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Boreal Foraging Strategies

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6.1. Introduction

In 1974–1976, in the book *Zoönomia or the Laws of Organic Life*, Erasmus Darwin (1794) speculated that modification of species was brought about through the satisfaction of three wants. He identified them with admirable directness as “lust, hunger, and danger.” In the more prosaic but parallel terminology of contemporary evolutionary ecology these have become mating, foraging and the avoidance of predators (and I would add hazards). The list is still meant to be inclusive, and to represent separable arenas of adaptive or fitness-enhancing behavior, each subject to somewhat different types of investigation. Other chapters in this volume cover the mating and demographic systems and the responses to climate, physical hazards, and the dangers from predation of native peoples living in the boreal forest of northern Ontario. Adjustments by residents to the effective environment of this region are described and analyzed as adaptations. In this chapter I add an analysis relevant to E. Darwin’s second category, hunger. In language more appropriate to the time, it is a study of foraging behavior.

The chapter has a narrow focus—the attempt to understand systematically how a Cree makes foraging decisions when harvesting food-producing resources found within the boreal forest. These resources are treated as valuable only in that they provide calories. Nutrients and nonconsumable products are, for the moment, ignored. This goal has determined the topics covered. Equally important, it excludes several obvious and relevant subjects: the acquisition and use of Euro-Canadian food stuffs, gardening, and, except peripherally, the effects

of the fur trade on foraging decisions. This is a severe restriction, but one with advantages. Foraging behavior is complex. Hunting and gathering as ecological processes are qualitatively and especially quantitatively little understood; thus, rather specific issues must be resolved before the more inclusive ones can receive reliable analysis. I hope to show that specific questions, systematically studied, can generate fresh appreciation of the more general issues that tend to engage anthropologists, and build a base necessary for expanded coverage.

6.2. Optimal Foraging Theory

The theory derives from evolutionary ecology, particularly from optimal foraging theory (Pyke *et al.*, 1977; Winterhalder, 1981a). I have applied it with two complementary goals in mind: (1) Use of the theory as a heuristic research procedure for analyzing the adaptive articulation of a particular group with their local habitat; and (2) use of data on Cree foraging to evaluate the applicability of this kind of theory to human foragers in general. Specifically, the problems are these: Can this theory guide productive research? Does it generate accurate predictions about the ways in which human foragers will behave in specified environmental circumstances?

Optimal foraging theory is a collection of models specifying the behaviors of an organism which has evolved to harvest resources to maximum efficiency (Schoener, 1971). It is based on the observation that individuals who improve their performance of basic life tasks—E. Darwin's triad—relative to time and energy expenditures will be better adapted, or, if a strict biological evaluation is applied, are likely to have a higher genetic fitness. Humans confront some of the same adaptive problems as other animals, including the efficient capture of food. While their adaptive processes are different, the goals and perhaps the form of the behaviors achieving them may be substantially the same. This biological theory can be adapted to anthropological questions on that basis (Durham, 1976; Richerson, 1977). Foraging models in particular are readily applicable to organisms that base their adaptive behavior on learning (Pulliam, 1981a, b; Winterhalder, 1981a).

In this case the optimization principle is as follows: Human foragers will develop behaviors which allow them to achieve the highest possible net rate of energy capture while foraging. Energy capture is measured per individual. This isolates the energetic value of resources, and ignores their other, partially independent qualities, such as nutrients or nonfood utility. An argument for this focus can take several forms (Smith, 1979; Winterhalder, 1981a): (1) There may be absolute shortages of available energy on a constant or periodic basis; (2) there may be opportunity costs to foraging, because of exposure to hazards or diversion of time from other important activities; and (3) there are practical reasons for this choice: energy and time are relatively easy to measure, conceptually pervasive, and common to human and nonhuman communities.

It is worth emphasizing the last clause of this optimization principle, "while foraging." This circumvents the assumption that hunter-gatherers strive to maximize resource use in general. It is fully compatible with behaviors that attempt to minimize the time required to obtain a fixed (and perhaps rather limited) quantity of resources. This would be a "time-minimizer" in Schoener's (1971, 1974; see also Smith, 1979) terminology. The principle is simply an operational form of the expectation that hunter-gatherers have developed behaviors which make them skillful and as successful as possible in the capture of game, relative to effort.

In the present case we know that Cree populations suffered periodic and occasionally severe food shortages throughout the fur trade era and perhaps earlier (Bishop, 1974; Leacock, 1973; Ray, 1974; Rogers and Black, 1976; Rogers, Chapter 5, this volume; Steegmann, Chapter 7, this volume). These have abated with the recent introduction of social services and Euro-Canadian foods. Hence this study relies on the belief that optimal foraging patterns have persisted into the present because the energetic goal is substantially the same as that of a contemporary Cree hunter exercising personal skill in the capture of game. There is also evidence that the largely meat diet of the Cree is nutritionally adequate, so that, to a first approximation, nutrient qualities of resource species can be overlooked (Berkes and Farkas, 1978). The use of energy and time as currencies reflects the testable assumption that these have been predominant influences on the development of Cree foraging behavior.

The models themselves are fairly simple. In the classification proposed by Levins (1966), they are general and realistic, but not precise. Their importance lies in what can be learned through attempts to assess derived hypotheses: Does the model suggest important phenomena or relationships to observe? Does it identify significant variables? Does it help, heuristically, to generate insights about the subject? Such tests cannot confirm that humans optimize—that is assumed at the onset. Rather, tests of specific hypotheses indicate if the constraints, optimization criterion, and behavioral possibilities incorporated into the model characterize the situation analyzed (Maynard Smith, 1978). If confirmed, such tests generate the systematic understanding of foraging decisions sought here. Unconfirmed, they can also structure insight, if one can determine which of the assumptions or constraints of the analysis was violated and in what manner. Much of the value of the procedure then stems from its self-conscious and quite specific development of functional arguments, using a group of models set into the context of evolutionary biology (Smith and Winterhalder, 1981; McCay, 1981).

6.2.1. Diet Breadth

This model is directed to the question of diet choice. Most organisms are exposed to a range of potential resources, and most are selective to some degree. This model asks which and how many of those potential resources an optimal

forager will harvest in different circumstances. It was developed originally by MacArthur and Pianka (1966; MacArthur, 1972; Pianka, 1978). More recent and somewhat different approaches have produced essentially the same predictions (Charnov, 1976a; Pyke *et al.*, 1977; Krebs, 1977; Sih, 1979; *cf.* McNair, 1979).

The model assumes that the forager randomly encounters resources (potential prey species), that is, in proportion to their relative abundances. Only certain of those encountered during searching will be pursued. Resources are ranked by net value relative to handling or pursuit costs (Fig. 1). Average search cost to locate a unit of resource declines as more of those encountered are pursued; average pursuit cost increases as the diet expands to include less desirable types or those more difficult to catch. An optimal forager (judged by maximal net energy return rate) takes the set of species to the left of the intersection of the curves. Stated differently, when a potential prey item is located the forager must decide whether to pursue it or to continue searching for other prey. The optimal forager will elect to pursue an encountered item unless for the same effort it could expect to locate and pursue one or more prey of greater net value.

One produces hypotheses with this model by observing how various factors change the positions or slopes of the search and pursuit curves or the prey rankings. Searching foragers, those that spend a relatively large amount of their foraging time looking for potential prey, will be dietary generalists; pursuing foragers, those spending relatively more time in pursuit of prey, will be specialists. A general increase in habitat richness will reduce average search time and lead to specialization; overall resource impoverishment produces the reverse effect. Anything that improves the general efficiency of searching, such as increased velocity, will cause diet breadth to contract; anything that improves the efficiency of pursuing the organisms should cause diet to expand. Further, changes in the absolute density of low-ranked species (those to the right of the intersection of the ΔS and ΔP curves) should not affect their harvest. A prey type not worth pursuing when rare will not be worth pursuing however abundant it becomes. This latter result can be restated: whether or not an item is included

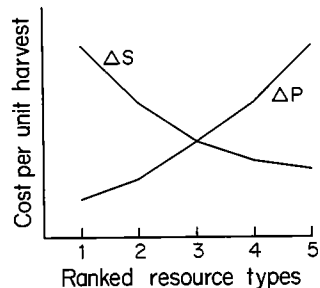


FIGURE 1. The MacArthur and Pianka diet breadth foraging model. The ΔS curve plots decreasing average search costs, and the ΔP curve increasing average pursuit costs, both per unit of resource, as an increasing number of resource types is added to the diet. The optimal diet includes all items to the left of the intersection of the two curves. After MacArthur and Pianka (1966). Copyright 1966, the University of Chicago; used with permission.

in the optimal diet is independent of its own abundance and depends only on its rank and the abundance of items of higher rank.

6.2.2. Patch Choice

A second MacArthur and Pianka (1966) model considers patch choice. Most organisms are faced with a variety of different habitats—a mosaic of potential resource “patches.” Foraging efficiency depends on how many habitat types the forager exploits and how it elects to move among them. The patch-choice model produces hypotheses about the former aspect of patch use.

This model (Fig. 2) assumes that the environment is coarse-grained. Resources are distributed in a mosaic of patch-types, each somewhat different. The boreal forest, (Winterhalder, this volume, Chapter 2, Fig. 10) provides an excellent example. Foraging occurs in two phases. First is hunting time within a suitable patch-type (per unit item caught). This includes both search and pursuit time as defined in the previous model. A forager will, of course, visit the patch with the highest net return on search and pursuit time within its borders. However, as it expands its itinerary to include less suitable patch-types, the average hunting cost (ΔH) becomes greater. Second is the time spent traveling between, or searching for, suitable patches (per item caught). This (ΔT) is a decreasing function of the number of patch-types an organism exploits. As more patches encountered are harvested, less time and energy are lost to nonproductive traveling.

Figure 2 depicts the optimization rule for this model. Patch-types are ranked from the most to least productive by their expectation of yield relative to hunting time or energy costs (Pianka, 1978: 265). The optimal forager expands its exploitation of patch-types until the loss from the increase in hunting time within the last patch added is greater than the savings from the decreasing travel time between patches. In the model, this includes all patch-types up to the intersection of the ΔT and ΔH curves.

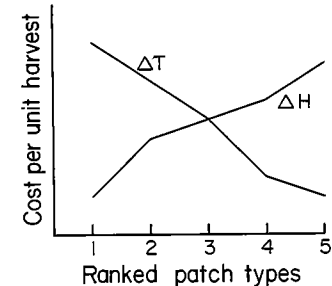


FIGURE 2. The MacArthur and Pianka patch use foraging model. The ΔT curve plots decreasing average between-patch travel costs, and the ΔH curve increasing average within-patch foraging costs, both per unit of resource, as an increasing number of patch-types are added to the foraging itinerary. The optimal itinerary includes all patch-types to the left of the intersection of the two curves. After MacArthur and Pianka (1966). Copyright 1966, the University of Chicago; used with permission.

The form of this model is similar to that for diet choice, but the predictions are not so definitive. Some factors affect the ΔT and ΔH curves simultaneously, with an indeterminate influence on their intersection. Increased resource abundance, for instance, lowers the ΔH curve because search within patches becomes easier, but it also lowers ΔT because more patches included in the diet are likely to be productive, and productive for a longer time. Less time is spent traveling. Hence, the effect on patch choice is uncertain.

The relative size of patches (grain size) has a more apparent effect. Two environments can be similar in the proportion and quality of their patch-types but differ in the size of the patches. The optimal forager will use the environment with the relatively larger patches in the more specialized way. This occurs because travel time between exploited patches is a linear function of environmental dimensionality, whereas hunting time is a squared function. Thus, larger scale patches decrease travel time relatively more than hunting time within a patch, effecting a restriction in the types of patches foraged. In the extreme case, where environmental grain size is very large relative to the organism's size and mobility, coarse-grained or specialized use of the patches is unavoidable, as is fine-grained utilization when patches are very small (Pianka, 1978: 266).

6.2.3. Foraging Itinerary

Charnov (1976b) has devised a model that indicates how an optimal forager should move in a patchy habitat. The "marginal value theorem" (MVT) specifies when a forager should leave the patch it is currently exploiting to search out another, unharvested patch.

The MVT has these assumptions: Food is encountered within patches; the forager also travels between patches. Within each patch the forager "depresses" (Charnov *et al.*, 1976) the rate of food intake as it forages. Depression can result (1) from absolute depletion of prey, (2) from early removal of easier to locate prey, (3) from dispersal of alerted prey out of the patch, or (4) from behavioral changes which make the alerted prey difficult or impossible to catch. Depression causes the forager's intake to approach an asymptote which represents effective exhaustion of that particular location. The forager visits many patches with little probability of return to any one on a short time interval. Finally, the forager behaves so as to maximize its net rate of energy intake while foraging.

With these assumptions, Charnov (1976: 131–133) derives the following theorem: "The predator should leave the patch it is presently in when the *marginal capture rate in the patch* ($\partial g/\partial T$) drops to the *average capture rate for the habitat*" (italics in original). Figure 3 depicts this situation. The organism that remains beyond the optimal time reduces its immediate net rate of energy intake below the habitat average or what it could expect if it moved on. An optimal forager nearly always abandons patches before they cease to be productive, and it leaves behind a string of patches of uniformly low quality.

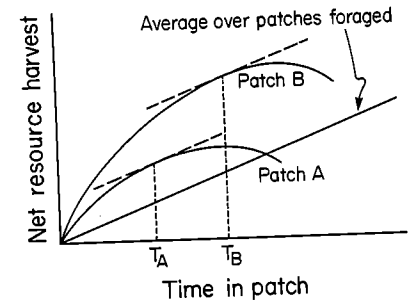


FIGURE 3. The Charnov marginal value theorem. Net energy intake within a patch for two patch-types (A and B) decreases with time as the forager depresses the resource availability at that location. The straight line from the origin represents the average net acquisition rate for the complete set of patch-types included in the foraging itinerary. The optimal forager abandons each patch when its marginal capture rate drops to the average rate for the habitat. This point is represented by the intersection of the patch depression curve and a tangent parallel to the line for average net acquisition rate. After Charnov (1976b). Copyright 1966, Academic Press; used with permission.

The MVT indicates that to forage efficiently in a patchy habitat an organism must have extensive environmental information. It must assess its immediate return rate (i.e., the shape of the depression function) and how well it could do on average in the surrounding habitat (Charnov *et al.*, 1976). In addition, the MVT has bearing on the exclusive use of foraging ranges. The interval between use of a patch and its recovery to the point of profitability is called "return time" (Charnov *et al.*, 1976: 256). Efficient foraging requires that the forager adjust its movements on the basis of return time for certain patches. Maintenance of the requisite knowledge gives an advantage to the organism living within a home range or territory; a forager entering the unfamiliar home range of a conspecific is hindered. The resident knows which patches are depressed and which not, information not easily gained by the intruder. Charnov *et al.* suggest that this may account for "passive" (i.e., undefended) territories. The likelihood of passive territoriality would depend on the difficulty of making a rapid and comprehensive assessment of an environment. The "visibility" of resources (size, dispersion, density, ability to hide), variation in the recovery rate for patches, the stability of the environment, and patch complexity would be pertinent factors.

6.2.4. Settlement Pattern

The final model considers settlement pattern and size in relation to resource distribution and predictability (Horn, 1968; also Wilmsen, 1973: 6–10; Heffley, 1981). The Horn model assesses the geometric distance from the forager to the location of a food source, weighted by the probability of finding food at a particular point, as a means of establishing the relative costs of obtaining food. If resources are predictably and evenly dispersed, then the more efficient settlement pattern is regular dispersion of small social units. If, on the other hand, the available resources are clumped together, and move unpredictably throughout a large range, then the optimal strategy is for aggregation of the foraging pop-

ulation at a central location within that range. Foragers (such as humans) able to exchange information at a central location about unpredictably located resources gain an added advantage from aggregation, one not explicitly considered in the model.

6.3. *The Boreal Environment*

Careful environmental analysis is quite important to evolutionary ecology research (Winterhalder, 1980a). Foraging models take as input specific information about habitat (e.g., prey densities and distributions). In addition, longer term evaluation of foraging requires knowing the degree to which effective environmental patterns are repeated (MacArthur, 1972; Winterhalder, 1981a). A description of the northern Ontario boreal forest is presented in Chapter 2 of this volume. Features relevant to the present analysis are recalled here briefly.

Northern Ontario has a strong continental climate. Three secondary aspects of this climate are especially important to foraging: freeze-up and break-up, stream flow levels, and the quality and depth of the snow cover. Freeze-up and break-up are phenological set points in the annual foraging cycle, and periods of limited mobility for humans. Stream flow levels affect human mobility, access to portions of the landscape, and animal distributions. For instance, low water levels in summer force moose to seek shelter from heat and insects along stream channels, where they are easily located; it also attracts migrating waterfowl (the dabbling ducks), which feed in shallow water. Snow depth also affects forager mobility and the number and distribution of prey. Moderate snow depths, for instance, cause moose to move slowly from feeding patch to feeding patch, a pattern which makes them relatively easy to locate and pursue (see Section 6.5.2). Very deep snows confine moose to small, favorable feeding patches, making them quite difficult to locate. Deep snows may also reduce the moose population by starvation. Conversely, shallow snow may cause the death of large numbers of small mammals, such as muskrats, through exposure.

Hare and moose are used in Chapter 2 to exemplify such relationships among secondary climatic factors and the densities and availability of prey. For these and other species, examples could be multiplied to fill many pages. It should be evident, however, that the irregular fluctuations in these factors may impart considerable year-to-year variability in the forager's ability to locate and capture various species. This suggests that an optimal forager will have a highly dynamic response to this environment.

Spatial patterns in the environment are significant as well. The boreal forest is a patchwork of lakes set into the terrestrial habitat, itself mottled with a cover of distinct vegetation patches. Each of these is different with respect to the game it attracts and the impediments it places between forager and prey. When mapped, these habitat patches show an irregular distribution of small-scale vegetation zones. Further, the landscape mosaic is a dynamic one: fire, wind, and snow

disturbances constantly change the distribution of vegetation.

Animals are the major prey species for boreal foragers. Generally, they are low in density, solitary or in small groups, and well-dispersed. Each species is probabilistically associated with one or more vegetation patch-types, and therefore is somewhat localized in distribution. With the exception of fish, each has marked population fluctuations, in somewhat different patterns.

6.4. *Provisional Hypotheses*

This environmental information allows the identification of preliminary hypotheses. The prey available to the Cree are solitary (or in small "packets") and dispersed. Some aggregation occurs for reasons of habitat, but patch-types are themselves small and irregularly dispersed. As a consequence Cree foragers should spend considerable time searching, and, as a result, have a fairly broad diet breadth. If so, a Cree forager will pursue a relatively large proportion of the species encountered on a given trip.

Patch-use should be similarly generalized, due to the small-scale "grain" of the environment relative to human mobility and hunting areas.

Similarly, the structural conditions exist for the marginal value theorem. Hence a Cree forager should abandon localized resource capture opportunities prior to exhausting them, and at the point at which the immediate net energy efficiency drops to that for the overall habitat.

Finally, settlement pattern in this environment should be one of small, dispersed social units.

6.5. *Field Work and Results*

Field work to test these hypotheses was undertaken in a small community, Muskrat Dam Lake, in northern Ontario (Winterhalder, 1977). About 100 people lived there in 1975 in two extended families. The community had formed about 10 years prior to the research. Approximately half of the adult males do considerable hunting, although community monetary income is mainly through part-time wage labor and social services. Snowmobiles are used to travel to hunting areas, and sometimes to search for tracks along rivers, but not for hunting itself, which is still done by snowshoe. Game regulations prohibit, and deep soft snows impede, the use of snowmobiles for pursuing animals in the bush. Small outboards are used during open water, again for search but not pursuit of animals.

Field work involved accompanying hunters, discussing tactics, recording the routes of their trips on topographic maps and aerial photos, and measuring time and energy investment and energy capture. I obtained similar information from returning hunters. The latter was less detailed, but represents data on trips uninfluenced by my own presence. I deliberately chose proficient hunters; hence

the information is not necessarily representative of the average contemporary Cree hunter.

Evaluation of foraging hypotheses requires both qualitative and quantitative information. The former include foraging tactics, Cree knowledge of animal behavior, and their perception of the environmental conditions affecting the success of searching for and pursuing various species. The quantitative information is of several types. It includes mapping of trips on acetate over aerial photos to gain information on movement patterns, distances between prey encounters, and total distance covered. Time and motion data on foraging were recorded in order to measure foraging energy inputs. For instance, the tasks involved in hare snaring were identified by function and expenditure level, timed, assigned to published energy expenditure categories (Durmin and Passmore, 1967), and then aggregated to estimate the total energy costs of this activity (Table 1). With measures of the caloric value of the animals caught, acquisition efficiencies and net acquisition rates for various resources and conditions were calculated (Table 2). This information was then used to rank prey species with respect to the diet breadth model (Table 3).

In parallel with Chapter 2, hare and moose will be used to exemplify the information gathered to evaluate foraging decisions.

TABLE 1. Time and Energy Cost of Hare Snaring

Activity	Time, min	Expenditure level	Energy, kcal	Notes
I. Fall snare line (14–28 November) ^a				
Activity				
1. Snowmobiling	228	LT	796 ± 341	8.3 km × 13 round trips
2. Walking	56	LT	196 ± 84	4 checks, short line
3. Walking	184	LT	644 ± 277	9 checks, extended line
4. Locating snares	34	LT	118 ± 50	21 snares total
5. Constructing snares	113	LT	397 ± 170	21 snares total
6. Resetting snares	60	LT	210 ± 90	16 snares total
Total	675		2361 ± 1012	
II. Hypothetical fall snare line (details in text) ^b				
Activity				
1. Snowmobiling	174	LT	615 ± 262	8.3 km × 10 round trips
2. Walking	205	LT	715 ± 308	10 round trips × 1.3 km
3. Locating snares	32	LT	112 ± 48	20 snares total
4. Constructing snares	108	LT	378 ± 162	20 snares total
5. Resetting snares	375	LT	1330 ± 562	100 snares total
Total	895		3150 ± 1342	

^aThe fall snare line (I) was set and maintained by an adult male.

^bThe same is true in the hypothetical fall snare line.

TABLE 2. Output–Input Analysis of Hare Snaring

	Fall snare line I	Fall snare line II
Inputs ^a		
Time, min	675 (11.3 hr)	895 (14.9 hr)
Energy, kcal	2,360	3,150
Other		
Gasoline/oil, liters/liters	36/1.8	28/1.4
EV of gasoline, kcal	300,000	233,000
Cost of both (\$)	21.30	16.40
Outputs		
Weight (edible), kg	14.6	77
EV (edible), kcal	23,750	125,000
Energetics		
Acquisition efficiency	10.1	39.8
Net acquisition rate, kcal/hr	1,900	8,180
Energy cost/snare per snare check, kcal	11.6	15.7

^aTime and energy inputs from Table 1.

6.5.1. Hare

Hare have had a critical, periodic role in the Cree diet throughout the historical period (Rogers, 1967; Bishop, 1974; 186–87, 265, 269; Rogers and Black, 1976). They are captured with the pole and stationary snare, and more recently the .22 rifle. Hare can be snared year around, but late fall is best, after freeze-up, as is late spring; rifles are used mainly in the spring. Hare are abundant and active in the fall, and the soft and shallow snow cover facilitates identification of runways and their degree of use. Hare become relatively inactive during the cold of midwinter, and are consequently harder to catch. As spring approaches, their movements increase, as does snare susceptibility, even though natural mortality has greatly reduced population density. In summer, hare have abundant browse, and they need not confine themselves to especially favorable habitats or runways.

The stationary wire snares analyzed here are simple to set. When a runway is located a jack pine (or spruce) is felled and the top 1.5 m removed. The top is set across the runway (to make a snare “fence”) and a short portion is limbed to create an opening directly over the rabbit’s path. A 10-cm slip loop of pliable wire is suspended in this opening, toggled to the jack pine trunk. If there is a natural constriction in a runway a similar snare will sometimes be set without the fence. This type of snare can be constructed in 2–5 min of light activity, and while care is taken with functional aspects of the snare loop—its size, position, and the ease with which it slips receive lingering attention—peripheral

TABLE 3. Measured Net Acquisition Rate of Foraging for Boreal Forest Resource^a

Resource and season	Net acquisition rate, kcal/hr	Net acquisition rate/pursuit time, kcal/hr
Moose and caribou		
Winter	6,050	8,220
Early spring	11,950	25,140
Summer and fall	5,920	95,600
Fall (rut)	11,280	—
Net fishing		
Winter, net I	1,060	1,790
Spring, net II	3,180	3,710
Spring, net III	9,680	11,660
Summer, net IV	2,260	21,340
Summer, net V	5,320	34,000
Fall, net VI	6,390	7,980
Hare snaring		
Fall (measured)	1,900	8,260
Fall (hypothetical)	8,180	15,220
Muskrats		
Spring trapping, case I	250	1,280
Spring trapping, case II	2,500	6,230
Fall hunting, case I	2,370	4,740
Fall hunting, case II	1,330	—
Beaver		
Early winter trapping	1,640	5,690
Early winter trapping (est.)	4,360	23,620
Early winter trapping (est.)	5,280	—
Waterfowl		
Pre-break-up	720	3,000
Post-break-up	1,980	—
Pre-freeze-up	1,190	—
Game Birds		
Grouse, case I	—	1,740
Grouse, case II	—	1,220
Vegetable foods		
Blueberry picking	250	650
Potato cultivation	2,330	—

^aSee Winterhalder (1981b) for further details.

details are treated cursorily. These snares can be set at a rate of 50 or more a day.

A snare line which I monitored in the late fall of 1975 is typical. The line was built and checked in the early morning. Sunrise is ideal and least likely to disturb the hare. The whiskey jack (*Perisoreus canadensis*), common crow (*Corvus brachyrhynchos*), or common raven (*Corvus corax*) will occasionally find and consume or foul the overnight catch by midmorning. Hare must be retrieved before they are lost to this scavenging.

The snare line was 4.1 km by snowmobile from the village, an 8- or 9-min ride. From lake edge, where the snowmobile was parked, it was a 185-m walk to the beginning of the line, which itself represented a wandering trail another 450 m in length. Total round-trip walking distance along the trail and snare line was 1.3 km. The snare line was located in a small patch of jack pine, a common location. The Cree associate hare with several discrete vegetation types, and return regularly to known locations (Winterhalder, 1977: 388; Rogers and Black, 1976: 10). This particular line had been used several years before, so a rough trail already existed.

To set the snare line the forager walked this trail, occasionally removed undergrowth, and surveyed the mossy ground cover to either side for the subtle signs of a runway. A soft snow surface would have made this easy, but was missing. Whenever a promising runway was located a snare was set just to the side of the trail. In all, 19 snares were placed within a distance of about 450 m, some as close as 3–5 m apart. Once a snare was set it required only a minute or 2 to locate the next runway, although conditions for this were not particularly good.

The snare line was checked by walking the trail, adjusting snares that were disturbed, and removing those containing hare. Snares were reset in the same location several times. Removing a hare and resetting the snare required about 4 min of light work. A .22 rifle was always carried, and the few hare caught but still alive were shot.

From village departure to return this snare line could be checked in 40–60 min. On Sundays the line was checked and hare removed, but the snares were not reset until the following day. On warm, calm, and overcast nights a good catch is expected; fewer hare are likely to be snared on cold, clear nights with wind. In addition, it is thought that the hare can see and thus avoid the snares in moonlight. These expectations fit the description of hare behavior given in Chapter 2.

Hare populations fluctuate dramatically. Availability, however, may not correlate directly with cyclic abundance. Capture techniques, environment, and hare behavior somewhat smooth the effects of the population fluctuations. At the low point and peak of the cycle hare are either virtually absent or else superabundant. More interesting are the intermediate points in the ascending and descending curves. When overall density is low, hare tend to concentrate in small patches of favorable habitat (see Chapter 2, this volume). These localized

concentrations during periods of overall scarcity extend the period during which a good catch is possible. In the descending portion of the cycle localization is more complicated. At the peak and after, hare should be easy to snare because starvation would drive them to the snare fences [a delayed density-dependent population control initiates the downturn; see Keith (1974)]. A year or two after the peak, however, lynx are reaching a peak of numbers, and they probably offer significant competition to the human forager during the declining phase of the cycle. It should be noted that these annual changes are overlain by the seasonal ones described earlier.

The time and energy costs of maintaining this snare line are given in Table 1, an input-output analysis in Table 2.

This line was set during the first year of the ascending portion of a hare cycle. Residents stated that there had been no hare for the previous 3 years, and that hare were most abundant about 7 years prior to the field work (1967–1968) (see also Rogers, 1962). Hare were apparently at a low point in their cycle in northern Ontario in 1972–1974, and just beginning to recover in 1975.

The line was set for 15 days and checked 13 times. A total of 21 snares were constructed, 19 hare were caught, and 16 snares were reset following removal of hare. Although the catch was not large, it was steady. When this line was abandoned 18 snares remained constructed.

Overall, the energy efficiency (ratio of output to input) for the snare line was 10.1 and the net acquisition rate (net energy gain per unit time) was 1900 kcal/hr. No one continued their snare line for more than a few weeks under these circumstances, despite initial enthusiasm. Hence this is probably a baseline efficiency for hare. In addition, the Cree probably appreciated that the efficiency of snaring would decrease as winter progressed. The monetary cost was \$21.30. At a little over a dollar a hare, this may have hastened abandonment of the line.

Travel to and from the patch containing this snare line absorbed 34% of the time and energy involved. If this is considered search time, and the remainder of the input considered pursuit costs, then the EE (energy efficiency) and NAR (net acquisition rate) with respect to pursuit costs are 15.2 and 2980 kcal/hr, respectively (Fig. 4).

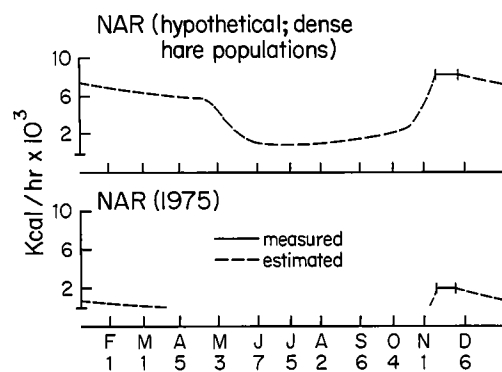


FIGURE 4. Measured and interpolated net acquisition rate (NAR) for hare snaring in two cases. The hypothetical case estimates the NAR by season for a year of moderate-to-high hare abundance. The observed 1975 case gives a similar curve for a year of quite low hare density. The letters on the abscissa indicate months, the numbers the first day of each month that initiated a weekly sample.

Pursuit costs can also be envisioned somewhat differently. In the course of general foraging a Cree may run across a hare runway. Assuming that the location will be revisited in a subsequent search, the decision to set a snare should be evaluated relative to pursuit costs involving only the setting and resetting of the snare. The EE and NAR with respect to pure pursuit costs are quite high—38.7 and 7870 kcal/hr, respectively. According to the diet breadth model, the snare should be set unless a greater net return can be expected from both searching for and pursuing other prey, an unlikely prospect. Hare snares are remarkably inexpensive relative to their potential catch.

To estimate snare line productivity at the peak of a hare cycle, I asked how many hare would be expected per night from 20 snares when hare were most abundant. Answers were given reluctantly, and only after stressing the great variability in the figure I sought. There was some exasperation with the question—no one catches an average—that is suitable qualification on interpreting the answer. Agreement, however, centered on ten. Based on this estimate, and the costs and conditions from the measured case (and allowing for the additional cost of removing hare and resetting the successful snares), Table 1 (case II) gives the input costs, and Table 2 (case II) the energetic analysis for a hare cycle peak.

Ten nights are considered in this hypothetical case; the monetary cost of fuel and oil would be \$16.40, or about 16¢ per hare.

The acquisition efficiency in this case is 39.8, and the net acquisition rate 8180 kcal/hr, figures roughly four times those measured based on availability at the beginning of cyclic population growth (Fig. 4).

Acquisition efficiency and net acquisition rate with respect to pursuit costs are as follows in this case: Considering the whole visit to a snare line as pursuit, the values are 49.7 and 10,280 kcal/hr, respectively. Faced with the immediate decision to set a snare in the context of general foraging, the values would be 73.6 and 15,320 kcal/hr, respectively.

In years of hare abundance, a snare can compete with net fishing and with moose hunting in terms of energetic efficiency relative to pursuit costs. Its short-term reliability will also be somewhat higher than moose hunting.

6.5.2. Moose

The Cree place cultural emphasis on hunting large game animals: "Of the native foods, the moose is the most important and the most sought after" (Bishop, 1974: 24; see also Rogers, 1962: C42; Dunning, 1959: 24). Caribou are rare in northern Ontario and hence of less importance in contemporary diets.

The recent population history of moose in this region was discussed in Chapter 2, this volume. Briefly, this animal was probably abundant prior to the 1820s (Bishop, 1974: 263–265) and became so again in the 20th century following near or complete absence from the area.

Techniques of moose hunting are seasonal. Winter begins with freeze-up and extends into the thaw of spring, roughly from November through March. It

is a period of very cold temperatures, frozen or hardpacked lakes and rivers, and deep soft snows in the forest. Searching for moose begins with knowledge of the animal's habits and habitats. In winter moose are usually found in brushy areas; the willows (*Salix* spp.) and alders (*Alnus rugosa*, *A. crispa*) lining small streams are favored habitats, as are areas that burned 2–3 or more years previously. The forager often goes to an area that has a mix of patch-types with sizes, composition, and positioning that in the aggregate make it favorable for moose.

A forager does not look for moose directly, but attempts to locate tracks in areas that (1) offer easy forager mobility, (2) are open and thus increase the chances of sighting tracks, and (3) a moose is likely to travel through but not necessarily browse within. Moose occasionally will browse the dense strip of vegetation along a shoreline, partly, apparently, also for the ease of walking there. Skirting these shorelines, or the patches of alder and willow that mark the drainage of a small stream into a river or lake, with a snowmobile is one method of locating a trail. Foragers on foot travel along the small streams and rivers that a moose must cross when moving between upland patches of browse (often old burns). A common pattern is to circle an island, or to cut across and then circle a peninsula, looking for tracks that put a moose within the bounded area. Different parts of a complicated search path may be used to "close" the circles that might isolate the animal. These procedures establish the general location of a moose relative to the landscape mosaic that the actual pursuit will focus on.

The effectiveness of this technique of searching—in which the forager attempts to cross moose trails in the "interstices" between the patches browsed by moose—depends on the snow depth and structure. A shallow snow allows the moose to roam about freely and in an unpredictable pattern, while at the same time reducing the ability of humans to move efficiently and stalk quietly. Deep snow works against the forager by confining the animals to favorable browse patches. This diminishes the chance of discovering tracks. Moose move to and remain in habitats with the densest cover. Here wind movements are reduced, along with the chance that the forager can stalk and visually locate the animal before being discovered. The ideal snow depth is intermediate: moose move regularly between small, favorable patches, spending several days in each.

A trail in snow is appraised carefully for clues indicating its direction and age. The pivoting leg of a walking animal packs the front edge of the symmetric track. The Cree use a hand or rifle butt to feel for this compacted edge; they state that the wolf does the same with its forepaw. The snow disturbed by a walking animal hardens at a rate determined by temperature and time. This can be used to age the track, as can a partial covering of fresh or newly drifted snow which can be dated. A recently broken or chewed branch end is white; in a day or two it will turn reddish-brown. Moose pellets are dull brown and the size of a large olive. Scattered on the snow, they absorb sunlight, and thus warmed, melt slowly into the crust. By appraising the snow surface, air temperature, and

sunlight, an experienced hunter can say when a moose passed over that particular spot.

Pursuit is never direct. It is a silent contest made difficult by the exceptional wariness of the prey. The forager's tactics are based on his anticipation of the prey's behavior and movement patterns relative to a (usually) known landscape. Pursuit requires wind and is always oriented on its axis. In the bush, even in winter, moose are rarely visible or shot from a distance greater than 50 m. The animal has keen smell, eyesight, and hearing, making it difficult for a hunter to get within that range. A squeaking snowshoe, barely audible to the man standing on it, is easily heard by a moose 200 m distant. If the forager is detected the pursuit is nearly always called off.

Wool clothing and cloth-wrapped snowshoe frames contribute silence to the hunter's stealth, but experience with the animal's behavior relative to wind and vegetation is central. Moose routinely circle downwind of their trails or feeding areas. As a consequence, the Cree have adopted a side-tracking technique (Fig. 5; see Rogers, 1962: C42; Bishop, 1974: 263; Winterhalder, 1977: 301–304). The forager pursues a moose trail in a series of downwind arcs, until the animal is outdistanced. The hunter then backtracks in arcs always downwind and each circumscribing a smaller area containing the prey. This part of the hunt may last for hours and cover only 100 m. For long periods the hunter stands silently, listening and watching. Occasionally he will squat to look along the snow surface, below the thicker branches of the tall shrubs and small trees. It is thought that moose do the same.

Sidetracking is modified to anticipate the particular movements of each animal in relation to habitat patchiness. The Cree identify "kinds" of moose by their individualized habitat preferences, idiosyncracies the Cree believe the moose learns as a young animal. Each moose is said to browse in certain habitats, perhaps avoiding or passing through other vegetation types equally desirable in general and perhaps used by other moose. As the hunter learns the habits of each pursued animal, he couples this with knowledge of the microgeography of patch-types in that area to anticipate likely movements of the prey.

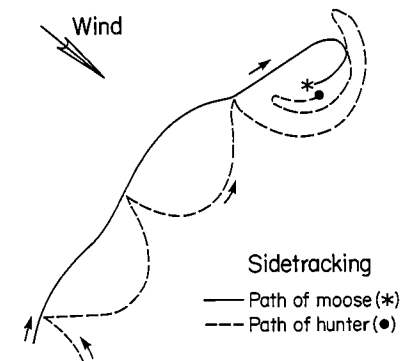


FIGURE 5. The side-tracking technique for pursuit of moose. Details in text.

Finally, the wind, which deflects odors and covers sound, is the least predictable and most important of factors in moose hunting. If it stops, so does the pursuit.

Early spring hunting is defined specifically by snow surface conditions. An example occurred in 1975. A 3-day thaw (15–17 March; see Fig. 5, Chapter 2, this volume) followed by colder temperatures produced a hard crust on the snow. On 21 and 22 March a light, powdery snow fell. Because moose step through this crust, it severely limits their ability to move about. The same crust, however, facilitates the mobility of a snowshoed hunter, while the light snowfall muffles the sound of the snowshoes. These temporary conditions stimulated a peak moose harvest during the last week of March and the first week of April. By 8 April warming made the snow soft and slushy, and the season ended. This brief 2-week period was particularly good for moose hunting (Fig. 6). However, it depended on a unique sequence and combination of climatic factors. Hence it is unlikely that the existence, timing, or duration of such conditions is predictable from year to year.

Search and pursuit of moose change dramatically in summer. Thick leafy vegetation reduces visibility, and thunderstorms and unpredictable frontal movements increase wind variability. Both reduce the efficacy of stalking. Tracks are

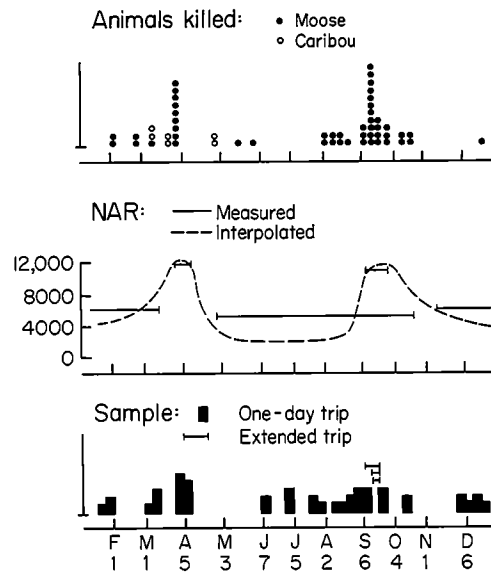


FIGURE 6. Moose and caribou foraging; sample and energy analysis summary. The graphs indicate, respectively: the seasonal distribution of large game kills during 1975; the measured and interpolated net acquisition rate (NAR) for this foraging activity; and the sample used in the energy analysis. The letters on the abscissa show months, the numbers the first day of each month that initiated a weekly sample.

less visible, and in any event, in the thick brush, the soggy hummocked surface of much of the northern landscape (Chapter 2, this volume) makes movement slow, arduous, and uncomfortable.

In summer the Cree wait for conditions that move the moose from forest cover into the aquatic vegetation that lines waterways, where they are easily seen and sought. A hot still afternoon is best. Moose move into the water to avoid the heat and swarms of insects. They are sought by scanning shorelines from a canoe propelled by an outboard. Habitually used moose trails are checked where they emerge from the forest, but the discovery of fresh tracks rarely leads to active pursuit. Rather, the forager may retire downwind and wait to see if the moose appears.

Tracks are not difficult to locate in summer, even in the rich undergrowth and herb layer of the boreal forest. Subtle clues include a crushed leaf, a slight impression in the litter, or a broken stem. Wild sarsaparilla (*Aralia nudicaulis*) is a tall herb with distinctive, horizontal compound leaves. A walking moose leaves a trail identified by the broken stems and crumpled frond of the plant. Such movement also overturns leaves, some of which (e.g., lungwort, *Mertensia paniculata*) have a whitish underside that stands out against the dark green of other herbs. Thick aquatic sedges stand in an arc about 25 cm above the water, leaning away from prevailing winds. A wading moose often cuts a swath through these against their normal orientation, causing leaves and stems to glisten in the sunlight where they have been pressed onto the water surface. An analogous clue comes from the narrow-leaved bur-reed (*Sparganium angustifolium*), an aquatic plant with long slender leaves that normally float on the water, parallel to the current. Finally, the bushy banks and rich aquatic and other vegetations in and around beaver ponds make these good moose habitats. When entering the mouth of a small stream, a Cree watches the water closely for floating vegetation [e.g., the broken stalks of sedges (*Carex spp.*) or narrow-leaved bur-reed] which indicate that a moose is wading or feeding in the water upstream.

The age of tracks is determined by their sharpness, with reference, perhaps, to a recent rainfall. The rate at which a track is filling with water or the degree to which sediments have settled from a puddled track provide additional clues. In one instance a small mushroom had sprung up in an otherwise fresh-appearing track, and my Cree companion wondered aloud just how rapidly it could have grown. In early autumn, tracks obscured by fallen leaves are old.

Moose shot during the summer and fall were nearly all found by boat along rivers and streams between 5:00 and 7:00 p.m. Of three dozen instances in September and October, the animals escaped only twice, in both cases from inexperienced hunters. Only several minutes were devoted to pursuit. Oddly, moose pay little attention to the sound of outboard motors. The Cree explain this by noting that an outboard and a bush plane sound remarkably alike. Moose are apparently so accustomed to the latter that they ignore boats.

Due to its aquatic orientation, the success of summer moose hunting depends on water level. Low stream flow forces moose from the well-sheltered and

extensive wetland habitats (mostly bushy swamps and bogs) into the streams and lakes where they are easily found. High water (as in 1975) gives moose relief from heat and insects within the more inaccessible areas, making them difficult to locate and pursue.

In mid-September in northern Ontario moose go into rut. They begin to vocalize and move onto waterways. Wariness, especially in the males, succumbs to bellicosity. Day trips, and longer trips involving up to three hunters and 10 days away from the village, occurred at this time, with great success. Charter aircraft were sometimes used to ferry men and supplies to a distant camp.

Moose are noisiest after sundown. The hunter approaches an area where a moose is bellowing and waits for it to appear along the shoreline or to expose itself in an adjacent sedge swamp. Sometimes one hunter will go ashore and approach the moose from behind, hoping to move it into a partner's sight. In general, however, even experienced hunters are reluctant to do this: the moose are belligerent, and the dense cover, which makes it difficult for the hunter to shoot accurately or flee quickly, heightens the danger. Ideal conditions for moose hunting during rut are a still evening with a full moon. Silence aids in hearing and locating precisely the calls of male or female moose; a moon extends visibility past dusk.

Figure 6 shows the weekly distribution of moose (and caribou) kills, measured and estimated acquisition efficiency, and the sample underlying the energetic analysis. Each type of information reinforces the others, but they are not strictly independent. The sample is, however, more evenly distributed than either measured or estimated efficiencies or the actual distribution of kills.

The number of animals killed has two peaks: the first corresponds to the ideal spring snow conditions of 1975, the second to the fall rut. Only a few animals were taken through the colder winter months or during the summer; none were taken during break-up or freeze-up. An experienced hunter, asked to comment on this pattern, said:

Well, in January and February it is pretty hard to get them [moose]. And not too many people go out. In March and April the people start going more and it is easier to get them.

Question: Is it usual to get so few during the summer or is it because people are working?

Well, partly it is because the water is so high. See, the moose travels around the shore. If the water is high he can stay back from the rivers and lakes and lie down in the water in the swamps. If it is dry he has to come out where you can see him. But in the fall that doesn't matter so much because they start traveling.

Thus the pattern, although based on a quite small sample, is generally accurate for 1975. It would certainly vary from year to year. The combination of weather events that made spring hunting in late March so successful was to some degree fortuitous; lower water levels would have made for much better hunting in summer. In addition, November and December 1975 following freeze-up were not good hunting months. An unusually shallow snow cover made it difficult to

use snowshoes to walk quietly or rapidly. These and many other annually variable factors can influence the frequency with which moose are located and the efficiency and success with which they are pursued.

For energetic analysis recorded hunts have been divided into sample periods based on the seasonal and functional changes mentioned above and on sample size. For some trips allocation of cost to search and pursuit is estimated.

Nearly all winter moose hunting trips involved two persons, and on average 11 person-hr of effort. In each about 3000 metabolic kcal were expended, and somewhat more than 115,000 kcal of gasoline burned. Gas and oil cost about \$8.00. The average trip covered 32 km by snowmobile and 7 km on snowshoe. Searching was fairly successful. Moose were located on half of the trips devoted to searching, on average one for each 4 hr. In contrast, pursuit is an activity of greater uncertainty. On nine trips animals were pursued but only two resulted in the successful capture of game. For each moose or caribou captured about 25 hr was spent in pursuit (including retrieval). The acquisition efficiency for the winter period is 22.3; the net acquisition rate, 6050 kcal/hr. The net acquisition rate per unit of pursuit cost is 9390 kcal/hr; the acquisition efficiency, 27.2.

The nine spring trips averaged 12.5 person-hr, with a metabolic energy investment of 3300 kcal. Fuel use (on average 183,000 kcal, costing \$13.10, including oil) increased considerably, largely because two snowmobiles were taken on nearly all trips, partly for the added safety. The average distance covered by snowmobile was 33 km; that by snowshoes 9 km. The total time spent in pursuit was about equal to that spent searching, and relative to winter, pursuits were more successful. One unit of large game was located for each 5 hr of searching, and one captured for each 14 hr of pursuit. The acquisition efficiency in this case is 46; the net acquisition rate, 11,950 kcal/hr. The net acquisition rate per unit of pursuit cost is 25,100 kcal/hr; acquisition efficiency, 78.

The summer and fall sample consists of 23 trips between 12 June and 14 October. It excludes overnight trips focused solely on the rut (see end of this subsection). The hunters involved made almost 20 trips through the summer without sighting a moose, and then located and shot moose on two of three trips during the rut. While there were good environmental and behavioral reasons to expect this pattern, the smallness of the sample (with respect to captured game) suggests caution.

Two people participated in nearly all of the trips. The average person-hr investment was 10, representing about 2100 kcal. In addition, each trip consumed about 16 liters of gasoline, representing 135,000 kcal, at a cost, when mixed with oil, of \$9.50.

Searching consumed nearly all of the time investment, with little success. Only one unit of game was located for each 47 hr. Pursuit time, however, was slight—4 hr per unit of game, nearly all devoted to carcass retrieval—and very successful—each animal located was successfully pursued. Search was conducted by canoe and covered an average of 55 km. Less than 1 km was the average distance on foot.

The acquisition efficiency for this sample is 28.3, but because of the large amounts of time invested (relative to metabolic energy expenditure) the net acquisition rate is only 5920 kcal/hr. Net acquisition efficiency per unit of pursuit cost is, however, high; 87,400 kcal/hr; acquisition efficiency, 404.

Perhaps the most important lesson of this sample concerns the relationship between efficiency measures and short-term risk. While reasonably efficient if averaged over months, such hunting has a high risk of failing to produce food for significant periods of time. This could have a large influence on a forager's decision to pursue a particular species.

To estimate the energetics of foraging during the rut I have analyzed three extended hunting trips separately. Two or three persons participated in each for from 5 to 10 days. All occurred between 10 and 21 September; all were successful, suggesting the high reliability of moose hunting during this period.

The acquisition efficiency and net acquisition rate for these trips are 53.2 and 11,280 kcal/hr, respectively. My information is not complete enough to indicate the relative expenditures on search and pursuit. Hunters said they had no difficulty locating moose by their calls, but they did spend a great deal of time waiting for the animals to come into the open, suggesting that pursuit time predominates.

6.5.3. Aggregate Energetics

Moose and hare have been examined in brief but sufficient detail to suggest some of the particular properties of boreal foraging. Each of the other species has its own peculiarities. If the diet breadth hypothesis is correct (see Section 6.6.1), it supplies a decision rule which approximates a forager's choices. Even with such a rule, however, we will know little about the practice of Cree foraging, and especially about its dynamics, unless we can also specify in some detail how variables incorporated into the model actually behave.

Based on similar procedures, energy expenditure and capture data were aggregated by season and hunt type (Table 3) and used to estimate (interpolate) an annual curve of net acquisition rate (per pursuit time) for all major prey species. When the curves are superimposed, the complexities of prey ranking as a function of seasonality are evident (Fig. 7). Each time two curves cross it inverts the foraging rank of two potential prey species. With the diet breadth model these prey rankings allow fairly precise predictions about the foraging decisions of Cree hunter-gatherers. If one considers the annual variability of climatic factors affecting pursuit, then year-to-year changes in the configuration of such curves and in subsistence choices can be quite complex.

6.5.4. A Foraging Diary

The actual pattern of Cree foraging will become more evident through an examination of an instance of beaver trapping which occurred shortly after freeze-

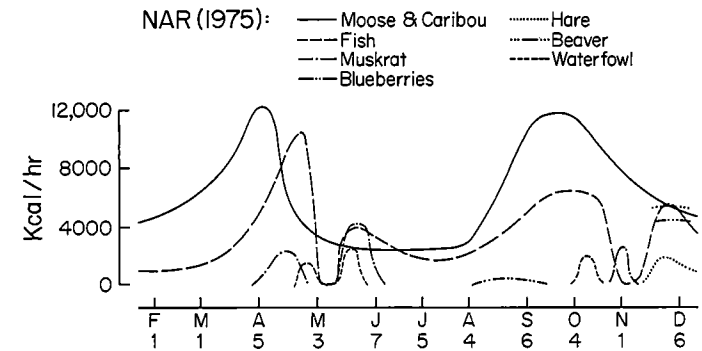


FIGURE 7. Seasonal net acquisition rate (NAR) of foraging for various resources in 1975. All curves are complete with the exception of beaver trapping, which was sampled for only a short period in late November and early December. The letters on the abscissa show months, the numbers the first day of each month that initiated a weekly sample.

up. I accompanied a Cree trapper. Except for minor editorial changes, and the bracketed comments added for clarity, this is a verbatim account as recorded in my field notes. It conveys several kinds of information: the actual events of one foraging trip, the kinds of data which I recorded systematically and picked up incidentally, and the interaction between the trapper and an anthropologist. It can be read as an example of Cree foraging, and also as an example of an ecological anthropologist's methodology. I learned most and the Cree were at their best teaching me through experience.

25 November. Trapping with G. We both took Ski-doo's. Our departure was delayed a bit while G mediated a relative's complaint about two misplaced propane tanks. Weather: clear; wind calm; -9.5°C max., -15°C min. temperatures for the 24-hour period. Sunrise 8:12/sunset 3:50. G's equipment: Beaver and hare snare wire; #1 & #4 traps; .22 rifle, .30-.30 rifle.

This is one of the first trips made downriver [following an unusually late freeze-up; see Fig. 5, Chapter 2, this volume].

9:28 Leave Rat Dam.

9:36 Stop at narrows (A) [My Ski-doo is running poorly so] I replace spark plug; G begins a mink set [this is a river cut through an esker]. G sets the trap in a small cave in a 6' rock/dirt bank. It is 6" high, 12" wide and tapers to a point about 2' back. The cubby is about 2 meters above the river, and 6 meters from it behind river-edge alders. G pushes a 2" piece of jackfish [northern pike] into the back of the cave and a centers #1 trap on the dirt about a foot in front of it. Poplar leaves are sprinkled lightly over the trap. It is toggled to a stick, the loop tied with cotton cord, the cord in turn tied to a root.

9:42 Set finished.

9:42-9:44 I finish repairs.

9:44-9:45 Travel to river-bank beaver house, B.

9:45-9:47 G explores beaver house but finds no evidence of recent beaver activity.

9:47-9:52 Travel to C, another beaver house.

9:52–9:54 G checks for beaver. I ask how he locates the beaver runways. His answer, look for bubbles in the ice. As beaver swim along their [habitual] routes they release air which collects under the ice and eventually freezes in [to it]. We see bubbles here but leave. G says the ice was too thick. [He later explained that if the beaver are active the ice over their pathways is also thinner, in the shape of an arcade.]

9:54–9:57 Travel to D.

9:57–10:15 Stop here because G sees roughed grouse (*Bonsa umbellus*) in shoreline trees and brush. Two fly one minute after we stop. A 15 m shot (.22) at the third grouse misses, grouse flies. Two shells misfire. Remaining grouse flies. G removes Ski-doo suit and follows into bush at 10:00. Each grouse flies about 25 m and lands in the top of a spruce. They are most easily located as a silhouette. With some caution one can walk to within 10–15 meters of one. G locates a grouse and kills it on the third shot. It is plucked immediately. A few minutes later he finds the first grouse shot at, dead, about 15 m from where it was first located. A careful search locates no more grouse. On ice. The open water (through the narrows) can be seen from a distance because it steams. Whenever we come to a constriction [in the river or lake] or when we ride around a point, we stay close to the shore, almost into the rocks and brush. In open areas G instructs me to follow him about 50 m behind and 10 m to the side, on the shore side if there is a choice. Thus if he cracks the ice on the first pass I will not go through the weak area.

[This freeze-up occurred late, in an unusually intense and prolonged cold spell, without snow.

As a consequence] In open areas [of the lakes and rivers] the ice is almost perfectly transparent above the black water. [Looking forward it presents a mirror-smooth inversion of the sky.] Looking down provides an unobstructed and uneasy view into the murky depths. Seemingly, nothing supports the Ski-doo. The ice is, however, 8" to 10" thick. Riding, we watch for fractures, which reflect silver, top to bottom of the ice, and confirm there is substance to this invisible surface beneath us.

We are also unable to steer the Ski-doo. There is no traction for the skis. Crossing lakes we must begin oriented in the right direction, and occasionally stop completely and reorient the Ski-doo. The good riding is along the shores and bay edges, both windward and leeward, where frost or snow have collected on the surface.

10:15–10:15/30 Ride about 30 m and stop. Fresh grouse tracks in the willow and alder lining the shore. G goes into the bush, looking. Locates one partridge but it flies a long distance [this he knows by listening]. Old moose tracks also located. We leave. [The age of these tracks and poor hunting conditions for moose—no wind—are the reasons given].

10:15/30 to 10:20 Duration of above stop.

10:20–10:25 Ride, checking shoreline, to E. [The shoreline is a thicket of willows, sweet gale (*Myrica Gale*) and alders, and hence an attractive game habitat.]

10:25–10:28 Prepare to leave Ski-doo. G removes his Ski-doo suit; I my down jacket, with some reluctance. [Both garments are nylon and hence noisy. In addition, despite the cold, strenuous bush activities are matched to light clothing, to stay warm without perspiration. I am wearing thermal underwear, pants, a flannel shirt, and a lightweight wool jacket.] Packs prepared.

10:28–10:37 Walk to F. [The snow cover is light, we are on foot rather than snowshoes.] I ask about the trail, as it was somewhat cleared and worn about a foot deep and wide into the muskeg. G: It was an old portage [before people had outboards] between the river [Severn] and Axe Lake. Fresh wolf tracks followed the same trail.

10:37–10:41 Reach the creek, walking upstream towards a beaver dam [G knows the location closely]. G taps the ice with the axe handle just ahead of his step, saying that you can never trust [the depth of the ice on] these creeks. We stop at the beaver dam spillway, where the ice is thin.

10:41–10:55 G explores the beaver dam, lake and lodge, first breaking the spillway ice to check the size of the opening. Near the lodge he scrapes away the frost, checking for bubbles and natural openings. He explains he is looking for clear routes for runways (between the house and dam, house and feed pile, etc.). One clear bubble path also has stripped alder branches frozen into the ice. G breaks the ice over another spillway; it was much thicker there. He breaks a small hole between two grassy tussocks, to check the depth of what appears to be a 'natural' under-ice path from the beaverhouse and to the second notch in the dam. Again he checks around the house, moving frost aside with his foot, and thumping the ice to determine its thickness. He checks the food pile: "it is big . . . there must be lots [of beaver]." G checks the South end of the pond and [in the light frost on the ice] quickly identifies the tracks of fisher, mink and wolf.

10:55–11:00 G chops a hole, 2' × 8" through the 8" ice, parallel to the side of the lodge.

11:00–11:07 G strips a slender 7' alder sapling and bends it into an arc [which it holds due to the cold]. With this probe he explores under the ice, "looking" for the runway and the entrance into the house. Easy in theory, but the water is an inky tangle of stripped poplar, roots, mud, brush and confusing shapes.

11:07–11:10 G chops a second hole, oriented differently than the first.

11:10–11:11 Explore.

11:11–11:12 Chop to enlarge hole.

11:12–11:18 Clear slush from hole and continue exploring. Without thinking, I start to dish out a piece of slush with a gloved hand. G stopped me quickly, "bare hands only: keep your mitts dry, if they get wet that's it!" [We wear large leather mitts with wool liners. These can be removed for working in the frigid water, and then quickly replaced.]

11:18–11:19 Set one pole for the snare.

11:19–11:21 Cut remaining poles (straight, dry nearly limbless spruce, 1 1/2 to 2 inches in diameter and 6–9 feet long). In the distance and utter stillness the thickening ice on the river rumbles and cracks. Sometimes with the sharpness of a sonic boom, sometimes with the warble of a giant sheet of rippling steel. G works briskly.

11:21–11:34 Continue building the snare. G unbraids the snare wire into strands of three for the loops. He tells me never to use rusty wire and never to let tobacco spill on the wire. The beaver will know right away. G enlarges his loop, to 11". I asked why, he answers that the smaller beaver would go through. Confused, I ask if the larger loop meant he would only catch the larger beaver. "No." [We did not get this cleared up.*] G notches the side of the pole, folds a small piece of grass over the snare loop wire and pulls the ends of the grass into the notch. He says his dad taught him that. As the beaver swims along the water shakes a little and it can wiggle the wire [unless it is so held]. The beaver will see the movement and turn aside. I asked how far the bottom of the loop was above the mud. An inch, but this has to be measured carefully on the pole because of course you cannot see. The top is about 2" below the ice surface (bottom).

11:34–11:46 Set otter trap in spillway. The spillway is fenced with parallel rows of stakes, 9" apart and 19" long. A #4 trap is placed in the center, under 6" of water and toggled to a branch. Jack fish is tightly bound to a stick and set in the water, directly over the edge of the trap.

11:46–11:47 Gather supplies and walk to upper end of beaver pond, to mink tracks.

11:47–11:57 Set mink trap. The upturned root bundle of a fallen birch is about half submerged in the ice. G hollows out a nook in this bundle, at ice level. With the axe he cuts a bundle of dry grass into small pieces, and lines the nook. "This is to make the place softer, so

* A Ft. Severn resident provided Marshall Hurlich (personal communication) this answer to a similar question: Small beaver can occasionally escape from a snare unless it catches them around the midsection, between the fore and hind limbs. The larger loop allows them to pass part of the way through before becoming caught in this manner.

- the trap will sit evenly. I am setting this because of the tracks." This trap is toggled with wire. G states the mink will eat through the cord.
- 11:57-12:12 Walk upstream, over a small lake and up another stream, to a beaver house.
- 12:12-12:15 G explores around this beaver house.
- 12:15-12:16 G chops a hole.
- 12:16-12:23 G explores perimeter of pond for grouse tracks and returns with poles for setting the snares. [I spend 4 min chopping the hole for him while he is gone.]
- 12:23-12:30 G continues chopping: "It is only sometimes that it [the ice and chopping a hole for snare sets] gets really hard like this. When there is no snow and it freezes for a long time. This is the deepest I have seen it [the ice at] this time [season]. In the winter we use a chisel rather than an axe."
- 12:30-12:50 G sets the snare, devoting another 3 minutes to chopping. As before, but with two loops, one set above the other, both held by grass. G asks if I would turn my notes into a book. I answer some day. He laughs and adds that I should take plenty of pictures. This snare is about 6 meters from the house. I ask about the distance. He says there is a trail (which I can vaguely discern in the brush growing through the ice). I look for bubbles and confirm his location of the route. Several pieces of barked alder frozen into the ice make chopping difficult. G kicks slush into the water when the set is finished.
- 12:50-12:52 G looks close to the house.
- 12:52-12:56 G chops two small holes and abandons them; false starts. Chops one larger.
- 12:56-1:10 G sets a snare in the larger hole. Most of the time he explores with the curved pole. He makes me review clues to locate a beaver runway, and adds wood chips to my list: "They carry it inside to eat, and then throw it out of the lodge exits or along the runways." G "measures" beneath the ice carefully, moving the pole from side to side. He comments that the snare must be oriented exactly across [perpendicular to] the pathway to work. Runway orientation is not predictable: some chutes come out straight, some turn abruptly. The water is shallower here, so he uses two snares with one behind the other. G kicks slush into the holes above the snares.
- 1:10-1:13 Prepare to leave.
- 1:13-1:22 Walk back to small lake.
- 1:22-1:31 G sets a mink trap into a cubby chopped into the side of a small abandoned beaver lodge. The base is lined with grass; grass and sticks make a roof over the set. Again, fish is placed behind the trap in the back of the cubby. The trap is toggled with wire to a large limb. 1:31-1:32 Prepare to leave.
- 1:32-1:35 Continue walking back.
- 1:35-1:41 G prepares another mink trap, this one to sit on the water surface of a creek, where the ice margins expose a long stretch of flowing water 8" wide. The trap is fixed to a wedge driven into the side of a pole, which will be stuck into the creek bottom. The trap is toggled below the water level, and tied with cord.
- 1:41-1:42 Walk to creek.
- 1:42-1:43 Set this mink trap into the flowing water. G says that mink commonly swim along narrow rivulets of open water like this one.
- 1:43-1:50 Walk back to original beaverhouse. G decides to set another snare.
- 1:50-1:54 Chopping. G again comments that he has not seen the ice this thick before.
- 1:54-1:56 Fish out the slush and ice chips.
- 1:56-1:58 Explore with the curved pole. G takes his time. He comments that the sun is getting low, but that it probably will take us only 20 minutes to get home.
- 1:58-2:04 Explore.
- 2:04-2:07 G cuts poles for the set. He uses one loop behind the other.
- 2:07-2:19 G prepares the sets. As he is making it he comments that "trapping might die out in the future." He asks what I think. I answer that I do not know; [although] it is declining. He laughs and says that he will have to keep in shape [for it], "just in case I

- go on strike." [Strikes were common and newsworthy in Canada in 1975.] I ask if he kicked the slush back into the hole to make it freeze more rapidly. He says that if the water just froze it would be clear and the light shining through would scare the beaver. With the slush it is less clear.
- 2:23-2:48 Walk back to the Ski-doo. On the way G sets three hare snares. (2:28-2:32, 2:33-2:37, and 2:43-2:48). The last is 20 m from the snowmobiles. In each case the hare runway crosses our trail.
- 2:48-2:52 Pack the Ski-doo, dress into warmer clothes.
- 2:52-3:10 travel back to Rat Dam. I note that where the river narrows it has cracked from shore to shore, with the upstream plate thrust under the lower. This creates a jagged ice lip, and dammed above it a small pond of water. With a covering layer of soft snow it would be hard to recognize and quite dangerous.

[After returning, this trip was traced on acetate over aerial photos. We traveled 23 km by snowmobile; 3.5 km on foot. G's time input was 357 min. Preparation, riding on the snowmobile, exploring for sets, constructing trap or snare sets, and shooting the grouse were assigned to a light energy expenditure level (3.5 kcal/min), walking to a moderate energy expenditure level (6.2 kcal/min), and chopping ice to a heavy expenditure level (8.7 kcal/min). In the aggregate his energy expenditure was 1530 kcal. This resulted in the capture of two grouse and the setting of four beaver snares, four mink sets, one otter set, and three hare snares. Three beaver houses were explored but unpromising. Evidence of moose, fisher, and wolf was located but passed by.]

This diary should establish the congruity between Cree hunting and the structure of the diet breadth model: prey are searched for generally but pursued singly. Less apparent, because unrecorded in written form, is the fact that we traveled through some habitats (river and lake, muskeg, and closed spruce forest) in order to reach or search within others (lake margin vegetation, and the brushy areas surrounding and associated with beaver ponds). The importance for the patch use model of discovering tracks (rather than organisms) will be discussed below, as will the import of this information for the marginal value theorem.

6.6. Evaluation of Hypotheses

6.6.1. Diet Breadth

The energy data cited above are drawn from the analysis of trips that were successful in locating and capturing one or a few species. The significant information for diet breadth, however, is the prey that *would* have been pursued if located. For given conditions diet breadth may be more general than the species actually captured. The anthropologist can of course ask about this, but with the Cree there is a more direct method of determining diet breadth. To each species there corresponds a weapon, and the technology carried indicates what species the hunter expects to pursue if encountered. A hunter may say he is going moose hunting, but the shotgun and snare wire added to his tools are a sure sign that waterfowl and hare will be pursued. Although Fig. 7 is based on individual trips of limited success, in many instances a hunter will leave the village technolog-

ically prepared to pursue species represented there with a net energy return greater than 1000–1500 kcal/hour. A .30-.30 for large game is nearly always taken. Depending on the season, various kinds of snare wire, a .22, and a shotgun will also be carried along.

I earlier hypothesized a generalized diet for Cree foragers based on boreal forest habitat qualities. Actually, the Cree often set out for only a few species. With snowmobiles and outboard motors, searching or reaching areas to search within can be quite time efficient. High search efficiencies—low physical effort subsidized by fossil fuels—lead to the prediction of a narrow diet breadth. My original hypothesis did not anticipate the effects of transportation on search velocity (Fig. 8A).

However, if we go back about 15 years, snowmobiles and outboards were not in widespread use. Snowmobiles travel 20–35 km/hr, depending on snow conditions and power; boats from 10 to 35 km/hr, depending on power and load. In contrast, walking or rowing velocities are approximately 5–8 km/hr. If search is related directly to distance covered, then search times would increase from three to seven times without this motorized transport. Physical effort and metabolic energy investment increases would be somewhat more. The model predicts that diet breadth was wider in these circumstances (Fig. 8B), and several information sources substantiate this: (1) The first is weekly hunting results collected by Rogers (1973) while traveling with a Cree family during the winter of 1953–1954. Foraging was done by snowshoe, assisted occasionally by dogsled. Rogers' record of weekly game capture suggests a broader diet than would occur at Muskrat Dam today, especially when it is realized that more species were probably sought than obtained in a given week (e.g., moose would probably have been pursued consistently, even if located or captured in only six of the weekly

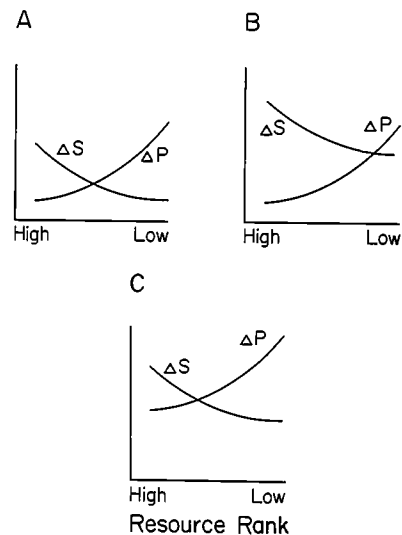


FIGURE 8. Optimal diet breadth hypothesized for three historical periods. In the contemporary situation (A) the use of outboards and snowmobiles and efficient steel traps, wire snares, and repeating rifles has resulted in relatively low search and pursuit costs. Diet breadth for a given foraging trip is fairly specialized. In the recent past (B), prior to the use of motorized transport, search velocity was lower and hence search costs higher in terms of time and metabolic energy requirements. Pursuit costs in the recent past probably remained much the same, leading to the prediction of a more generalized diet breadth. In the more distant past (C), prior to the widespread use of steel traps, snare wire, and repeating rifles, pursuit costs would have been higher. Again, the prediction indicates a short-term foraging effort that will be fairly specialized in terms of the resources pursued.

samples). Some species (such as squirrel or bear) were hunted that would be passed by today. Other northern anthropologists (Hurlich, personal communication; McCormack, personal communication) have also observed that snowmobile use has reduced the variety of game taken by northern hunters. (2) The Cree themselves indirectly substantiate this hypothesis in their commentary on the qualities of hunters. Young men say, "Before [snowmobiles] I had to come back with [at least] something, a beaver or whatever." Whereas now they will go with one animal or a few in mind. Older Cree men, when asked what makes a "good" hunter, will say, "A good hunter can hunt all of the animals, even if he is not too good at any one of them," and they will contrast this with the present situation in which young men tend to specialize. They are recalling the period when pursuit of a variety of animals was the common strategy. The foraging trip recorded by diary in Section 6.5.4, is indicative of this older approach.

There is a third case, as yet untested. If we go back a century or more, repeating rifles, snare wire, steel traps, and prefabricated gill nets were generally unavailable to the Cree (Rogers, Chapter 4, this volume). These devices all reduce pursuit costs, and their indigenous alternatives are more costly to use, construct, or maintain. The use of indigenous technology would increase pursuit costs and should lead to more specialized foraging (Fig. 8C). It may be possible to use ethnohistoric or archaeological information to confirm or refute this possibility (Dawson, Chapter 3, this volume).

Comparative tests of this sort, starting from actual field research, are probably the most satisfactory way of testing optimal foraging models (see also O'Connell and Hawkes, 1981). Archaeological and historical records of human innovations affecting search or pursuit abilities and other aspects of subsistence represent an important opportunity in this respect. In addition, linear programming can eventually be used to extend this energy-oriented analysis. This technique is analogous to the approach used here, but allows one to analyze optimization with respect to multiple resource attributes (e.g., for a game species: nutrients, energy, and nonconsumed derivatives such as pelts). Linear programming has already been adopted for archaeological investigations of subsistence systems (Keene, 1979, 1981; Reidhead, 1979). Using the present data base and interpretations, it should prove useful in analysis of Cree foraging in the context of the fur trade, and with an expanded notion of game utility. Thomas *et al.* (1979) have argued that analyses of human adaptations should rest on the interplay of simple and more complex models.

The optimal diet model assumes that a forager will make resource decisions based strictly on pursuit efficiency and the absolute abundance of highly ranked resources. With the Cree these may not be the only considerations. Short-term risk of failure may be quite important. Depending on the forager's stock of food or immediate nutritional state, he or she may rank highly resources of low efficiency but immediate return. Thus, in some circumstances moose will be pursued more efficiently than hare, but the day-to-day reliability of the latter

may elevate its rank above that of moose. The forager may, after all, go for days before actually securing that efficiently pursued moose.

6.6.2. Patch Choice

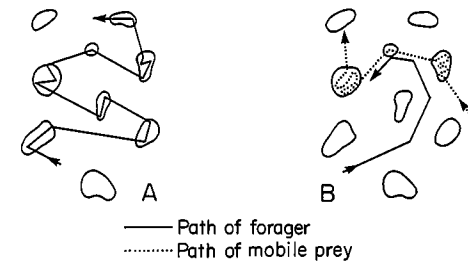
The hypothesis of generalized patch choice was less satisfactory. Often the Cree forage within only a few of the vegetation areas likely to contain the game being sought. As with diet breadth, this specialization is due partly to enhanced mobility. The forager who thinks nothing of traveling 15 km by snowmobile to a favorable location for moose hunting would, in earlier days, have foraged in many habitats along the way. Second, patches are not homogeneous (as is assumed in the model) with respect to travel rate or costs (e.g., spruce forest *versus* thawed muskeg) or the efficacy of pursuit (open *versus* brushy habitats containing moose) (O'Connell and Hawkes, 1981). Third, the diet breadth and patch choice models both assume random encounter. While prey encounters do tend to be random, this is not the case for patches. A Cree forager knows the microgeography of the landscape closely, and can adjust travel routes so as to encounter only those locations likely to be productive. According to the model, this also should result in greater specialization.

Finally, and perhaps most important, Cree foraging in some instances violates an important constraint incorporated into the structure of the patch choice model. The model assumes that a forager moves from patch to patch, and the Cree do follow this pattern when hunting relatively sedentary and localized prey like muskrat, hare, or beaver. However, when seeking mobile prey, such as moose or widely foraging carnivores, the Cree search for tracks between patches rather than animals within them. Some animals leave a reticular etching of their tracks on the landscape. In a functional and metaphorical sense they drag about very long "tails," and it is these tails rather than the animal itself that the forager attempts to locate. If moose move between patches frequently relative to the duration of the trail they leave behind, and if the animals are fewer in number than the patches they visit, then the forager's tactic is to attempt to cross and thus discover old trails rather than directly locate the animal. This "interstice" foraging pattern (Fig. 9) places the forager on easy travel routes where visibility is good, often the creeks and rivers which drain the matrix between the productive upland patches. By encountering tracks the forager can make sophisticated adjustments of pursuit tactics (Section 6.5.2). Thus, while the Cree respond to patchiness, the assumptions and constraints of the patch choice model are not always appropriate to their foraging. This restricts the usefulness and reliability of its hypotheses.

6.6.3. Foraging Itinerary

The marginal value theorem (MVT) is more difficult to assess. Close quantitative substantiation requires precise and rather extensive data. Several quali-

FIGURE 9. The patch-to-patch and interstice foraging patterns. The MacArthur and Pianka (1966) patch use model assumes that the forager moves from patch to patch in search of localized prey. This research suggests a somewhat different model in which the forager seeks mobile prey by moving in the interstices of the patches being visited by the prey organism. Additional discussion can be found in the text.



tative observations suggest, however, that it is correct in the Cree case. In 1975 Cree foragers abandoned hare snare lines even before they ceased to be productive. Somewhat earlier in the fall, muskrat were shot while they sat on the ice-encrusted coves along river shorelines. In all instances, after the more readily available muskrat were taken from a location, the forager moved on to the next one, rather than wait for several minutes for local animals to reappear. Similarly, several exits may be located at a beaver house but snares set at only one or two of them. This suggests that the "return" on the first or second snare at the next beaver house is greater than that on a third or fourth snare at the present lodge. Each example conforms to the general principle of the MVT, but does not establish if the "marginal value" at patch abandonment matches the average rate of intake for the overall habitat.* Further, and especially with respect to "manageable" prey such as the beaver (Feit, 1973), the prediction of this model is not easily distinguished from that of long-term conservation. Management by harvesting at a sustained yield makes a prediction rather similar to that of the MVT (Durham, 1981). Thus, it is difficult to assess which of these alternatives has the greater causal importance. It is worth noting—in light of the apparent ecological stability of hunter-gatherer adaptations—that "prudent predation" over the long term can be an incidental result of optimal (e.g., maximizing) foraging over the short term, at least in patchy environments.

6.6.4. Settlement Pattern

An historical pattern of dispersed family hunting groups is widely documented for the eastern boreal forest (Damas, 1969; Dunning, 1959; Leacock, 1973; Rogers, 1962; 1963a; 1969a; Rogers and Black, 1976), as is the recent change to more permanent and larger settlements (Bucksar, 1973; Ervin, 1969;

* Ted Steegmann (personal communication) made this observation on the marginal value theorem: "While at Ft. Severn, I went along on at least two fishing expeditions (angling) on which we canoed miles up distant rivers. On all occasions, the men raced to fishing spots (stream mouths or shoals) and immediately pulled out one or two trout. They then left abruptly for the next location, leaving me to continue fishing unaware that the patch had just been temporarily exhausted. This tells me that these spots were patches, had well-known short recovery limitations, and that active fishing conforms beautifully to this concept."

Fried, 1963; Lotz, 1965; Rogers, 1963*b*; VanStone, 1963). Rogers discusses this in Chapter 4 of this volume. Until recently the Cree spent most of the year in family hunting groups which occupied home range areas. Economic and governmental inducements have shifted this to a village pattern, while the use of snowmobiles, outboards, and bush planes allows the village Cree to reach into the large foraging areas surrounding these settlements.

While correct in the general sense that it specifies how a particular ecological situation (formerly) contributed to settlement pattern, ethnohistoric evidence shows that this model overlooks much important detail. Peculiarities of the environment, of family composition, and of kinship relationships contribute elements missing from the generalized ecological hypothesis (Rogers and Black, 1976: 39–40). An essentially correct ecological prediction may still capture only a portion of the actual variability of a human situation. It is important to observe, however, that a definitive prediction about the ecological influences at work allows us to distinguish the effects of *other* causes with greater assurance [Caraco and Wolf (1975); see also the discussion in the next section concerning territories].

6.7. Interpretation and Conclusions

6.7.1. Space, Time, and Recurrence

A shortcoming of human ecology analysis has been its generally static interpretation of natural environments (Winterhalder, 1980*a*; Chapter 2, this volume). As a consequence the dynamic qualities of human adaptation over time periods longer than the ethnographic year have received little attention. The present analysis does not escape the inadequacy of a short year-long period of field data collection. Nonetheless, if one can verify models that indicate systematically and in some detail how an optimal forager will respond to a set of environmental conditions, and if an analysis of the environment can establish how the combination of relevant environmental factors behaves over time, then one can reconstruct (or project) the qualities of the longer term adaptation. This is possible in the Cree case. Dynamic aspects of the spatial and temporal environment are fairly well known (Chapter 2, this volume), and optimal foraging models assist prediction of the effects of those on human behavior.

The boreal forest is vast. Its resources are spread widely, but not evenly. As a consequence, the Cree forager becomes familiar with a large area, even though in any season or year only a small proportion of it is productive. Most species used by the Cree are usually associated with five patch-types (aspen-birch forest, recent burn, aquatic vegetation, vegetation of lake margins, and aquatic areas) which together make up 28% of the landscape. If we allow for the fact that only a small part of the aquatic areas—points and shorelines—are used for fishing, then the patch-types used intensively amount to a little more

than 10% of the landscape. Conversely, 62% is in bogs, muskegs, and black spruce forest, areas containing little of use to the human forager. The productive 10% is scattered in an irregular distribution of small patches surrounded by the larger areas of bog, muskeg, and water. This pattern makes mobility critical to the forager.

Favorable foraging locations, then, are small patches, randomly distributed, and, by virtue of disturbance and succession, always shifting in their locations. This is the case for hare snare lines (Section 6.5.1; also Rogers and Black, 1976). It is demonstrated by the tactics used to hunt moose. The suitability of these patches for locating or pursuing game changes seasonally. Their shifting distribution occurs at a rate which produces significant but nonrepeating change over a forager's life span. It takes considerable experience to acquire original familiarity with a hunting area: each hunting trip reappraises that information, as once favorable areas through succession become less attractive to game, and as fire or wind create new areas. The observation of microgeography is a daily exercise over a lifetime.

Boreal forest ethnographers dispute whether family hunting groups were territorial, and if so, when and why this type of spatial system developed [see summaries in Bishop (1970), Knight (1965), Rogers (1963*a*)]. The major question seems to be whether family hunting territories were aboriginal or whether they developed historically in response to (1) the fur trade or acculturation in general, or (2) changing ecological conditions.

Spatial attributes of Cree foraging and of the boreal forest may shed some light on this question. Optimal foraging models suggest that territorial defense of resources should occur only where exclusive use provides benefits above the costs of defense. Such a net advantage is most likely to occur when resources are stable in their abundance and distribution and moderately dense (Brown, 1964; Dyson-Hudson and Smith, 1978). These requirements make territoriality of boreal forest hunters ecologically unlikely. When applying the model to humans there is, however, some ambiguity about the "cost" of territorial defense. The model assumes this involves active patrol of the boundary whether the defending unit is an individual (Brown, 1964) or a group (Hamilton and Watt, 1970). But human defense may escape much of this metabolic cost if boundaries are sanctioned culturally. Otherwise marginal resources might be profitably defended through energetically inexpensive manipulation of sorcery or supernatural intervention. Rogers, for instance, argues that hunting groups in Ontario are small (relative to those in Quebec) due less to ecological factors than to the Ojibwa's "preoccupation with, and highly developed concepts of, witchcraft in interpersonal relations in which no one can trust anyone else and there is constant fear of one's neighbours" (Rogers, 1969*b*: 37).

Bishop (1970, 1974; see also Rogers, Chapter 4, this volume) has gathered ethnohistorical information for northern Ontario which indicates that a family hunting territory system appeared in the early 19th century and became weakened toward the end of that century. He argues that its emergence was caused by two

factors: (1) the disappearance of large "migratory" game, particularly moose and caribou; and (2) the changing trade policies that accompanied the 1821 merger of the rival fur trade companies operating in the region, the North West Company and the Hudson's Bay Company. These are given as parallel but separable causes, one ecological and the second economic and historical. Additionally, Bishop argues that the late 19th century return of moose to the region was causal in the breakdown of the territory system.

Bishop's economic and historical arguments are convincing, the ecological ones less so. Caribou are too scarce in northern Ontario to carry much weight in the argument. Moose are not migratory, nor in most instances are they regularly pursued over long distances. Moose in northern Ontario have summer and winter ranges which can be contiguous or separated by up to about 10 km. Winter home ranges are less than 3 km²; summer ranges up to 15 km² [summary and references in Winterhalder (1977)]. Relative to the normal movements of a boreal hunter these distances and areas are quite small. For instance, Mistassini Cree hunting groups (usually three married men and their families) average 675 km²/man (Rogers, 1963a: 69–74). Thus, with respect to locating an animal, moose represent one of the more sedentary and stable of the resources in this area. Their disappearance would make a given region of the boreal forest *less* ecologically defensible. Thus, the ecological forces favoring territoriality would have produced a pattern in the 19th century just opposite to that observed. In this instance, use of the ecological model affirms that the countervailing nonecological causes were particularly significant.

The concept of passive territoriality, which arises from the MVT, is more interesting with respect to prehistoric Cree–Ojibwa land tenure. Effective foraging requires that small dispersed patches be continually assessed for their potential resource value, that their locations be known, and that movement among them follow efficacious paths. Such knowledge is gained and maintained through extensive experience with a region of boreal landscape and with its history. Special characteristics of the boreal forest suggest that passive territoriality might develop there: a complex patch structure, variable resource recovery rates, spatial and temporal instability of partially irregular resource pattern, and low visibility of resources.

The passive territory hypothesis does not suggest that territories are economically defensible (or that they are defended at all). Rather, a forager entering an area of boreal forest in which he or she has no experience is (1) at a disadvantage with respect to its long-term occupants, and (2) is reducing his or her foraging effectiveness in an environment in which subsistence adaptations may be marginal to begin with. Accidental foraging overlap is costly. It would be hard to detect without some kind of passive territory or home range system. Human foragers, unlike their nonhuman counterparts, can move among such passive territories unpenalized, so long as at least one person preserves continuity of knowledge and shares it with immigrants.

The temporal dynamics of this environment and of Cree foraging are even more striking than the spatial. The population density of each prey species fluctuates in a more or less patterned fashion, sometimes quite dramatically. Such changes occur seasonally and over longer periods. The fluctuations are only loosely intercorrelated, due to food-chain effects and to the effects of common environmental factors. For instance, the fluctuation of lynx populations responds to that of hare [references in Winterhalder (1980b)]. As another example, while deep snow lowers the survival rates of moose, it enhances those of small mammals like hare or muskrat, which depend on the snow cover for subnival survival over the winter. In the aggregate, these population fluctuations for each species generate a complex picture of nonrepeating absolute densities. These densities plus changes in seasonal visibility, snow and water conditions, and other factors that affect encounter rates give a highly dynamic quality to the searching component of the diet breadth model.

A similar set of environmental considerations imparts flux to pursuit costs, and hence to the ranking of various species with respect to optimal diet breadth. Prey can be ranked by their pursuit costs, but this ranking is unstable due to environmental influences on pursuit methods and success. These influences range from the ease of identifying a hare runway and hence the costs of setting snares, to the effects of snow depth and minute-to-minute changes in wind on the pursuit of moose. Steegmann (Chapter 7, this volume) gives ethnohistoric examples in which the vagaries of weather make summer and winter travel difficult and unpredictable. The seasonal pattern (which smooths the day-to-day fluctuations) of rankings for 1 year are evident in Fig. 7. Each year will be different, as is each day.

Optimal foraging theory identifies a "rule" that translates environmental variability into foraging decision variability. However, because the environmental factors affecting the forager vary more or less independently and on different time scales and dimensions of space, and because optimal foraging decisions must evaluate simultaneously many factors of the environment, it is possible to assert (Winterhalder, 1981b) that the significant elements of the environment of the boreal forager, taken together, are nonrecurrent on the scale of his or her lifetime. The foraging experience is always novel.

These fluctuations also raise a question about the notion of carrying capacity (Brush, 1975; Street, 1969; Glassow, 1978). Irregular, partially phased, and dramatic population fluctuations make it impossible to assign a value to the carrying capacity in this environment. Nonetheless it is evident that in the aggregate there will be large and probably irregular fluctuations (Fig. 10). The greatest subsistence pressure on humans thus arises periodically and for a fairly short time period (Rogers, Chapter 4, this volume). Adversity in the boreal forest is erratic. It is associated with unique and to some extent unpredictable combinations of conditions. These occur sporadically on a scale of decades, most likely at the nadir of the hare cycle and in the late spring and/or early summer.

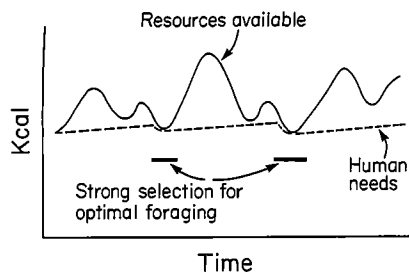


FIGURE 10. Resource availability and selection for efficient foraging. Environments that fluctuate strongly and with a frequency that is short relative to the rate of human population growth generate sporadic and relatively brief periods of strong selection for optimal foraging. For long periods the resource base will be abundant relative to the needs of the human population.

Over the longer and favorable intervals the resource base grows much faster than the human population, and the pressure for optimal foraging is relaxed. This allows considerable opportunity for competing foraging goals (e.g., taste preferences) to take precedence. These may divert behavior from the optimal *relative to the energy efficiency goal* being assumed here, or it may slow the development of such behavior. In addition, this situation is different from the claim often made in cultural ecology that in more severe (unstable, cold—the designation is never carefully defined) environments, the causal link between environment and adaptation should be strongest and most consistent. Even if controlled in a density-dependent fashion, due to environmental fluctuations the Cree population would have had abundant resources most of the time. Because of the spatially heterogeneous quality of their habitat, it is also unlikely that they would have overexploited their resources. The marginal efficiency of the foraging effort required to deplete each patch would be quite low, perhaps below the sustenance minimum.

6.7.2. Skills

There is another dimension to Cree foraging not suggested in the optimality models themselves—the skill of the Cree forager. The descriptions of hare snaring and moose hunting only hint at this, as do the data in the foraging diary. The forager is adept at steadying a beaver snare with a loop of grass, at aging tracks, at noticing the broken bits of sedge at the mouth of a stream. But proficient application of such techniques is quite demanding. The Cree forager is always learning about climate, landscape, and animal behavior. Because the environment changes rapidly, in multiple ways, and with significant degrees of statistical unpredictability, the major adaptive skills of the human forager are (1) observational sensitivity to the state of the ecosystem, (2) the ability to evaluate simultaneously many environmental factors which will affect foraging methods and abilities, and (3) flexible responses. Foraging in the boreal forest is the application of simple rules in a complex and skill-demanding setting. Each Cree forager has a history, built on experience and always engaged with the changes of the moment.

6.7.3. Summary

I will phrase the summary around the two questions asked earlier: What can this approach tell us about the Cree? And what can the Cree tell us about analysis of foraging behavior using evolutionary ecology models?

First, what does this approach say of the Cree?

1. The diet breadth model depicted Cree foraging well. Hypotheses derived from the model were confirmed by the evidence gathered for seasonal, and examined for historical, changes in diet. The assumption that an energy currency would reflect the adaptive forces on Cree foraging and the qualities of resources was supported. As hoped, the research procedure did direct attention to relevant foraging variables and habitat processes. It revealed some of the complexity and intricacies of the Cree articulation with their habitat, and provided models capable of handling them systematically.
2. Cree foraging decisions respond to a complex set of fluctuating factors, each with a different period and degree of regularity. In the aggregate these factors are nonrecurrent over a hunter's lifespan. Consequently, the hunting pattern of a Cree is always novel to some degree. The diet breadth model provides evidence that the strategic rules used by a Cree forager are quite simple. At the same time, gathering, assessing, and updating the environmental information and developing the skills necessary to apply the rules require extensive experience. Cree foraging is the knowledgeable application of simple rules in an always changing and immensely intricate setting.
3. Finally, one commonly hears that Western technology has disrupted the lifeways of hunter-gatherers, or that it inevitably compromises this subsistence pattern. This may be true in some cases. The Cree, however, have subsumed such technology without altering their basic strategy of harvesting forest resources. Optimal foraging models demonstrate the continuing efficiency and rationale of Cree hunting and trapping efforts, even as they take fewer game species. The latter is not evidence of a "disengagement" from their forest habitat. Rather, it reflects their enduring skill and proficiency *as foragers* living in a new technological context (see also Rogers, Chapter 4, this volume).

What do the Cree tell us about optimal foraging models?

1. Generally this is an interesting and valuable research procedure that points to good data and demands significant quantities of data for secure refutation or confirmation of hypotheses. In the present case much of the information gained on Cree foraging was used to identify model constraints, set parameters, and choose appropriate hypotheses. These are all aspects of the modeling procedure, with value in their

own right, but they fall short of a clean or thorough test of the predictions in most instances. It can be stated that some models are more useful and reliable than others when used for human adaptation analysis. The diet breadth model and the MVT worked well; the optimal patch use model was less adequate. The Horn model was substantiated for the historical period prior to large-scale governmental influences. However, ethnohistoric evidence shows in this case that even an essentially correct ecological hypothesis will not fully capture the situation. It should also be evident that the application of foraging models requires sensitive and detailed analysis of environmental properties and of specialized tactics and the technical aspects of energy costs and returns if it is to result in accurate depictions.

2. Finally, models eventually identified as reliable can be used to interpret the ecological adaptations of prehistoric hunter-gatherers. To date, such interpretations are often intuitive and less systematic than foraging theory. For instance, anthropologists [references in O'Connell and Hawkes (1981)] have often assumed that prey harvest is proportional to absolute prey densities. The optimal diet breadth model confirmed here makes it clear that this is not always the case. In another example, paleoanthropologists (e.g., Wolpoff, 1971, 1978) have found it difficult to conceive how two sympatric hominid species could avoid competitive exclusion due to overlapping resource use. This is a question of how foraging niches respond to competition, one which may eventually be resolved with optimization models (Winterhalder, 1980c, 1981c). Used to evaluate general evolutionary ecology theory, observations of Cree foraging may tell us a great deal about their and our foraging ancestors, wherever they lived and whatever the specific content of their adaptive lifestyle.

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Please see Winterhalder, Chapter 2 of this volume, page 49.

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