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ARNHEM LAND ABORIGINES AND MBUTI: OBSERVATIONS UPON HUNTER-GATHERER FORAGING EFFICIENCY

ABSTRACT — *Ethnographic information from essentially unacculturated groups of Arnhem Land Aborigines and Mbuti has been perused for possible insights into foraging efficiency and optimality. A wide variance in foraging success characterizes each group. Large yields are produced by Fish Creek kangaroo hunts and Mbuti net hunting. Large differences in foraging success between Mbuti bands cannot be explained. The poor returns that characterize Fish Creek plant collecting raise several, mutually compatible hypotheses for the persistence of such activity. Acquisition of essential nutrients may be important and such aspects of feeding behavior may be under the partial mediation of a multi-factorial genetic program. However, if low efficiency foraging behavior is set within an overall context of group caloric efficiency, cognitive rewards that focus upon social experiences (often ritualistic) may be an important priority that also mediates the continuance of such activity.*

KEY WORDS: Arnhem Land — Cognition — Ecological anthropology — Foraging motivation — Foraging success — Foraging variance — Mbuti — optimal foraging.

INTRODUCTION

Set within the framework of evolutionary ecology, optimal foraging theory is a valuable conceptual tool for delineating an appropriate context for discussing hunter-gatherer foraging behavior (Winterhalder 1983a, Winterhalder and Smith 1981). Optimal foraging theory has its origin with animal ecologists. Its most precise and rigorous form predicts the range and relative value of each item on a predator's menu, where and how long foraging should take place and specific search strategies (Charnov 1977; McArthur and Planka 1966; Pyke, Pulliam and Charnov 1977; Schoener 1971). Applications to the description of hunter-gatherer resource procurement behavior have recently been made and serve to illustrate the considerable heuristic value of the models (Hames and Vickers 1982; Hawkes et al. 1982; O'Connell and Hawkes 1981; Smith 1981; Winterhalder 1983a, b).

The fundamental theorem predicts under what conditions a new food item may be added to the diet; i.e. only if its return relative to pursuit and handling costs is greater than average for the diet containing all items of higher rank (Charnov and Orians 1973). Ache foraging behavior is consistent with assumptions and predictions derived from this model (Hawkes et al. 1982). The marginal value theorem predicts when a forager shall leave one discrete patch for another (Charnov 1976; Charnov, Orians and Hyatt 1976; Parker and Stuart 1976) and has provided a context for a detailed analysis of Cree-Ojibwa hunting (Winterhalder 1981b). Winterhalder (1983a) provides a concise summary of these models that is oriented towards ecological anthropology.

With one exception, these hunter-gatherer studies were conducted with peoples who have made an accomodation to Western culture and employ various transportation modalities, tools and weapons that

are products of advanced technology. Opportunity is thereby provided to investigate relationships between diet breadth and technological change (Hames and Vickers 1982, Winterhalder 1981b). (The one exception is data from bow hunting Yanomana included in Hames and Vicker's (1982) study.) Unfortunately, optimal foraging theory was developed after the opportunity had passed to design field work with unacculturated hunter-gatherers within the context of such models (see dates on references above). Winterhalder's 1975 field work with the boreal forest Cree-Ojibwa represents the first ethnographic field work whose design was determined by a consideration of optimal foraging models (Winterhalder 1983a).

Bushmen (Lee 1979) excepted, I know of only three ethnographic reports that describe the activites of essentially unacculturated hunter-gatherers from which quantitative data on foraging behavior may be extracted (Harako 1976, McCarthy and McArthur 1960, Tanno 1976). Parameters that are described include size of foraging party, foraging time, species collected, animal taxa killed and net yield. Species identification and net yield allow for the calculation of edible protein and caloric value of each resource item. Because these data were gathered by workers with no awareness of optimal foraging theory, they are less than perfect for the type of analysis proposed here; travel and processing time can only be inferred indirectly and thereby categorized as discrete variables. Nonetheless, in conjunction with Bushmen data, these reports may represent the only information with which to discuss the optimality of foraging behaviors for hunter-gatherers whose resource procurement activities were little modified by Western influence; i.e. all travel by foot, foraging implements manufactured from local materials, no firearms, etc. While the data do not permit a precise testing of specific predictions derived from either the fundamental or marginal value theorems, they do allow for observations about the optimality and efficiency (in the general sense) of various foraging behaviors.

METHODS.

A close reading of McCarthy and McArthur (1960) provides the net weight of each dietary item and for many foraging trips, the net yield is given. The data presented in Fysh et al. (1960) allow for the nutritional composition of plant foods to be determined. For animals, an estimate of usable weight was made by subtracting the skeletal mass (SM), as estimated from the allometric relationship with body weight (Prange 1979); net weight was used as BW.

$$SM = 0.06BW^{1.09} \quad (1)$$

Edible protein and kcal were calculated using the conversion factors in Meehan (1977a, b).

I have identified discrete foraging trips in a manner different from McCarthy and McArthur (1960). Without being explicit, these workers treat each day's foraging by various subgroups as comprising a single foraging trip. In this study, the end of a particular foraging trip is defined by a period of rest, sleep

or eating that allows for a change in group composition and/or foraging priorities. Such an approach allows for the description of three hunters stalking and killing a kangaroo followed by one hunter foraging alone as two separate and discrete hunts.

In contrast, a single day's hunting by a Mbuti band is considered a single, discrete foraging experience. Such hunting represents the continuous activities of a group whose composition and objectives do not change from village departure to return (Harako, 1976, Tanno 1976). The exact size of net hunting parties by Mbuti band M is not specified by Tanno (1976) but considering his discussion of village activities, the estimate used here is unlikely to be in error by more than one or two participants and the error so introduced into the calculations is thus acceptable.

Usable weight (W_u) as distinct from edible yield (W_e) was calculated for Mbuti prey as described above for Arnhem Land Aborigines. This distinction has validity because the Mbuti make a variety of culturally important objects from the inedible portions of an animal carcass (Turnbull 1965). Edible meat is taken to be 65 % of carcass weight (Marks 1973: Tab. 3, 1976: Appendix B). The percent of W_e that is edible protein and its caloric value is taken from Lee (1979: 270). Lee's (1979) correction for shrinkage during cooking is not employed for much of the resulting liquid is not lost but consumed as high caloric fats and oils. Weight estimates for the small game species identified in Tanno (1976) were obtained from Dorst (1969) and averaged. This simplification does not take into account the relative frequency with which each species is obtained but such information cannot be extracted from Tanno (1976). In any case, small game forms a tiny percentage of hunt yields and the error so introduced should be negligible.

A "typical" plant collecting trip of the Western Desert Aborigines was derived from the composite scenario provided by Gould (1969: 26) and the conversion factors provided by Meehan (1977a: Tab. 1). The plant collecting activities of a single! Kung woman during the relatively unassimilated 1960's period may be found in Lee (1979) and adjusted for seasonal differences. Likewise, several hunts may be reconstructed with enough precision to contribute to the analysis undertaken here. Where possible, information from these societies will be discussed in conjunction with the primary analysis that focuses upon Arnhem Land Aborigines and the Mbuti.

The analysis of foraging yield is derived from O'Connell and Hawkes (1981) where t_t = travel time to and from the foraging site, t_s = search time, t_g = gathering time, t_p = processing time and $t_T = t_t + t_s + t_g + t_p$. The reports of Harako (1976), McCarthy and McArthur (1960) and Tanno (1976) do not allow for t_s and t_g to be differentiated and identified independently of one another.

The analytical protocol may be summarized as follows:

Energy gained per unit of time invested in foraging including travel time to site but excluding processing —

$$E_n^1 = (kcal)/(t_t + t_s + t_g) \quad (2)$$

Energy gained per unit of time invested in foraging including travel and processing time —

$$E_n^2 = (kcal)/t_T \quad (3)$$

Kcal per forager hour including processing time —

$$E_p = (kcal)/(t_s + t_g + t_p) \quad (4)$$

Total calories recovered per forager per trip —

$$E_t = (kcal)/n \quad (5)$$

Net return on resources

$$E_i/h_i = (kcal)/(n)/(t_s + t_g + t_p) \quad (6)$$

Greatest imprecision rests with estimates of t_t and t_p for the Mbuti (see Tanno 1976: 119). Travel time (t_t for all Mbuti hunting trips was arbitrarily set to 1 hr., an approximation that while inferred, is not likely to be grossly inaccurate.

Two indices of efficiency were calculated according to Smith (1980) where E_a = the total calories acquired per trip and E_e = the caloric expenditure of the foragers per trip. E_e was approximated using the data provided by Passmore and Durnin (1955) and Smith (1981). The anthropometric data in Ghesquiere and Karvonen (1981) and Rimoin et al. (1967) suggest that adult Mbuti body weight is 70 % that of "full sized" peoples and estimates of their energy expenditure will be correspondingly reduced, although in strict metabolic terms, metabolic rate $\propto BW^{.75}$.

Net rate of energy capture per unit of time —

$$R = (E_a - E_e)/ (t_T) \quad (7)$$

Net rate of energy capture per forager hour —

$$\bar{R} = (E_a - E_e)/((t_T)(n)) \quad (8)$$

Equation (8) will be emphasized here for the reasons given in Smith (1981: 53). Optimal foraging theory would define a group's (village?, band?, horde?) objective as the maximization of R or $\bar{R}$. The "optimality" to be considered in this analysis will be assessed within a context that includes physiological, psychological and cognitive parameters.

RESULTS AND DISCUSSION

Before proceeding with a discussion of efficiency and optimality, a few comments can be made about the relationship between foraging time and number of participants using the observations recorded by McCarthy and McArthur (1960). A significant correlation with foraging time was found for the combined male foraging activities of the Fish Creek group ($r = 0.439$, $0.05 > p > 0.02$ for 17 $d.f.$), the plant collecting activities of the Fish Creek women ($r = 0.636$, $0.02 > p > 0.01$ for 11 $d.f.$) and the collecting activities of the Hemple Bay men ($r = -0.859$, $0.05 > p > 0.02$ for 5 $d.f.$). Note that the last situation is characterized by a negative correlation coefficient. Considering the small range in number of foragers in each situation ($n \leq 5$), these results can only hint at relationships that remain to be established. To

the extent that foraging time is a function of size of foraging party, several underlying structural factors may be postulated to be of importance. If foraging is both an extractive and social activity (Winterhalder, personal communication), perhaps larger groups are in less of a hurry to return home because the increased diversity of social interactions available on a given trip to the larger group takes a longer time to complete.

As measured by the E_n and E_t/h_t indices, the Fish Creek people show the worst returns for foraging effort when plant collecting and the highest returns when kangaroo hunting. For plant collecting, $E_n^1 = 18 - 482$ kcal/hr and $E_n^2 = 52 - 359$ kcal/hr with n (foraging trips) = 9. When kangaroo hunting, $E_n^1 = 5,502 - 41,092$ kcal/hr and $E_n^2 = 3,709$ to 22.049 kcal/hr with $n = 6$. This differential input into the overall dietary regime stands in direct contrast to the Kung foraging context (Lee 1979) and serves to illustrate the hazards of generalizing that model to all hunter-gatherers (cf Hawkes and O'Connell 1981). Such results do support Lee's contention that hunting is riskier than plant collecting on a day to day basis (see also *Table 1*) but only with respect to greater variability (variance of V^* of R indices). In terms of absolute yield (mean $\bar{R}$ value and lower 95 % limit (L_1) of $V_{\bar{R}}^*$), hunting appears more reliable. Plant collecting is characterized by mean $\bar{R} = -156 \pm 135$ kcal/forager hr and $V_{\bar{R}_{L_1}}^* = -38$. Fish Creek kangaroo hunting yields mean $\bar{R} = 2,912 \pm 4,463$ (kcal/forager hour) and $V_{\bar{R}_{L_1}}^* = +67$. This larger variance in foraging success, as measured by several indices, is similar to that characteristic of the Alyawara who have access to modern vehicles and tools (O'Connell and Hawkes 1981). The yield obtained from kangaroo hunting is truly impressive and of an order of magnitude similar to that derived for modern day Cree who make extensive use of repeating rifles, steel traps and nylon fishnets (Winterhalder 1981b).

The Hemple Bay people exhibit a similar range and variance in foraging return but do not repeatedly engage in one activity that consistently provides very low returns. For Hemple Bay plant collecting, $E_n^1 = 373 - 12,839$ kcal/hr and $E_n^2 = 327 - 12,839$ kcal/hr with $n = 21$. When fishing, $E_n^1 = 698 - 28,635$ kcal/hr and $E_n^2 = 441 - 15,419$ kcal/hr with $n = 7$. For plant collecting, mean $\bar{R} = 618 \pm 786$ kcal/forager hr and $V_{\bar{R}}^* = 129 \pm 21$. For fishing, mean $\bar{R} = 2,602 \pm 4,841$ kcal/forager hr and $V_{\bar{R}}^* = 193 \pm 52$. Net fishing yields occasionally reach the level typical of successful Fish Creek kangaroo hunts.

As described by E_n^1 and E_n^2, returns from Mbuti net hunting are similar to those for Fish Creek kangaroo hunts. For Mbuti Band A, $E_n^1 = 1,607 - 13,203$ kcal/hr, $E_n^2 = 1,179 - 9,707$ kcal/hr, with $n = 14$. Mean $\bar{R} = 140 \pm 193$ kcal/forager hr with $V_{\bar{R}}^* = 140 \pm 27$. For Mbuti Band M, $E_n^1 = 8,200 - 32,276$ kcal/hr, $E_n^2 = 5,720 - 23,033$ kcal/hr with $n = 13$ and mean $\bar{R} = 591 \pm 302$ kcal/forager hr with $V_{\bar{R}}^* = 52 \pm 10$.

On *average*, the returns from these latter two foraging contexts considerably exceed those of the Alyawara.

For all foragers, the coefficient of variation (V^*) of the R index is very high and also characterized by a very wide range ($V^* = 52 - 214$). This unpredictability (large variance) in return for all types of foraging activities within both societies (Arnhem Land Aborigines and Mbuti) is thereby highlighted. Irrespective of absolute yield in terms of weight or caloric value, those foraging activities that yield the most consistent and predictable returns are plant collecting by the Fish Creek group and net hunting as performed by Mbuti band M. As judged by $\bar{R}$ values, foraging activity that is characterized by the most unpredictable returns per forager on a daily basis is fishing by the Hemple Bay people. The range in absolute value of the R indices is striking especially when noting that the time span over which each group was studied was relatively short and might be suspected to hide much of the inherent variance if data could be gathered over yearly time scales. For all groups and each type of foraging behavior, R values fluctuate over at least one order of magnitude and always encompass some negative values. This enormous variability is reflected in the high standard deviations and V^* coefficients that accompany mean R values. Nonetheless with one exception, all mean $\bar{R}$ values are positive with the greatest returns per forager associated with kangaroo hunting by Fish Creek men (*Table 1*) and fishing by the Hemple Bay group. In both of these situations, one particularly successful day's yield is responsible for the high mean $\bar{R}$ value.

R values portray the caloric return per group and are as valid an index of foraging success as the $\bar{R}$ index. The most spectacular mean R value is associated with Mbuti band M net hunting (*Table 1*). Group behavior is the second level in the analytical hierarchy herein considered. While exhibiting characteristics that may be attributed to individual behavior, and indeed exhibiting a feedback relationship with the "lower" level, group behavior nonetheless possesses unique intrinsic properties that do not feedback or interact with other levels in the hierarchy. If sharing is, in part, risk minimizing behavior (Gould 1982, Jochim 1976, Yellen and Harpending 1972), then the wide fluctuation in R values that characterizes most types of foraging activity might indicate a prediction of both Arnhem Land Aborigines and Mbuti to share food.

Benefits also accrue to the food sharing group in terms of the establishment of new, and reinforcement of old, reciprocity networks that may be drawn on during times of resource stress (Gould 1982b, Myers 1982).

When considered on a trip by trip basis, the great variability in R and $\bar{R}$ values illustrates the limitations to this type of analysis when using a single composite foraging profile that, in effect, "averages" the data from many individual trips. Nonetheless, such was the only procedure available to produce the efficiency analysis for Western Desert Aborigines and !Kung Bushmen presented in *Table 2*. These calculations suggest that the mean R and $\bar{R}$ that characterize the foraging activities of these societies lie at the high end of the range descriptive of Arnhem Land Aborigines and Mbuti. Similar results are presented by Smith (1981) for Hudson Bay Inuit who use mechanical transport and modern weapons.

Such an analysis raises several important, but potentially unanswerable questions. To all appearances, Mbuti bands A and M live in identical environments, net hunt very similar prey and are therefore faced with similar foraging challenges. In the absence of ethnographic comment to the contrary (Harako 1976, 1981; Tanno 1976), I assume that nearly identical skill and expertise is brought to each hunt by each group. Why then such spectacular differences in foraging returns when the two bands are compared?

Considering the consistently poor returns by the Fish Creek people when plant collecting (mean $\bar{R} = -156 \pm 135$, *Table 1*), why do they continue the activity? The caloric context of the total group foraging effort set within a behavioral context that includes sharing allows for this inefficient plant collecting to be accomodated without endangering the overall energy budget of the group. But the question remains, why bother? One reason might be the need to supply essential metabolites, vitamins and/or minerals and fiber (Glander 1982, Pulliam 1981: 64). The opportunity cost of foraging for such resources may be low enough to make them profitable in the broader sense and the subjective importance of variety in the diet cannot be ignored (Winterhalder 1983a).

A second category of "needs" might be the desire to experience the pleasurable social interaction that results from such foraging activity. (Yet two of such trips were conducted by a single individual.?) Hart's (1978: 337) observations about Mbuti net hunting are particularly relevant to this hypothesis. "The overall pace of the hunt is so leisurely that old people and mothers with infants may join. Between casts of the nets, the hunters regroup in a gathering called *bimba* to share tobacco or snacks of fruits and nuts gathered along the way. *Bimba* is an important time to flirt and visit, to play with babies and to discuss the next drive. In effect, the net hunt is as much a social event as it is the means of subsistence". Winterhalder's (1983a) observations on Inuit foraging and group size and Ache sexual division of labor highlight the importance of social and cognitive factors to the construction of foraging groups. Increased foraging efficiency due to the sharing of information is difficult to document but may well be important (Smith 1981: 43—45).

Winterhalder's (1983b: Fig. 2) model for an energy maximizer (energy limited organism) predicts that items of low value (*i.e.* low e_i/e_i) will be added to the diet. Increased net energy intake has priority over maximizing foraging efficiency. However, problems with this interpretation remain, for the predictive model was developed for a stationary forager. Predictions generated from a searching forager model (Winterhalder 1983b: Fig. 4 & 5) do not help in resolving this question. Should Fish Creek plant collecting be treated as a stationary forager problem? (Yet, there is little evidence that they are energy limited.) As with the Ache of Paraquay (Hawkes et al 1982), the Fish Creek people apparently could have procurred enough meat to make up all of their caloric needs but chose to gather plants that offer a low energy return. Such an observation does not conform to a simple view of optimization as portrayed by the fundamental theorem (Winterhalder 1983a). Nonoptimal foraging models are a subject worthy

of increased attention (Janetos and Cole 1981).

Additonal factors that may be relevant are suggested by nonhuman primate data. As reviewed by Clutton-Brock (1977) and C. M. Hladik (1977), several species, including chimpanzee, unconsciously select plants and insects with complementary amino acids and/or do a diversity search for such complementarity. Particular foods may be selected that aid in digestion. Avoidance of toxic plant secondary compounds is strongly indicated by the primate data (Glander 1982) and could be of importance with respect to human hunter-gatherers. The extraordinary observations recorded some years ago by Davis (1928) suggest that such feeding behaviors are part of the human foraging repertoire.

Sympatric primates are well known to show differences in feeding level (Blumenberg 1984, Caldecott 1980, A. Hladik 1978, Milton 1981, Struhsaker 1978, Waser 1980, Wheatley 1982). Do hunter-gatherers make dietary choices in order to avoid competition with other fauna resident in their ecosystem? If such choices are made, are the human foragers consciously aware of their decisions and are such decisions associated with myth, ritual or taboo? Considering our primate heritage, could such a decision making process reside, in part, within a flexible multifactorial genetic program?

There is no hint in either ethnographic observations or quantitative analyses that the highest *possible* net rate of caloric return is not being achieved. As Winterhalder (1983a) also observes, the optimization principle refers to a commonsense intuitive hypothesis; "hunter-gatherers will have developed behaviors which make them as skillful and successful as is possible in the capture of game or harvesting of plants, relative to their effort." Optimal results will rarely be achieved by satisfying absolute criteria but the process of optimization will always be operable, be it designed for strictly caloric goals or constrained by much wider considerations that include cognitive and emotional needs.

At some times and in some places, particularly those environments that are not rainfall limited (cf Blumenberg 1981), are hunter-gatherers time maximizers with considerations of a behavioral indifference space not superfluous? Are some foraging constraints based upon behavioral considerations alone (independent of too difficult challenges) and thus independent of caloric considerations per se? Do group social and interpersonal behavior patterns and rewards place limits upon foraging efficiency as viewed by orthodox optimal foraging models? Such situations could be described by modified fitness indifference curves (Winterhalder 1983a) in which nonforaging cognitive rewards are gained while searching (inefficiently?) for food.

As a further illustration of the complex modifications that are possible as a result of the human need for cognitive experience upon biologically oriented (optimal?) foraging models I quote the following ethnographic observation (Dick Kimber, personal communication). In this instance, the cognitive need is the fulfillment of a ritualistic act. "One day, 2 senior Pintupi men back on a first visit to

TABLE 1. *Coefficient of variation analysis of* R *indices**

Group		n	$\bar{X}$	$s_{\bar{x}}$	V^*	s_{V^*}	L_1	L_2
Fish Creek plant collecting	R	8	—398	±290	75	±18	—32	—119
	$\bar{R}$	8	—156	±135	89	±22	—38	—141
Fish Creek kangaroo hunt	R	8	1,022	±13,338	134	±34	557	2,135
	$\bar{R}$	8	2,912	±4,463	158	±40	67	249
Fish Creek net fishing	R	13	805	±892	113	±22	65	161
	$\bar{R}$	13	523	±688	134	±26	77	191
Hemple Bay plant collecting	R	19	1,560	±2,770	180	±29	119	241
	$\bar{R}$	19	618	±786	129	±21	85	173
Hemple Bay fishing	R	7	5,749	±10,170	183	±49	67	299
	$\bar{R}$	7	2,602	±4,841	193	±52	71	315
Mbuti band A net hunting high prey BW	R	14	2,974	±3,960	136	±26	81	190
	$\bar{R}$	14	140	±193	140	±27	83	197
Mbuti band M net hunting high prey BW	R	13	14,180	±7,255	52	±10	30	74
	$\bar{R}$	13	591	±302	52	±10	30	74

* Where S_{V^*} is the standard error of the coefficient of variation (V^*). L_1 and L_2 are the upper and lower confidence limits, respectively, of V^* where $L = V^* \pm t_{.05(n)} s_{V^*}$.

EPILOG? AFTERWORD?

Recent correspondence about this paper with several interested colleagues has raised some interesting points that deserve mention. Nicholas Peterson and Jon Altman of the Australian National University have pointed out that the Fish Creek Group was artificial in composition (no children or elders) and likely exhibited an abnormally high hunting intensity because of their employment by McCarthy and McArthur. The contextual validity of their foraging activities, therefore, must be rigorously assessed. The activities of the Fish Creek Group certainly demonstrate a possible profile of foraging activities in the area. Altman (1984) extracts some important information from his thesis about the foraging of a band of Gunwinggu people who reside only 100 km from Fish Creek. More than 90 % of the kcal and 88 % of the protein were produced by men and animals provided 90 % of subsistence production. However, a number of factors may have produced a dramatic decline in the productivity of plant gathering by women including a) the introduction by 1948 of feral water buffalo that may have ruined beds of previously exploited lilies and yams (Altman 1982); and b) access to market carbohydrates. The maximum return observed for female gathering Altman (1984) observed was 600 kcal/woman hour. The range in E_p values calculated for this study was 95—411 kcal/forager hour (equation 4). Extending the upper limit of the range to 600 kcal/forager hour would not alter the very low *net* rate of return for plant collecting (equations 7 & 8), nor eliminate the possible relevance of the questions I've raised with regard to the persistence of such low return subsistence activities. Indeed, Altman (1984: 185) hints at such perplexing issues. Clearly, the R and $\bar{R}$ values for Fish Creek hunting may be highly inaccurate. However, women could have produced ~ 50 % of the daily kcal (1,000 kcal/forager/day) with additional time devoted to plant collecting as Altman (1984) points out. In strict metabolic terms, a low positive $\bar{R}$ value suffices.

As Altman observes, a long term (full year) approach to these problems should take into account variability imposed by the seasonal and ceremonial cycles, variation in sharing patterns, variation in residential patterns, food taboos and food preferences determined by high vitamin content (Brand et al 1962). I've attempted to indicate some of these complexities in the discussion section of the paper. Those interested in the nutritional composition of

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traditional country after a gap of perhaps 15—20 years spent a very long time digging out a lizard. I was surprised that they persevered for such a long time — probably half an hour or more — when lizards normally take but 1—5 minutes to catch. Eventually I asked the men why they had persevered and one, whom I had known for nearly 10 years, replied that the first attempt at catching game in fresh country *must* be successful, otherwise bad luck will ensue in the following days of hunting ... In this particular instance, a very rare case, the lizard was not caught, the hole being very long and unusually deep. The men had used rough, improvised digging-sticks and their hands. They eventually stopped digging on the understanding (by themselves) that they could have caught the goanna and therefore they had effectively succeeded in their task." The priority reward (nourishment) sought for appears to be the appropriate completion of a symbolic activity and only secondarily the acquisition of food (cf de Garine 1978).

The bottom line is that physiological survival must not be threatened by the search for pleasurable (meaningful) social or ritual experiences. However above 2,000 well balanced calories per day, is it more important for the human brain to engage in *complex behavior for its own sake* than to continue a highly focused priority upon the aquisition of additional calories? Within such a context, rank assignments to resources might (subconsciously) include such psychic rewards to the nervous system; *i.e.* certain foraging activites provide more "cognitive nourishment" than others.

Jochim's (1982) model suggests a second category of risk avoidance — the desire to avoid boring, simplistic, repetitive cognitive and emotional experiences. Hart's (1978) observations about Mbuti net hunting quoted above suport this hypothesis. To illustrate such an expanded concept of risk avoidance, Fish Creek plant collecting could be describcd as risk indifferent (category #1 — calories) with respect to the group as a whole, failing at risk avoidance #1 (coming home without food) but succeeding at risk avoidance #2 (acquiring essential cognitive nourishment — complex experience). Confirming the existence and operational importance of this second category of risk avoidance would require extensive interviews with foraging parties of varying size and objectives, both on matters of foraging priorities and perceptions of the group social experience. Such speculation is consistent with Winterhalder's (1983a) thoughts about mammalian laziness wherein he concludes that animals have a finite satiety for the products of foraging. For human hunter-gatherers physical inactivity might not necessarily follow — merely a shift in perceived priority needs/benefits/objectives to the cognitive realm.

CONCLUSIONS AND SUMMARY

With reference to the traditonal life styles of Arnhem Land Aborigines and Mbuti:

1. Very limited data hint at a complex relationship between foraging time and number of participants that may be influenced by such variables as sex and specific type of foraging activity.

2. Greatest foraging yields are obtained from kangaroo hunts, as conducted by the Fish Creek people, and Mbuti net hunting. Such yields are of a magnitude comparable to those produced by hunter-gatherers that employ modern vehicles and tools.

3. A large variance (unpredictability) in foraging success is demonstrable for all three groups studied and is similar in scope to that characteristic of hunter-gatherers who have access to modern modes of transportation and weaponry. This variance is given quantitative expression by high values for the coefficient of variation of the $\bar{R}$ index. Large standard errors and a wide range also characterize this index.

4. The overall picture of foraging behavior (effort, return, efficiency) is not consistent with the Lee (1979) model for the !Kung.

5. Foraging activities that produce the most consistent and predictable returns, irrespective of absolute weight or caloric value, are plant collecting by the Fish Creek group and net hunting as practiced by Mbuti band *M*. The foraging activitiy that results in the most unpredictable returns per forager on a daily basis is fishing by the Hemple Bay people. The greatest returns per forager characterize kangaroo hunting by Fish Creek men and fishing by the Hemple Bay group.

6. The large difference is net hunting success between the two Mbuti bands is not readily explainable using the available ethnographic information.

7. The consistently poor returns that characterize plant collecting by the Fish Creek people raise several intriguing questions. Does such activity provide essential trace metabolites, and/or vitamins and/or minerals and/or fiber? To the extent that some human foraging patterns may be rooted in our hominoid ancestry, primate data hint at the existence of a multifactorial genetic program that might mediate some aspects of feeding behavior such as the ingestion of complementary amino acids and the avoidance of toxic plant secondary compounds.

8. Predictions from the model of feeding behavior for an energy maximizer (stationary forager) postulate that increasing net energy intake has priority over maximizing foraging efficiency. Are Fish Creek plant foraging groups best considered time maximizers that forage within a context that places a high priority upon fulfilling cognitive needs (*i.e.* acquiring "cognitive nourishment")? Beyond 2,000 well balanced calories per day, is it more important for the human brain to engage in *complex behavior* (cognitive, social, ritual) for its own sake than continue a highly focused priority upon the acquisition of additional calories? Several observations exist in the ethnographic record that are compatible with this hypothesis. This hypothesis refers to some of the variance in human foraging behavior *not* accounted for by the multifactorial genetic program postulated above and may model a different subset of genetically mediated variance in human behavior (*i.e.* the "drive" for complexity in experience) that is a unique attribute of the advanced hominid brain (cf Blumenberg 1983).

TABLE 2. *Composite Hunter-Gather Foraging Profiles*

Season	n	t_t	$t_s + t_g$	t_p	t_T	kg/n	Kcal/kg	E_n^1	E_n^2	E_p	E_i	E_i/h_i	hr^1/kg	hr^2/kg	E_a^*	E_e	R	$\bar{R}$
Western Desert Aborigines Plant collecting (1960's) after Gould (1969)																		
	4	1	3.5	2.5	7	4.5	1,310	5,242	3,370	3,931	5,897	983	0.19	0.33	23,587	4,320	4,282	1,070
!Kung Bushmen (1964—1968) after Lee (1979) Female plant collecting																		
Minimum A—S	1	2	3	6	11	10	1,410	2,820	1,280	1,282	14,100	1,507	0.30	0.90	14,100	1,650	2,490	2,490
Maximum A—S	1	5	3	15	23	15	1,410	2,644	920	1,175	21,150	1,175	0.20	1.20	21,150	2,640	2,314	2,314
Minimum O—M	1	2	3	6	11	10	949	1,898	863	1,054	9,490	1,054	0.30	0.90	9,490	1,650	1,568	1,568
Maximum O—M	1	5	3	15	23	15	949	1,779	619	791	14,235	791	0.20	1.20	14,235	2,640	1,449	1,449
Big game hunting 1967																		
	5	7	1	5	13	18	1,950	21,938	13,500	29,250	35,100	5,850	0.01	0.07	175,500***	15,600***	19,988	3,998

Notes: * Lee 1979 : 187
** Lee 1979 : 270 and text
*** Lee 1979 : 271 Male hunters expend 2,250 Kcal/day when foraging

Australian bush foods should not fail to consult Brand et al (1983). Where there are foods in common, Brand et al (1983) confirms Fysch, Hodges and Siggins (1960). Tables of nutrient composition, resource yield and optimal foraging analysis (equations 2—8) for each foraging trip of each group can be supplied to interested colleagues upon request.

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