any nutritional gain made from gathering this fruit (see Blurton Jones and Sibly 1978:147). In contrast, Hiwi men may incur relatively low costs from collecting mangos since they are unencumbered by children and have larger body sizes. The advantages

of having men do most mango collecting should increase under conditions where plant foods are scarce close to camp and where the within-patch caloric return rates for gathering are extremely high.

The mango patches exploited by the Hiwi are very far from the main foraging camp; indeed, mangos are found much further away than any of the other plant foods that Hiwi women gather. Men exploit mango patches located 5, 6, 13, and 14 kilometers from the main camp. Two men in a canoe paddle at a rate of 4 kilometers per hour (upstream). We believe that women travel in canoes about half as fast, but this has not been measured. Allowing for an hour of collecting, round-trips take men from 3 to 9 hours to complete. We believe women would take roughly twice as long. Men also collect mangos from patches located across savannas that can only be reached by foot. Patches that we observed exploited were located 18 and 25 kilometers from the main camp. Men walk about 5 kilometers per hour in the savanna, and we believe that women walk at between 3 to 4 kilometers per hour. In many cases men left late in the evening to collect savanna mangos and returned the next morning (so as not to walk during the day). They generally carried back loads that weighed from 40 to 60 kilograms. Collecting mangos in savanna patches again takes only about an hour, and more eating takes place there than at riverine patches since savanna mangos cannot be transported in canoes. Thus, for men, collecting mangos in the savanna represents a minimum of from 7.6 to 11 hours of time away from camp. For women, this might mean 10 to 15 hours out of camp, and probably they could not carry such large loads over long distances without incurring high reproductive costs.

Additionally, the seasonal fertility data we have presented suggest that if women were to increase their annual work load by collecting mangos, they would probably experience decreased fertility. The effects of mango collecting on Hiwi men suggest that the increase in female work load could be considerable if women took over this gathering task. Men usually return from mango-collecting trips exhausted and soaked with sweat. In contrast to the mangos, the roots and fruits exploited by Hiwi women are almost always located within 2 kilometers of the main camp. Consequently, women can more easily find caretakers for infants and small children in the main camp until their return from gathering in the early afternoon (Hurtado and Hill 1990).

According to informants, Hiwi bands were more nomadic in precontact times than they are today. Under those conditions, men may have engaged in less fruit gathering than we observed because women were generally closer to collectible resources. Recently, as the Hiwi have become more sedentary, mangos appear to be the only available carbohydrate food in the late dry-early wet transition period of about two months. The maintenance of a permanent camp and the spatial distribution of mangos, along with a desire to obtain some carbohydrate in the diet, seemingly have led to Hiwi men collecting plant foods almost exclusively in the mango season. A complete test of our current working hypotheses will require considerable additional data collection.

In summary, it is possible that the *spatial distribution of wild plant foods with respect to camp sites* (or sites of food consumption) among hunter-gatherers may influence the timing of collection and the extent to which men gather those wild plant foods that women foragers generally collect. We have suggested that as the distance between the foraging site and camp increases, men may be more willing to do the gathering. This may be due to a combination of two factors. First, women may be more likely to be harassed and sexually abused by men from other groups when they visit mango patches at considerable distances from the main camp. Second, because the size of the load to be brought back to camp is expected to increase as the distance between food consumption and foraging sites increases, female work loads may also increase substantially. Thus women may ignore plant foods far from camp due to important energetic and reproductive costs. On the other hand, men, who are unencumbered by children, may choose to pursue, rather than ignore, scarce carbohydrate resources that are located far from main camps. This may be due to strong male preferences for balanced diets during seasons when women ignore gathering opportunities.

TIME ALLOCATION TO FORAGING: WHY WORK SO LITTLE?

The Hiwi spend few hours per day foraging in order to acquire food energy: men and women work less than three hours per day on average. Perhaps such a small subsistence effort would be expected if the Hiwi population were well nourished and more food would not be useful, but available data suggest that this is not the case. First, Hiwi of all age and sex classes constantly complain of hunger. The word for hunger, *jainpa*, was one of the first Hiwi expressions we learned, and it is a commonly heard expression in all Hiwi camps we have visited. The per capita consumption we measured is one of the lowest ever reported in careful quantitative studies of forager diets, and the consumption per kilogram of body weight is also very low (see Hurtado and Hill 1987). By comparison to the well-fed Ache that we have also studied (Hill et al. 1984), the Hiwi are shorter, thinner, and more lethargic and appear less healthy. The Hiwi also show significant seasonal fluctuations in body weights, are quite anemic, and suffer from substantial levels of parasitic infection, primarily by hookworms (Hurtado, Hurtado, and Hill 1989).

More important than all these health indicators, however, is the fact that there is good reason to believe that more food would increase survivorship among Hiwi children. Only 50 percent of all Hiwi children ever born survive to the age of fifteen years (Hurtado and Hill 1987). Most children die from diseases which are less likely to be lethal in well-nourished individuals (cf. Mata 1978). Numerous studies of subsistence-level populations around the world indicate that populations eating only as much, or even more, than the Hiwi are characterized by disease and mortality rates that may be directly affected by increased nutritional intake (Behm 1983; Chen 1983). Additionally, increased

food intake would probably raise Hiwi female fertility rates since we discovered that change in food intake was an important factor correlating with seasonal changes in Hiwi female fertility. We also found that among Ache foragers, higher female body weight correlates positively with female fertility rates (Hill and Kaplan 1987).

From a strictly biological point of view, how much food is enough for a human population depends on whether more food can either (1) increase survivorship rates, or (2) increase fertility rates. In the Hiwi case, as for most other foragers, we believe that more food would increase both parameters. Since Hiwi informants voice a desire for higher survivorship of children and higher fertility and since natural selection will always favor the desire to increase these two parameters, we conclude that the Hiwi are probably not getting the amount of food they would prefer. This point has been made several times in other discussions about time allocation to subsistence effort (e.g., Hawkes et al. 1985; Hill 1983; Hurtado 1985).

If more food would be desirable to the Hiwi and would have positive biological consequences, why don't men and women simply forage more? It is puzzling, for example, that Hiwi men do not spend more time hunting per day in spite of high hourly return rates throughout the year (2,593 calories/hour). Similarly, in the late wet season, the hourly return rate from women's digging of roots is also high (1,127 calories/hour), yet women spend a mean of fewer than three hours foraging per day.

We believe that the most likely explanation for this low work effort is that increased time spent foraging may be accompanied by costs to the individual doing the work that more than offset the benefits he/she might derive from increased food production. In the Hiwi case, seasonal fluctuations in body weights among all adults and cyclical variability in female fertility provide some appreciation of the costs of subsistence effort. Both men and women lose weight during the periods of the year when they increase work effort (the late wet season for women and the late dry season for men), and women and men attain their highest weights during the seasons of the year when they do the least amount of work (the early and late wet seasons). These patterns are observed despite the fact that foraging return rates in calories per hour (2,593 among Hiwi men and 848 among Hiwi women) are higher than energy expenditure rates (about 480 calories per hour maximum) throughout the year and that the increases and decreases in foraging effort across seasons are small (0.2–1.9 hours/day).

Low female reproductive rates also appear to be an important health consequence of increased time spent foraging by Hiwi women. Relatively high levels of female work during the late wet and early dry seasons, in combination with a subsequent decrease in caloric consumption during the early dry season, coincide with a sharp decline in fertility in the early dry season. A decrease in net energy intake appears to be the most important predictor of fertility differentials across seasons.

These analyses suggest that if the Hiwi were to greatly increase time spent

foraging over current levels, both men and women would suffer even greater nutritional and reproductive losses than those they currently experience. It is possible that women would suffer even greater levels of infertility (see Hurtado and Hill 1987), and men would be skinnier and less robust. Thus Hiwi individuals may be avoiding these important nutritional and reproductive costs by limiting foraging effort to less than four hours per day.

We are still left with the question of why *slight absolute increases* in the time the Hiwi spend foraging during some seasons of the year lead to negative health outcomes in the short run. Two ecological factors might be responsible for this pattern. The entire Hiwi population experiences high levels of hookworm infection (Hurtado, Hurtado, and Hill 1989). The blood loss associated with this type of parasitic infection (Warren 1981; Bloch 1986) is in turn partially responsible for high levels of iron deficiency anemia among the Hiwi (Hurtado, Hurtado, and Hill 1989). Anemia negatively affects exercise performance and work output (Basta et al. 1979). In addition, it is not clear to what extent heat stress exacerbates the negative effects of parasitic infection on stamina (Newman 1975; Calloway 1982b). Hiwi informants often complain about the heat and attribute headaches and overall physical discomfort to sun exposure. Consequently, it is not surprising that most Hiwi prefer to forage very early in the morning or late in the day and that the most important in-camp activities in the middle of the day are resting and sleeping in hammocks (unpublished data). Thus, we tentatively propose that the combined effects of heat stress and parasite load on health are important costs to Hiwi individuals when they forage and that these costs more than offset the benefits they might derive from increased food production. We suspect that among the Hiwi, these factors increase the costs of foraging relative to those incurred by members of other hunting and gathering groups such as the forest-dwelling Ache. The Ache are extremely energetic, regardless of time of day. Substantial forest cover and lower temperatures may be partially responsible for these high activity levels compared to Hiwi foragers.

In summary, even though the Hiwi "enjoy" a leisurely fifteen-hour week, their nutritional and reproductive viability may be quite vulnerable to slight changes in foraging effort due to disease, ecology, and heat stress. Findings about the relationship between foraging effort and female fertility suggest that in their savanna environment, there is only a small window of time during which Hiwi women and men can acquire food without negatively affecting their reproductive viability and/or health status. Women may limit their work effort primarily to maintain desirable fertility levels, and men may limit their work effort so as not to reach undesirably low body weights.

CONCLUSIONS

Analyses show that there is considerable seasonal variation in the diet, work effort, nutritional status, female fertility, and sexual division of labor among Hiwi central-place foragers of the Venezuelan savanna. Seasonal variability

along various parameters has helped us examine the relationships among fluctuations in ecological conditions, adult health status, and the character of the sexual division of labor in this group of hunter-gatherers.

In spite of a long history of extensive contact with outsiders, hunting and gathering were the primary means of subsistence among the Hiwi throughout our sample period. Meat was the major food staple during most seasons and the most constant source of food energy across seasons for Hiwi foragers. The acquisition of plant foods, on the other hand, varied greatly across the year, thereby creating seasonal peaks and troughs in food energy intake.

In a previous study, we found that among Ache foragers, meat also was a more reliable food resource over a yearly cycle than were wild plant foods. If in other foraging populations meat is the more constant food staple across seasons as well, this evidence would have important implications for understanding the apparent pervasiveness of male food provisioning in humans. If most local ecologies tend to experience plant food shortages more often than game scarcity, then fitness incentives for males to acquire food for their mates and putative offspring, who might experience high mortality without such assistance, may be pervasive. Even periods of vegetable scarcity as short as a few weeks per year might provide strong selective pressures for male food provisioning if females do not hunt.

Seasonal fluctuations in the Hiwi diet reflect variability in the sexual division of labor across the year. Both men and women contributed to the balanced diet of the wet season months: females dug roots and gathered some fruit, while males engaged in both hunting and gathering fruits. During the dry months, however, men were the primary food providers, and meat was the main food staple. Because women's food contribution was only equivalent to that of men during the season when roots were taken in very large quantities, during three seasons of the year Hiwi females were dependent on their husbands and male kin for their children's and their own food energy consumption. Interestingly, during one season of the year, women depended on men not only for meat but also for plant foods. We suggest that among the Hiwi foragers, the spatial distribution of wild plant foods with respect to camp sites and macronutrient complementarity influence the timing of collection and the extent to which men gather the wild plant foods that women generally acquire.

Data on Ache, Duda (Draper 1984), and Agta (Goodman et al. 1985) hunter-gatherers over the seasonal round also show that women depend on men for most of their food consumption throughout the year (Hurtado et al. 1985).¹⁰ Again, comparative data are too scant to assess the generality of these trends. However, if future data indicate that female foragers generally tend to be more economically dependent on men than not, then we need to ask what social mechanisms might have led to this "universal" outcome and what aspects of food acquisition away from camp may be important deterrents to women's increased work output under (possibly) numerous conditions.

One important deterrent among Hiwi women appears to be impaired fertility.

In the population sampled, Hiwi female fertility was sensitive to changes in net energy balance. A drastic *relative* (not absolute) increase in work output between two seasons affected temporal fluctuations in net energy intake, and these fluctuations were highly correlated with seasonal variation in female fertility. The finding that a slight increase in female work effort can negatively affect female fertility suggests that if Hiwi women were to become much less economically dependent upon their husbands for their daily sustenance, their reproductive rates would probably decline below present levels.

Finally, we were faced with the issue of why both men and women in Hiwi society allocate relatively little time to foraging when data on hunting and gathering efficiency, as well as data on Ache foragers, suggest that individuals could be nutritionally much better-off if they increased work output. Seasonal weight loss patterns among the Hiwi may shed some light on this question: slight increases in men's and women's foraging efforts were associated with significant weight losses in the population sampled. We suggest that chronic parasitic infections and heat stress might be partially accountable for this pattern. These conditions may work synergistically so that slight changes in work output can very quickly have negative biological consequences such as weight loss. Parasites and heat stress among the Hiwi possibly increase the costs associated with their foraging relative to groups of hunter-gatherers who live in areas with forest cover and lower temperatures (e.g., the Ache of eastern Paraguay). If this inference is correct, then differences in disease vectors and climate may partially help explain why the Hiwi are less active than hunter-gatherers who live in forests.

In conclusion, this study of seasonal variation deals with various aspects of the sexual division of labor in one group of savanna hunter-gatherers of the New World. It is hoped that the quantitative descriptions as well as the hypotheses presented will motivate future research on the ecological determinants of sex differences in subsistence strategies.

NOTES

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2. The term "sexual division of labor" is not used to imply that a joint or common economic or reproductive goal exists for the two sexes. It is simply used to describe sex differences in time spent foraging, in the quantity and types of food that are acquired, and in food sharing between the sexes.

3. "Hiwi" is the English spelling of *Jigui*, the spelling that is used in Guajiboan practical orthography. Because earlier authors have used the English spelling, we retain it here.

4. In order to protect the study population, this and all subsequent locational references have been fictionalized. Band names are also fictional in order to protect study subjects.

5. Arcand states this emphatically in the film *Last of the Cuiva*, part of the Disappearing World Series produced by Granada Film Productions, London, England.

6. We have chosen children 3.5 years old because by this age they are totally dependent on solid foods. Ideally, we should present consumption rates that control for the age structure of our population and should incorporate in our analyses the lower caloric consumption of young children and the decreased caloric consumption of old individuals, as well as the high consumption rates of adolescents. However, this would require scaling food consumption to an almost daily fluctuation in the age structure of the population. This level of precision is probably unwarranted for the gross-level patterns we are attempting to characterize (see also Hill et al. 1984; Hurtado and Hill 1987).

7. Details of this resource are purposely left ambiguous because of its sensitive nature. More information may be obtained by writing to the authors.

8. For the calculations of net caloric intake among Hiwi women, we assumed an energy expenditure level of 5 cal/kg/hr for time spent in fruit collecting and 7.4 cal/kg/hr for time spent in root acquisition (analogous activities in Hill et al. 1984, Table 5, are "collecting" and "chopping tree" used in the analyses of Ache women's energy expenditure). We multiplied these numbers by the mean number of hours that women at risk of pregnancy (mainly nursing and nonnursing women) spent foraging for either roots or fruits in each season of the year. These products were then multiplied by the mean number of kilograms that women at risk of pregnancy weighed in each season. The resulting number represents a rough approximation of the relative differences in energy expenditure among women at risk of pregnancy in each season of the year. In order to arrive at an estimate of net energy intake, this estimate of energetic expenditure was then subtracted from the mean daily per capita consumption for each season as reported in Table 5.

9. Thirty percent of the total kilograms of meat acquired by the Hiwi we observed comes from feral cattle, which were apparently absent in Arcand's sample. This absence appears to account for the differences in meat consumption between the two studies.

10. !Kung (Lee 1979) and Gwi San (Tanaka 1980) foragers show the opposite pattern, with women acquiring more than 50 percent of the total calories. However, both data sets only represent the one month of the year when mongongo nuts are the major food staple.

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