



## EARLY PALEOINDIAN WOMEN, CHILDREN, MOBILITY, AND FERTILITY

Todd A. Surovell

---

*If we take the archaeological record at face value, the colonization of unglaciated North America appears to have been very rapid. The highly consistent dating of Clovis archaeological sites (11,500–10,800 B.P.) suggests that this continent was populated within a matter of centuries. To explain the spatial and temporal scales of this phenomenon, it is necessary to invoke both high mobility and high fertility rates during the initial colonization process. However, it is widely believed that it is maladaptive for mobile foragers to have large numbers of offspring due to the costs of transporting those children. Thus, the archaeological record presents us with a paradox. Using a mathematical model that estimates the costs of raising children for mobile hunter-gatherers, this paper asks the question—is high mobility compatible with high fertility? It is concluded that high mobility, if defined as the frequent movement of residential base camps, is quite compatible with high fertility, and that early Paleoindians could indeed have been characterized by high reproductive rates. Therefore, it is quite possible that the Americas were populated very rapidly by highly mobile hunter-gatherers.*

*Si nos circunscribimos a las evidencias existentes, el poblamiento de Norteamérica parece haber sido un fenómeno bastante rápido. Los datos altamente consistentes acerca de la ocupación Clovis (11,500–10,800 A.P.) sugieren que el continente fue poblado en cuestión de siglos. El explicar la dimensión espacial y temporal de este fenómeno nos lleva a considerar altos índices de movilidad y fertilidad durante el proceso de poblamiento inicial. Sin embargo, comúnmente se considera que, para recolectores móviles, es inadecuado tener un número muy elevado de infantes, debido a los costos de transporte de los mismos. En ese sentido, la evidencia arqueológica nos presenta una paradoja. A través de un modelo matemático de estimación de los costos de mantenimiento de niños en cazadores-recolectores móviles, este trabajo plantea la pregunta: ¿Es compatible la alta movilidad con la alta fertilidad? Se concluye que la alta movilidad, definida como el desplazamiento frecuente de campamentos residenciales, es bastante compatible con un alto índice de fertilidad y que los pobladores paleoindios tempranos podrían caracterizarse por altos índices reproductivos. De esta manera, es posible que América fuera poblada rápidamente por cazadores-recolectores altamente móviles.*

---

**A**lthough it is widely agreed that the New World was first colonized at some point prior to 11,500 B.P., there is considerable disagreement as to how the colonization process actually proceeded (Beaton 1991; Hassan 1981; Kelly and Todd 1988; Martin 1973; Meltzer 1993a, 1995; Steele et al. 1998; Webb and Rindos 1993). Understanding the colonization of empty landscapes requires that we tackle three central issues. First, what path would colonists have taken, including the question of the point or points of entry? Second, how fast would colonists migrate? And third, how fast would colonists reproduce? Using these three dimensions of variability, it is possible to make predictions about the structure of the archaeological record of colonization. Its pathway and speed should be directly linked to its time-space systematics, while the rate of population growth should be reflected in the strength of its archaeological signal. If colo-

nization is inherently tied to small, slowly reproducing populations, the archaeological record left by those populations will be exceedingly difficult to detect. This may give the appearance of colonization occurring long after it actually did. If, on the contrary, colonization is accompanied by rapid population growth, the incipient stages of the occupation of the New World should be evident archaeologically not long after initial entry.

These issues relate directly to the Clovis/pre-Clovis question. If we consider the early archaeological record of North America as it currently stands, and assume that Clovis represents the colonizing population, the narrow range of radiocarbon dates (11,500–10,800 B.P.) produced from Clovis sites implies that this land mass was colonized within a matter of centuries (Batt and Pollard 1996; Fiedel 1999; Haynes 1992, 1993; Haynes et al. 1984; Taylor et al. 1996). There has been some speculation that

---

Todd A. Surovell ■ Department of Anthropology, University of Arizona, Tucson, AZ 85721

American Antiquity, 65(3), 2000, pp. 493–508  
Copyright © 2000 by the Society for American Archaeology

this tight clustering of radiocarbon dates implies a "plateau" in the calibration curve such that the Clovis phase actually lasted longer than it appears (Haynes 1971; Meltzer 1995). However, recent calibrations suggest that just the opposite is true (Fiedel 1999:105; Kitagawa and van der Plicht 1998). If anything, the actual range of time represented  $^{14}\text{C}$  age estimates from Clovis sites has been inflated. Indeed, the Clovis phenomenon was very brief in archaeological terms.

If Clovis hunter-gatherers were the colonizing population, they must have had high reproductive rates while maintaining a very mobile lifestyle. Otherwise, it would have been impossible to saturate the continent with people in a few centuries while maintaining crucial reproductive ties between neighboring groups (Whitley and Dorn 1993). In this paper, I focus specifically on the relationship between fertility and mobility using a mathematical model that estimates the costs of rearing children for mobile hunter-gatherers. Using this model, I first address the central question of whether high mobility is compatible with high fertility. This permits evaluation of the question of whether we may be receiving a false picture of colonization through inadequate sampling of the archaeological record. If high mobility and high fertility prove to be incompatible, we may infer that human entry into the New World significantly predates the Clovis horizon. Otherwise, it can be argued that Clovis *could* represent the colonizing population, or its immediate ancestor. The model also predicts how a colonizing population should organize mobility assuming a goal of maximizing of reproductive potential. This prediction can then be compared with the archaeological record to determine if indeed early Paleoindians seem to have behaved as the model predicts they should have.

In light of the recent acceptance of the pre-Clovis status of the southern Chilean site of Monte Verde by much of the archaeological community (Adovasio and Pedler 1997; Meltzer 1997; Meltzer et al. 1997), to some, these issues may seem somewhat outdated. If we assume the occupants of Monte Verde are derived from an initial migration across the Bering land bridge, there must be pre-Clovis sites in North America as well. Even if it is argued that as of yet undiscovered North American pre-Clovis archaeological sites exist, the Clovis phenomenon still requires explanation. How were fluted-point makers able to traverse the entirety of unglaciated North

America within a matter of centuries if other populations were already firmly established? Similarly, how were they able to maintain a life way of high mobility in the presence of supposed pre-Clovis populations who certainly would have commanded large tracts of land? These issues also relate to the notion that the ubiquity of Clovis and Clovis-like projectile points across North America does not reflect a dispersal of people, but instead a rapid transfer of a highly successful technological concept among populations already in place (Adovasio and Pedler 1997:579; Stanford 1978 as cited by Adovasio and Pedler 1997; Young and Bonnicksen 1984; see also Storck 1991). Although this paper alone cannot refute the diffusion nor migration hypothesis, it can address the likelihood of concomitant rapid population and geographic expansions of early Paleoindian groups, a prerequisite of the migration argument.

### Modeling Mobility and Fertility

Hunter-gatherer demographic studies typically emphasize factors that directly or indirectly affect fertility and/or mortality such as age at menarche and menopause, lactational infecundability, marriage and sexual practices, nutrition, contraception and abortion, female workloads, venereal and other disease, infanticide, senilicide, accidental death, absenteeism, etc. (e.g, Balikci 1967; Bentley 1985; Binford and Chasko 1976; Campbell and Wood 1988; Ellison 1990; Handwerker 1983; Hassan 1981; Hayden 1972; Hill and Hurtado 1996; Howell 1976, 1979; Hurtado and Hill 1990; Irwin 1989; Kelly 1995; Konner and Worthman 1980; Pennington and Harpending 1988; Smith and Smith 1994; Spielmann 1989; Wilmsen 1978; Wood 1990; and many others). Recent work with the !Kung and Hadza has instead focused on the relative costs of raising children (Blurton Jones et al. 1992, 1994a, 1994b; Hawkes et al. 1995). In this framework, potential fertility ( $F_p$ ) can be estimated as:

$$F_p = \frac{R_{max}}{C}$$

where  $C$  is the per-child cost to the parents measured in the most limiting currency (whether physiological, behavioral, economic, or otherwise), and  $R_{max}$  is the maximum amount of that currency which a family can devote to child rearing. For example, imagine a situation in which total income is the most limiting factor controlling family size and raising a single child from conception to independence will

cost a family \$200,000. If a family can allocate \$1 million to child rearing throughout their lifetime, that family can “afford” to have 5 children. For hunter-gatherers, however, the major costs involved in raising children are related to foraging energetics. Parents must work hard to feed their children. This not only involves carrying a lot of food over long distances until offspring are able to fend for themselves but also carrying children at least until they are able keep up on their own. Thus, a work-related currency is likely more appropriate for estimating the cost of raising children for mobile hunter-gatherers. It should be noted here that potential fertility and actualized fertility are very different things. Although natural selection would favor behaviors that maximize reproductive output, it is unclear whether humans actually achieve that potential. Calculating the cost of child rearing allows for the estimation of maximum potential fertility levels, but actual fertility may be somewhat less than the maximum. Reducing mortality rates can accelerate population growth as well, but low mortality by itself cannot result in high rates of population growth without high fertility.

It is commonly argued that high mobility in hunter-gatherers leads to low fertility:

...it has been widely accepted, at least since the work of Alexander Carr-Saunders in 1922, that nomadism and high mobility result in long birth-spacing intervals and low fertility (Whitley and Dorn 1993:628).

This attitude has arisen from observations that hunter-gatherer population growth is at least partially limited by the necessity of carrying infants, as Carr-Saunders and many others have suggested:

Among more or less nomadic peoples abortion and infanticide are practised because of the difficulty of transporting and of suckling more than one child at a time (Carr-Saunders 1922:22).

More recently, Richard Lee (1972, 1979) working with the !Kung, demonstrated that dry-season female workloads increased dramatically if they had children less than four years apart. Blurton Jones and Sibly (1978) created a formal mathematical model based on Lee’s work, which estimated the maximum loads to be carried by !Kung mothers as a function of birth spacing. They concluded that the problem of transporting children and food for those children was the primary factor limiting !Kung fertility (see also Blurton Jones 1986, 1987, 1989, 1994; Harpending 1994).

The !Kung San are well known for their low reproductive output as a natural fertility population. This can be attributed in part to the long distances that !Kung women must travel from dry-season water holes to nut groves (Blurton Jones et al. 1989; Lee 1979; Draper 1976). However, it is not possible to generalize to all mobile hunter-gatherers from the !Kung. As there are different costs associated with different kinds of mobility, we would expect fertility to vary not only depending upon the scale of mobility, but also upon how it is organized. For example, while foraging, a woman must carry young children for the entire trip, but food is usually carried only one way. During residential moves, children must be carried, but food can be gathered along the way. Also, it is possible to leave children with babysitters when parents forage, but not while moving residential camps. Thus, the relative emphasis on residential and logistical mobility (*sensu* Binford 1980) should thus have important effects on the cost of raising children. For example, Blurton Jones et al. (1994b) cite the less “patchy” distribution of water and more frequent movement of residential camps as one factor contributing to the greater fertility of the Hadza relative to the !Kung.

Thus, the model presented below takes into account not only the scale of mobility (i.e., distance walked) but also its organization. The model is founded on the assumption that for mobile hunter-gatherers, an important factor limiting fertility is the cost of carrying children and food for those children. Potential fertility, therefore, should be inversely proportional to the total per-child transport costs for the period of dependency. *If carrying costs are high, fertility will be low; if carrying costs are low, fertility can be high.*

Following Lee (1972, 1979), carrying costs are estimated in the unit of kg•km, the amount of weight carried times the distance it is carried. A value of 10 kg•km is treated as equivalent to carrying a mass of 5 kg a distance of 2 km, or carrying 2 kg a distance of 5 km. Though the model treats a trip in which no burden is carried as cost free, in actual calculations average distances and weights are used, thus taking into account unsuccessful foraging trips. Total carrying costs are calculated per child for a monogamous couple for the total period of dependency, the length of which is allowed to vary as discussed below. A computer program was written as a Visual Basic macro for Microsoft Excel (Version 5.0a, for Mac-

Table 1. Model Parameters.

Parameter	Description	Unit
$F_R$	Average frequency of residential moves	days
$D_R$	Average distance of residential moves	km
$F_{ML}$	Average frequency of male logistical moves	days
$D_{ML}$	Average distance of male logistical moves	km
$F_{FL}$	Average frequency of female logistical moves	days
$D_{FL}$	Average distance of female logistical moves	km
$C_M$	Male contribution to the diet	%
$C_F$	Female contribution to the diet	%
$U_M$	Average male food utility	kcal/kg
$U_F$	Average female food utility	kcal/kg
Childcare	Childcare model (see Table 2, Figure 1)	
Child Foraging	Child foraging model (see Table 3, Figure 2)	

intosh) to calculate costs. Only costs directly resulting from the child's needs are tabulated. For example, the costs of adults foraging for themselves or other non-offspring individuals are not included. Similarly, during residential moves, all personal belongings must be transported, but these costs are independent of the child. Although they should affect the overall organization of mobility, they do not directly affect the costs of raising children and are not considered here.

The parameters used to calculate cost are listed in Table 1. Carrying costs are based on the average weight of children by age and their average daily nutritional intake by age as reported by the World Health Organization (1985). Age is calculated as years since conception, because mothers begin carrying their children 9 months before birth. Translating the mass of children into the mass to be carried by mothers requires an estimation of a child's ability to walk as a function of age. As children become more sure-footed and gain endurance, mothers will carry them less. By the age of 20 months, children take their first steps, and by age 5, they have generally developed a mature gait (Cech and Martin 1995; Sutherland et al. 1988). Although I was unable to locate any data relating age and endurance for young children, it seems that by age 5 or 6, children are quite mobile and able to keep up with adults (Blurton Jones et al. 1994b; Hawkes et al. 1995; Hill and Hurtado 1996; Lee 1972, 1979).

Because children may be left at the residential base camp with babysitters, such as grandparents or older siblings, the model can also estimate the degree to which transport costs are reduced by surrogate childcare. Three curves are used to model the average weight of children to be carried per kilometer

(Figure 1, Table 2). One curve depicts a scenario in which no babysitting is available. Another models babysitting for 50 percent of foraging trips, and the third models babysitting for 90 percent of foraging trips.

Food weights can be estimated from the daily nutritional requirements of children minus their own contribution to their diet. As children provide more food for themselves, the burden on parents decreases. Therefore, three child foraging scenarios have been created (Figure 2, Table 3). In the late foraging scenario, children do not begin foraging for themselves until age 10, and their own contribution to their diet gradually increases until independence at age 18. In the early child foraging scenario, children begin foraging at age 4 and reach independence by age 12. A middle foraging scenario is intermediate between the two. These scenarios are intended to span the full range of possible variability in child foraging behavior.

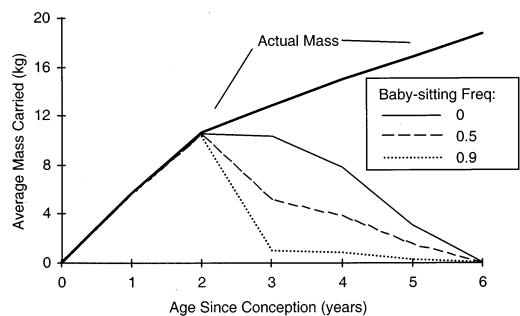


Figure 1. Age vs. average mass of children to be carried from Table 2. Three babysitting models are depicted: no babysitting, babysitting for one-half of female forays, and babysitting for 9 of 10 of female forays. Actual mass is based on the average mass of children worldwide from the World Health Organization (1985).

Table 2. Mass of Child to be Carried by Age and Childcare Model.

Age of Child (years)	0	1	2	3	4	5	6
Child mass (kg)	0	5.7	10.6	12.8	14.9	16.8	18.7
Average mass carried (kg)							
No childcare	0	5.7	10.5	10.3	7.7	3.1	0
Childcare 1/2	0	5.7	10.5	5.2	3.9	1.6	0
Childcare 9/10	0	5.7	10.5	1.0	.8	.3	0

Note: Age is measured as years since conception. Data from World Health Organization (1985).

To translate nutritional requirements into food weights, it is necessary to estimate the energetic content of foods as a function of mass. This is essentially a measure of portability. Food science data allowed the quantification of plant portability for 191 plant foods (Pennington 1989). These were subdivided according to class: seeds and nuts, legumes, fruits, roots and tubers, and leaves and stems (Figure 3). Seeds and legumes were the foodstuffs of the Neolithic and onward in many parts of the world. As they have high processing costs (O'Connell and Hawkes 1981), they were unlikely to have played a large part in early Paleoindian economies. The rarity of grinding technology in Paleoindian sites supports this contention. Because leaves and stems have low nutritional content, they also are unlikely to have been major constituents of Paleoindian diets, but they can play an important role in hunter-gatherer diets where plant use is minimal (Keeley 1995). Therefore, I assume that early Paleoindian plant use focused on roots and fruits. This yields an average of 680 kcal/kg for gathered foods. Hunter-gatherer energetics studies provided data for energy yields for 18 wild game

taxa (Hawkes et al. 1992; Hurtado and Hill 1987), for an average of 1473 kcal/kg (Figure 3).

The mass of food to be transported per day for a child is calculated as the daily nutritional energetic requirement divided by food portability. For example, in the early child foraging scenario, a 3-year-old child requires 1250 kcal/day from the parents for sustenance. If this is provided entirely by hunting (1473 kcal/kg), the child will need .85 kg of food per day. If it is provided entirely by gathering roots and fruits (680 kcal/kg), the child will require 1.84 kg of food per day. If some combination of hunting and gathering is used, the value will fall between these extremes.

Translating weights into cost requires taking into account how far and frequently these masses of food and children are to be carried. This is where mobility comes into play. Mobility is broken down into three components: residential mobility, male logistical mobility, and female logistical mobility. Following Binford (1980), residential mobility refers to the movement of an entire family from one base camp to a new base camp. Logistical mobility refers to food-getting forays starting from and returning to the base camp. In the model, each type of mobility is assigned an average frequency and one-way distance. Frequency of residential mobility is the average time elapsed (days) between residential moves or the average duration of occupation of a residential base camp. The frequency of logistical mobility for males or females is the time elapsed (days) between foraging trips.

When the residential camp is moved, children are always carried up to the age of 6, and no food is carried. It is further assumed that foraging takes place during residential moves. In male and female logistical forays, food is carried the one-way distance determined by the average daily foraging radius. A classic division of labor is assumed—men hunt, and women gather. Males never bring young children on

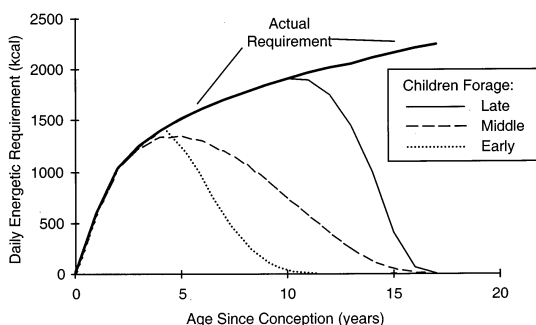


Figure 2. Age vs. daily energetic requirements of children from Table 3. Three child foraging models are depicted: early, middle, and late foraging. Actual requirements are based on the average nutritional intake of children worldwide from the World Health Organization (1985).

Table 3. Average Daily Energy Requirements by Age and Child Foraging Model.

Age of Child (years)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Energy Requirement (kcal/day)	0	589	1035	1250	1396	1511	1611	1695	1771	1839	1904	1965	2018	2056	2110	2163	2209	2250
Parental Contribution (kcal/day)																		
Late Child Foraging	0	589	1035	1250	1396	1511	1611	1695	1771	1839	1901	18889	1743	1443	1001	39	58	0
Middle Child Foraging	0	589	1035	1241	1331	1342	1298	1204	1075	918	746	569	397	243	122	45	7	0
Early Child Foraging	0	589	1035	1250	1396	1200	840	501	238	70	11	1	0	0	0	0	0	0

Note: Age is measured as years since conception. Data from World Health Organization (1985).

hunting forays, but females must always carry young children the roundtrip distance on foraging trips up to the age of two due to the requirement of breast feeding. Beyond this age, children may be left at the base camp depending on the babysitting model in use.

Mobility is controlled by the geometry of foraging in a homogenous environment (Figure 4), and is allowed to vary such that it approximates the “col-

lector/forager” continuum described by Binford (1980). This is similar to the “transient explorer/estate settler” distinction made by Beaton (1991) with respect to the colonization of unpopulated landscapes. At one extreme, foraging groups tend to move base camps frequently, essentially moving people to food patches. In its extreme form, this strategy maximizes the distances walked annually while moving base camps, but minimizes daily

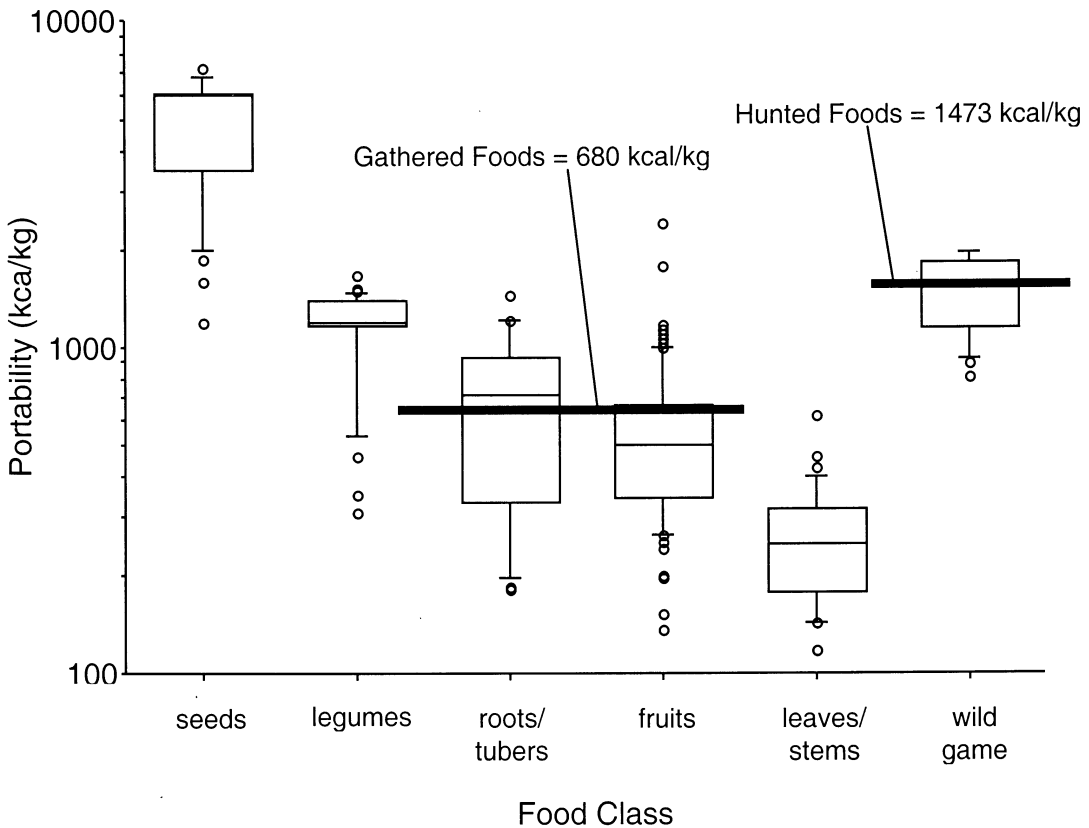
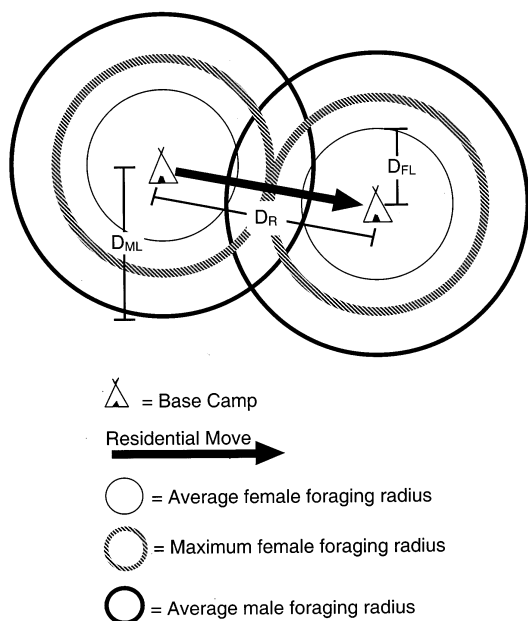


Figure 3. Portability of foods arranged by type. Foods gathered by women were assumed to be mainly roots and fruits, and thus an average value of 680 kcal/kg was chosen. For hunted foods, an average value of 1473 kcal/kg was used. Data for plant foods (N = 191) is from Pennington (1989). Data for wild game portability (N = 18) is from Hawkes et al. (1992) and Hurtado and Hill (1987).



**Figure 4.** The geometry of foraging in a homogenous environment. Average male foraging radius (DML) is twice the average female foraging radius (FML). The distance between residential camps (DR) is twice the maximum female foraging radius.

foraging distances. Groups using such a strategy will be referred to as *high residential foragers (high res)*. At the other extreme, groups move base camps infrequently, thus minimizing residential mobility and maximizing foraging distances. This strategy instead emphasizes moving food to people. Groups using this strategy will be referred to as *low residential foragers (low res)*. These strategies should not be seen as types, but instead as ends of an idealized continuum.

Duration of base camp occupation (also called the frequency of residential mobility) governs all other mobility variables. The exact relationship between length of stay at the residential camp and foraging radii is set arbitrarily, but these variables are related with a square root function so that foraging area increases as a function of the square of the foraging radius. Male foraging radii in kilometers were calculated as the square root of the duration of base camp occupation in days. Average female foraging radii ( $D_{FL}$ ) were arbitrarily set to one half of average male foraging radii, because males must travel farther for hunted resources which generally exist at lower densities than most gathered resources. This method seemed to produce reasonable foraging dis-

tances. In that these relationships are held constant for all runs of the model, the exact distances are irrelevant. The distance between residential base camps ( $D_R$ ) was set to twice the maximum female foraging radius ( $D_{FL}$ ) so as to prevent overlap of female foraging areas (Binford 1982; Kelly 1983). This distance is calculated as:

$$D_R = 2 \cdot D_{FL} \cdot \sqrt{2}$$

because the maximum foraging radius will be  $\sqrt{2}$  times larger than the average foraging radius, again because area increases as the square of the radius. Male foraging areas do overlap, but as animals are mobile and may inhabit areas just abandoned by people, returning to an area recently hunted is not necessarily an unproductive activity.

Total energetic expense per child ( $E_{Total}$ ) is calculated as the sum of the energetic expense for each mobility type for the period of dependency:

$$E_{total} = E_R = E_{FL} + E_{ML}$$

where  $E_R$  is the energy expended during residential moves,  $E_{FL}$  is the energy expended during female logistical mobility, and  $E_{ML}$  is the energy expended during male logistical mobility. Time is incremented in .1 year, or 36.5 day intervals, and total cost is calculated from the conception of a child to his or her independence (the time at which parental food gathering responsibilities cease). Therefore,  $E_R$  is calculated as the sum of all episodes of carrying children during residential moves from the time of conception ( $t = 0$ ) to the age of independence ( $t = A_i$ ):

$$E_R = \sum_{t=0}^{A_i} \left( M_t \cdot D_R \cdot \frac{36.5}{F_R} \right)$$

where  $M_t$  is the average mass of the child to be carried at time  $t$ ,  $D_R$  is the average distance (km) per residential move, and  $F_R$  is the frequency (days) of residential moves, measured as the duration of camp occupation. Thus  $36.5/F_R$  provides the number of residential moves in a 36.5-day interval. The average mass of a child to be carried is estimated from Table 2 by linear interpolation between points.

Estimating the cost of male logistical mobility ( $E_{ML}$ ) requires calculation of the mass of food to be carried by the male parent until the child reaches independence. The calculation is:

$$E_{ML} = \sum_{t=0}^{A_i} = \left( \frac{36.5}{F_{ML}} \cdot D_{ML} \cdot C_M \cdot \frac{R_t}{U_M} \cdot F_{ML} \right)$$

Table 4. Parameter Settings.

Case	$F_R$ (days)	$D_R$ (km)	$F_{ML}$ (days)	$D_{ML}$ (km)	$F_{FL}$ (days)	$D_{FL}$ (km)	$C_M$	$U_M$ (kcal/kg)	$C_F$	$U_F$ (kcal/kg)	Baby-sitting	Child-foraging
1	2.00	2.00	2.00	1.41	2.00	.71	.50	1473	.50	680	0, .5, .9	E, M, L
2	2.59	2.28	2.00	1.61	2.00	.81	.50	1473	.50	680	0, .5, .9	E, M, L
3	3.37	2.59	2.00	1.83	2.00	.92	.50	1473	.50	680	0, .5, .9	E, M, L
4	4.37	2.96	2.00	2.09	2.00	1.04	.50	1473	.50	680	0, .5, .9	E, M, L
5	5.67	3.37	2.00	2.38	2.00	1.19	.50	1473	.50	680	0, .5, .9	E, M, L
6	7.35	3.83	2.00	2.71	2.00	1.36	.50	1473	.50	680	0, .5, .9	E, M, L
7	9.54	4.37	2.00	3.09	2.00	1.54	.50	1473	.50	680	0, .5, .9	E, M, L
8	12.37	4.97	2.00	3.52	2.00	1.76	.50	1473	.50	680	0, .5, .9	E, M, L
9	16.05	5.67	2.00	4.01	2.00	2.00	.50	1473	.50	680	0, .5, .9	E, M, L
10	20.83	6.45	2.00	4.56	2.00	2.28	.50	1473	.50	680	0, .5, .9	E, M, L
11	27.02	7.35	2.00	5.2	2.00	2.60	.50	1473	.50	680	0, .5, .9	E, M, L
12	35.05	8.37	2.00	5.92	2.00	2.96	.50	1473	.50	680	0, .5, .9	E, M, L
13	45.48	9.54	2.00	6.74	2.00	3.37	.50	1473	.50	680	0, .5, .9	E, M, L
14	59.00	10.86	2.00	7.68	2.00	3.84	.50	1473	.50	680	0, .5, .9	E, M, L
15	76.55	12.37	2.00	8.75	2.00	4.37	.50	1473	.50	680	0, .5, .9	E, M, L
16	99.31	14.03	2.00	9.97	2.00	4.98	.50	1473	.50	680	0, .5, .9	E, M, L
17	128.84	16.05	2.00	11.35	2.00	5.68	.50	1473	.50	680	0, .5, .9	E, M, L
18	167.15	18.28	2.00	12.93	2.00	6.46	.50	1473	.50	680	0, .5, .9	E, M, L
19	216.86	20.83	2.00	14.73	2.00	7.36	.50	1473	.50	680	0, .5, .9	E, M, L
20	281.35	23.72	2.00	16.77	2.00	8.39	.50	1473	.50	680	0, .5, .9	E, M, L
21	365.01	27.02	2.00	19.11	2.00	9.55	.50	1473	.50	680	0, .5, .9	E, M, L

where  $F_{ML}$  is the average frequency (days) of male logistical mobility,  $D_{ML}$  is the average distance (km) of a male logistical foray,  $R_t$  is the daily parental contribution (kcal) to the child's diet at time  $t$ ,  $C_M$  is the percent contributed to the diet by males, and  $U_M$  is the average utility (kcal/kg) of foods acquired by males. Note that the frequency of male logistical mobility has no effect on the final calculation because males do not carry children, and energy is measured as the product of distance and weight. The model treats a scenario in which males make infrequent trips carrying a lot of food as energetically equivalent to one in which frequent trips are made carrying less food.

The calculation of energetic expense during female logistical mobility is identical to that of males with the addition of the added weight of children:

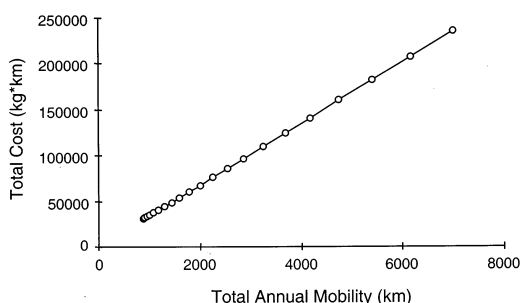
$$E_{FL} = \sum_{i=0}^{A_i} \left( \frac{36.5}{F_{FL}} \cdot 2 \cdot D_{FL} \cdot M_t \right) + \sum_{i=0}^{A_i} \left( \frac{36.5}{F_{FL}} \cdot D_{FL} \cdot C_F \cdot \frac{R_t}{U_F} \cdot F_{FL} \right)$$

where  $F_{FL}$  is the average frequency (days) of female logistical mobility,  $D_{FL}$  is the average distance (km) of a female logistical foray,  $M_t$  is the mass (kg) of the child at time  $t$ ,  $R_t$  is the daily parental energetic (kcal) investment in the child's diet,  $C_F$  is the female

percent contribution to the diet, and  $U_F$  is the average utility (kcal/kg) of foods collected by females. The term on the left calculates the total energy expended in carrying children during female logistical mobility. Distance is doubled because the child is carried in both directions. The right-hand term is identical to that of the male logistical mobility equation with the parameters for females inserted. Unlike the frequency of male logistical mobility, the frequency of female logistical mobility does have important consequences for the model because females must carry children. Thus, females should have incentive to forage as infrequently as possible and should carry heavier loads in order to minimize the distance that children must be carried. Of course, if foraging is too infrequent, mothers will not be able to carry enough food to meet the nutritional needs of their children.

#### Testing the Model

To estimate the costs of raising children across the *high res-low res* mobility continuum, 21 cases were created that span this range (Table 4). In the most residentially mobile scenario, the residential camp is moved every other day a distance of two kilometers. At the other extreme, the camp is only moved once a year to a new location 27 km away. The average distance of female logistical mobility ranged

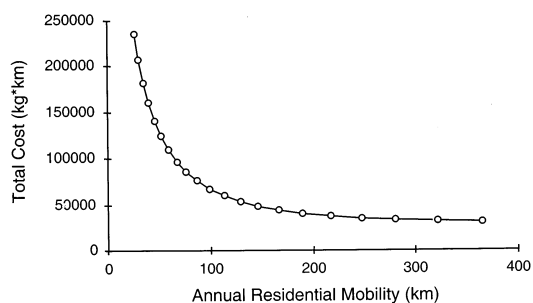


**Figure 5. Total annual mobility vs. total cost of child rearing.** Total annual mobility is calculated as the sum of the distances of all moves for a single family in which either children or food for those children are carried.

from .7 km with frequent residential mobility to 9.5 km in the least residentially mobile case. Average male distances ranged from 1.4 to 19.1 km. Male and female foraging frequencies were set at foraging every other day ( $F_{ML}, F_{FL} = 2$ ), but as discussed, this only affects the calculation of female workload. All three babysitting and child foraging models were examined to determine their differential effects for high residential and low residential mobility cases. When the babysitting model was varied, child foraging was held constant using the “late foraging” curve. When child foraging was varied, the “no babysitting” curve was used. Food portability values were held constant at the values discussed above. Male and female dietary contributions were each set to 50 percent.

*Results*

The model indeed confirms that high mobility in the strictest sense is incompatible with high fertility. **Figure 5** shows the total calculated costs of child rear-



**Figure 6. Annual residential mobility vs. total cost of child rearing.** Annual residential mobility is calculated as the sum of the distances of all residential moves for a single family for one year.

ing vs. the total annual mobility, calculated as the sum of the distances walked annually for a family in transporting food and/or children. Total cost increases almost linearly with distance walked. This is not unexpected since distance is a large component of that cost. **Figure 6** demonstrates, however, that as a greater emphasis is placed on residential mobility, the cost of child rearing actually decreases. The per-child transport cost for the least residentially mobile case is 6.5 to 7.5 times greater than that of the most residentially mobile case, depending upon the child foraging and babysitting model chosen. For foragers who move their residential base camp frequently, constraints on fertility are actually less than for those who emphasize logistical mobility from long-term base camps.

The greater costs for *low res* foragers result from increased foraging distances associated with greater duration of occupation of residential camps. All groups must provide the same amount of food to their children by foraging over the same land area, but *low res* groups have to walk greater distances to do so. This is graphically depicted in **Figure 7**. The *high res* hunter-gatherer makes 107 moves per year resulting in 279 km of total residential mobility, but due to short foraging distances, total mobility is only 953 km per year. In contrast, the *low res* hunter-gatherer will only cover 47 km per year in residential mobility, while transporting food and children a total of 4073 km per year when foraging is included. Note that the *high res* group may move much greater distances across the landscape, while actually minimizing total walking distances.

For all cases, the total per child costs from conception to independence ranged from 25,885 to 238,087 kg•km. When cost is broken down by mobility type, it is apparent that for most cases, the major determinant of total cost ( $E_{Total}$ ) is female logistical mobility ( $E_{FL}$ ), particularly for less residentially mobile cases (**Figure 8**). When the base camp is moved often, the costs of residential and logistical mobility are very similar, but as hunter-gatherers settle down, residential costs drop out and costs associated with foraging dominate. Although males tend to cover more ground than females in the model, women tend to carry much heavier loads due to the combination of food and children and the lower energetic content of gathered foods.

Although the timing and degree of child foraging can reduce the costs of child rearing up to approxi-

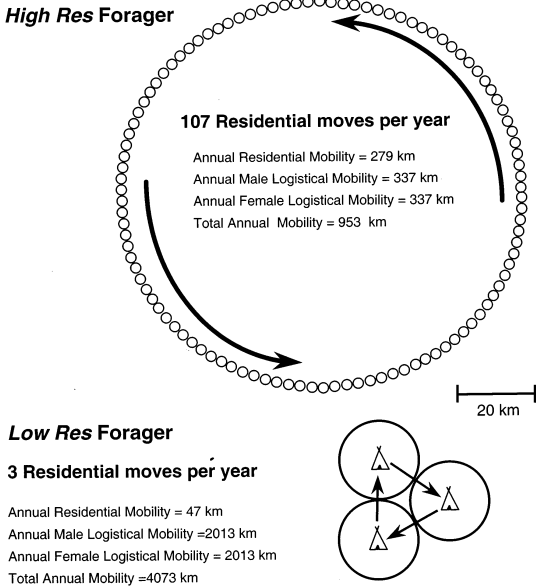


Figure 7. Two solutions to foraging in an identical environment. Each circle represents a maximum female foraging radius around a base camp. In both cases, the area foraged is equivalent. The high res forager moves 107 times per year for a total of 279 km in residential mobility and 337 km in male and female logistical mobility. The low res forager moves 3 times per year for a total of 47 km in residential mobility and 2013 km in male and female logistical mobility.

mately 30 percent, the general pattern of relative cost remains the same (Figure 9). Children are cheap for *high res* foragers; they are expensive for *low res* foragers. Babysitting can also reduce the costs of child rearing up to 30 percent (Figure 9). Still, the shape of the curve remains identical. It is cheapest to emphasize residential mobility. The energetic sav-

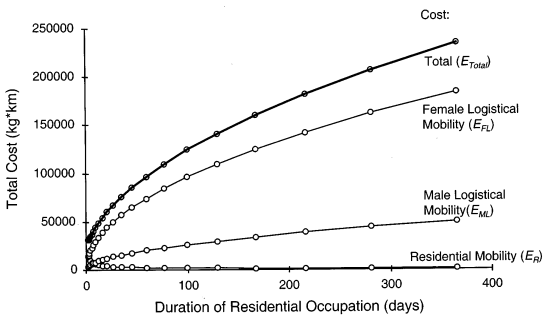


Figure 8. Relative energetic expenditure for residential, male logistical, and female logistical mobility as a function of the duration of occupation of residential base camps (FR,days).

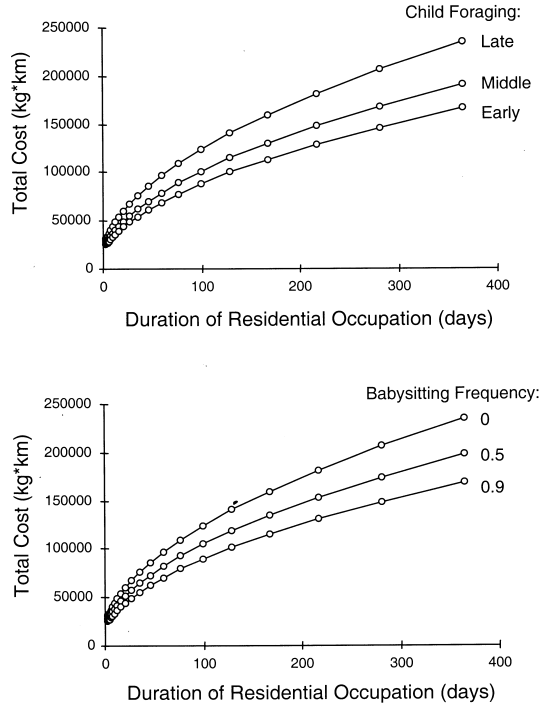
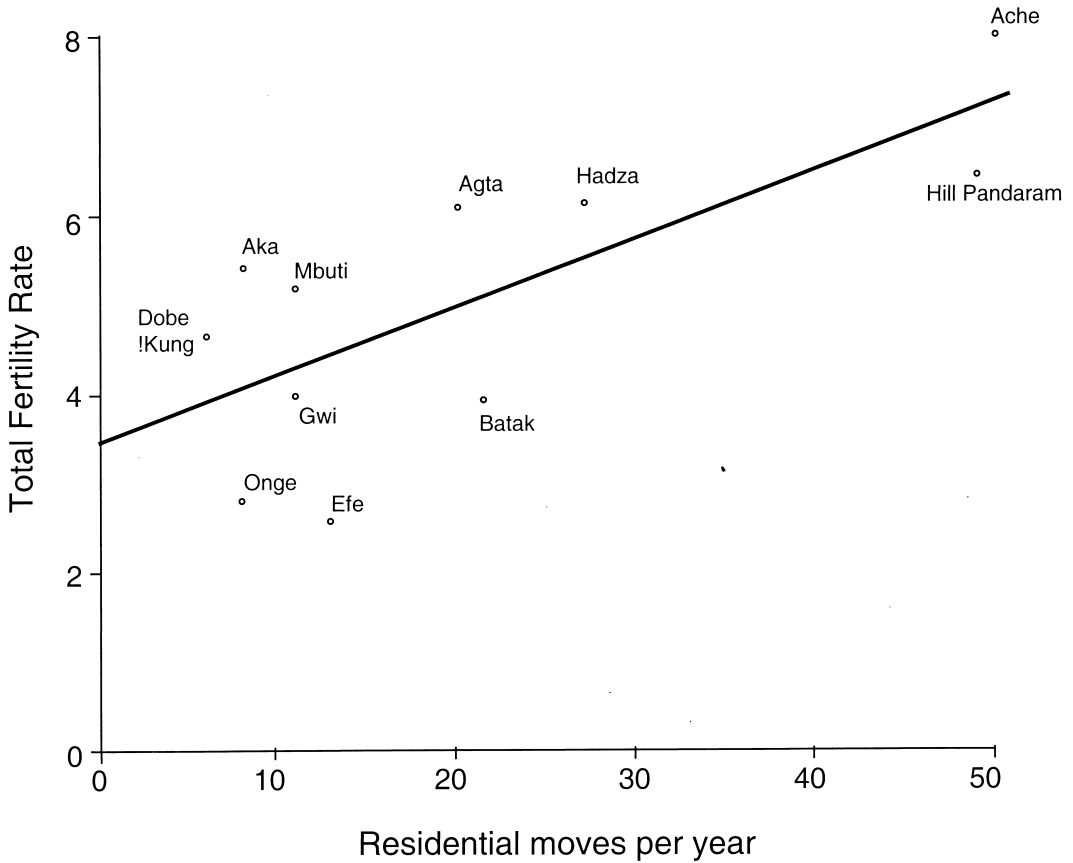


Figure 9. The effects of child foraging (top) and babysitting (bottom) on the total cost of child rearing.

ings gained by child foraging and babysitting could be quite significant, particularly in combination, and this further emphasizes the need to study the determinants of these behaviors.

Discussion

The model predicts that for any homogenous environment hunter-gatherers can minimize child-related transport costs by moving residential base camps as frequently as possible and by doing so, concomitantly maximize their reproductive output. However, in reality not all hunter-gatherers adopt such a strategy. Some foragers are highly mobile, others are sedentary, and still others switch seasonally from high to low mobility strategies (Binford 1980; Kelly 1983, 1995). The model, as currently formulated, cannot explain why hunter-gatherers would settle down. This shortcoming can be attributed to the assumption of a homogenous environment. If mobility is instead modeled for a patchy environment, longer duration occupations would in fact become optimal. As resource patches become more distantly spaced, the cost of residential mobility would increase, while the cost of logistical mobility would



**Figure 10.** The number of residential moves per year vs. total fertility rate for a sample of modern tropical and subtropical hunter-gatherers ( $N = 11$ ;  $p = .0099$ ;  $r = .735$ ). (Data from Hewlett 1991a, b; Hill and Hurtado 1996; Howell 1979; Kelly 1995; Morris 1982).

remain constant. Also, as resource patches become increasingly dense, the cost of logistical mobility would decrease, while the cost of residential mobility would remain the same. In either case, the relative cost of moving camp would increase relative to the cost of foraging. The net effect would be to encourage longer stays in any given camp to minimize total transport costs. In this light, sedentism should only be expected in environments characterized by “local abundance in a context of regional scarcity” (Kelly 1995:152).

A second assumption of the model is that diet remains constant across all mobility strategies. In actuality, the foraging radius may not expand at a constant rate because hunter-gatherers may opt to switch to foods with lower returns that are nearer to camp, rather than to keep exploiting ever more distant highly ranked foods. Switching to lower ranked resources, however, implies increased workloads and

decreased net return rates. Thus, the effect would still be a decrease in population growth rates, but this may not always be the case if lower ranked resources are in great abundance and/or have high reproductive rates (Winterhalder and Golan 1993). To address these problems more thoroughly, a test of the model against the modern ethnographic record of hunter-gatherers is planned, but a preliminary test is provided here.

The model suggests that if diet is held constant within a homogenous environment, hunter-gatherers who move frequently should be characterized by higher potential fertility than those who move infrequently. This hypothesis is supported by mobility and fertility data from a small sample ( $N = 11$ ) of tropical and subtropical hunter-gatherers (Figure 10). A highly significant relationship ( $p = .0099$ ;  $r = .735$ ) exists between the number of residential moves per year and the total fertility rate (TFR, the sum of all

age-specific fertility rates). This relationship is driven by two outlying points, the Ache and the Hill Pandaram. A positive correlation is still obtained even without these points, but the relationship is no longer statistically significant ( $p = .27$ ;  $r = .412$ ). Nonetheless, it is clear from Figure 10 that groups that move very frequently *can* have high fertility rates. Note that the three groups that move most frequently (Ache, Hill Pandaram, and Hadza) are also characterized by the highest levels of fertility. Prior to being forced onto reservations, the Ache of Paraguay stayed in a camp for one two to weeks at the longest, and recent observations of Ache foraging suggests that the camp is moved almost daily (Clastres 1972; Hawkes et al. 1982; Hill and Hurtado 1996). Prior to contact, average Ache TFR was quite high at 8.09 children per female (Hill and Hurtado 1996). Similarly, the Hill Pandaram move their camps on average every 7 or 8 days and average between 6 and 7 children per female (Morris 1982). Clearly, it is time to abandon blanket statements that fertility will always be low for mobile hunter-gatherers. If high mobility is defined as frequent movement of residential camps, then the data suggest that the high mobility and high fertility are quite compatible.

### Early Paleoindian Mobility and Fertility

Estimates for population growth rates during the colonization of the New World vary greatly, ranging from a .1 (Hassan 1981:202) to a 3.5 percent (Mosimann and Martin 1975) annual population increase. At a 3.5 percent growth rate, a population can expand from 100 individuals to over 1 million in just 269 years, while at .1 percent, it takes over 9,200 years to undergo an equivalent expansion. Martin (1973) and Mosimann and Martin (1975) argued that a population explosion would ensue when colonists met an untouched landscape teeming with fauna naive to human predation. Using a growth rate of 3.4 percent per year, Martin (1973) estimated that North America could have been colonized within 350 years and South America within 1,000 years. Other researchers have been more conservative, suggesting that population growth would have been limited (Hassan 1981:201-203; Whitley and Dorn 1993:628-633). Hassan (1981:202) proposed a population growth rate of .1 percent per year and suggested that the process of colonization lasted approximately 8455–9952 years. Haynes (1966:111–112) estimated intermediate rates of 120–140 percent per 28-year generation, roughly equivalent to a .65–1.2 percent

increase per year, and that the colonization of North America would have occurred within about 500 years. Most recently, Steele et al. (1998) utilized population growth rates ranging from .3–3 percent per year to model the colonization of North America. They found that an annual rate of increase of 3 percent produced regional population densities that most closely matched known fluted point distributions. They argued that this rate should be expected for a colonizing population existing far below carrying capacity as they begin their climb up the logistic population growth curve. Although much of the variance in the proposed demographics of colonizers can be attributed to whether researchers advocate a pre-Clovis or Clovis-first occupation of the New World, it is nonetheless surprising that estimates of annual population increase have varied 35-fold.

Although the model presented in this paper provides a means of estimating the potential for early Paleoindian population growth, it cannot directly translate work in  $\text{kg}\cdot\text{km}$  into a value of percent annual population increase. However, it can suggest whether we should expect Clovis children to have been inexpensive or costly and whether a Clovis population “explosion” would have been possible. To do so requires a consideration of Clovis mobility and settlement patterns.

Clovis hunter-gatherers are generally considered to have been very mobile, based for example, on the recurrent presence of high frequencies of exotic lithic raw materials transported very long distances (Goodyear 1989; Haynes 1980:118; Hester and Grady 1977; Tankersley 1991). Also, with few exceptions, occupations tend to be rather ephemeral (Haynes 1980:118; Kelly and Todd 1988:236–237). Lithic assemblages are usually small, and there is little investment in site facilities such as structures, storage pits, and other non-portable technologies. All of these lines of evidence suggest that early Paleoindians were not only moving long distances, but that they were moving base camps frequently, thus adopting a strategy more akin to the *high res* forager as discussed above (Kelly and Todd 1988; Webb and Rindos 1993). Frequent movement of base camps must have permitted short foraging distances around base camps. Under these conditions, Paleoindian children would have been relatively inexpensive to raise, and fertility could have been quite high. The model suggests that rapid colonization of the Americas was very possible as frequent movement of base camps would have allowed early hunter-gatherers to

move long distances across the landscape while actually minimizing daily walking distances.

These findings highlight a discrepancy between what is generally considered to be "high mobility" as evidenced by the archaeological record, and what in fact the term high mobility actually implies, walking long distances. All hunter-gatherers tend to walk long distances over the course of a year because they move daily or almost daily to feed themselves. However, regular occurrences of exotic lithic raw materials in archaeological sites hundreds of kilometers from their source may indeed suggest frequent residential mobility, but frequent residential mobility does not imply high total mobility. In fact, it implies just the opposite. It is therefore somewhat ironic that we generally consider the hunter-gatherers of the Paleoindian period to have been the most mobile of all of the pedestrian foragers in North American prehistory. It is very likely that with the advent of the Archaic, people were walking a lot more, but were doing it within smaller land areas. Paleoindian women must have carried children hundreds of kilometers every year, but their workloads may have been far less than those of the later inhabitants of North America. In this framework, we might expect population growth rates to have been maximized during the colonization phase, with rates gradually slowing through time as the Americas filled with people, and residential mobility options became increasingly limited.

It is commonly suggested that early Paleoindian foraging was based largely on the acquisition of large game due to the regular association of Clovis cultural materials with proboscidean or bison skeletal remains, although the notion of Clovis as large game *specialists* has come into question (Meltzer 1993b). The bones of large animals nonetheless dominate the faunal assemblage at virtually every Clovis site where conditions are favorable for the preservation of bone (Frison and Todd 1986; Haury 1953; Haury et al. 1959; Hemmings and Haynes 1969; Hemmings 1970; Hester 1972; Leonhardy 1966; Sellards 1952). An emphasis on large game hunting would have limited female contribution to the diet and therefore also limited the frequency and distance of female logistical mobility, the most costly of all forms of mobility in raising children. The effect would be to further reduce the cost of raising children for early Paleoindians.

Although it is impossible to estimate how much food Clovis children were providing for themselves, it is possible to speculate how children's foraging opportunities vary across the *high res-low res* mobil-

ity spectrum. Comparative studies of the Hadza and !Kung have identified some factors that condition child foraging. First, young children (under the age of 6 or 7) are limited in their ability to forage long distances from camp (Blurton Jones et al. 1994a, 1994b; Hawkes et al. 1995). Because nearby resources become quickly depleted around base camps, we should expect an inverse relation between the duration of camp occupation and opportunities for young children to forage, i.e., frequent residential moves should maximize foraging opportunities. Second, older !Kung children do not forage with their mothers, while Hadza children do. Hawkes et al. (1995) and Blurton Jones et al. (1994b) argue that !Kung families maximize their return rates by leaving children at home to crack mongongo nuts due to their high processing costs. Foods gathered by the Hadza, on the other hand, tend to have low processing costs, and thus team return rates are maximized if children actively engage in foraging with their mothers. Moving base camps frequently would allow hunter-gatherers to emphasize the gathering of foods with low processing costs as the supply of high ranked foods is renewed often with each move. Therefore, Clovis children may have been able to provide some of their own food at a relatively young age by foraging with their mothers or alone near camp, raising the potential for population growth even higher.

Finally, many authors have discussed the need to maintain social relationships with other bands, particularly for the exchange of mates, as a factor limiting the advance of colonists into an empty landscape (Beaton 1991; Hofman 1994; Meltzer 1999; MacDonald 1999; MacDonald and Hewlett 1999). Similarly, some have argued that high rates of inbreeding may result from conditions of high mobility and low population density during initial colonization (Beaton 1991; Hofman 1994). While low population densities necessarily translate to greater distances traveled in seeking mates (MacDonald 1999; MacDonald and Hewlett 1999), the model presented here suggests that the *high res* mobility strategy allows long-distance migration with minimal cost. In this light, there is little reason to suspect that frequent residential mobility would necessarily correlate with increased rates of inbreeding.

### Conclusions

A strategy incorporating frequent movement of residential base camps allows hunter-gatherers to access large land areas while minimizing total distances trav-

eled (Figure 7). The simple geometry of foraging provides a mechanism for the rapid colonization of empty landscapes. By adopting such a strategy, Clovis hunter-gatherers could have moved long distances across the American continent, had access to high-quality lithic raw materials, adopted a hunting emphasis that minimized female logistical mobility, and maintained access to neighboring groups for exchange of mates. This strategy may also have provided foraging opportunities for their children. High population growth rates would have been the result. While it is difficult to actually test the proposition that Clovis hunter-gatherers were characterized by very high fertility, the archaeological record suggests that these people were behaving as the model predicts they should have to maximize their reproductive rates within a homogenous environment. If we accept the Clovis archaeological record as representing the initial colonizing population, Clovis population growth rates had to be high. The model presented here also suggests that the narrow range of radiocarbon dates from early fluted point sites across the continent no longer needs to be viewed as anomalous.

From an evolutionary standpoint, maximizing reproductive rates is the key to long-term population success, even if this is not a conscious goal. In fact, hunter-gatherers can maximize potential reproductive rates inadvertently by adopting land-use strategies that minimize workloads. I argue this is exactly what early Pale Indians did when they entered the unpopulated landscapes of the New World. Finally, it is no longer necessary to argue that apparent speed of colonization, as revealed by the spatio-temporal distribution of archaeological sites, implies the presence of a low-density population significantly pre-dating Clovis. This notion is based on the idea that mobile hunter-gatherers must have inherently low fertility rates. Clearly, this is not always the case.

*Acknowledgments.* I sincerely thank Jeff Brantingham, Rusty Greaves, Henry Harpending, C. Vance Haynes, Bob Kelly, Kris Kerry, Marcel Kornfeld, Bill Longacre, Steve Kuhn, Carole Mandryk, Paul Martin, Dave Meltzer, Natalie Munro, Bill Stini, Mary Stiner, Nicole Waguespack, and three anonymous reviewers for critiques of this work. I am especially grateful to Mary, Steve, and Vance for their time, their teachings, and their guidance. I thank Rafael Vega-Centeno for his translation of my abstract. Finally, it should be noted that this research was largely inspired by the innovative work of Richard Lee, Nicholas Blurton Jones, Kristen Hawkes, James O'Connell, and Patricia Draper.

### References Cited

Adovasio, J. M., and D. R. Pedler

- 1997 Monte Verde and the Antiquity of Humankind in the Americas. *Antiquity* 71:573–580.
- Balicki, A.
- 1967 Female Infanticide on the Arctic Coast. *Man* 2:615–625.
- Batt, C. M., and A. M. Pollard
- 1996 Radiocarbon Calibration and the Peopling of North America. In *Archaeological Chemistry*, edited by A. M. Pollard, pp. 415–433. Royal Society of Chemistry, Cambridge.
- Beaton, J. M.
- 1991 Colonizing Continents: Some Problems from Australia and the Americas. In *The First Americans: Search and Research*, edited by T. D. Dillehay and D. J. Meltzer, pp. 209–230. CRC Press, Boca Raton.
- Bentley, G.
- 1985 Hunter-Gatherer Energetics and Fertility: A reassessment of the !Kung San. *Human Ecology* 13:79–109.
- Binford, L. R.
- 1980 Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45:4–20.
- 1982 The Archaeology of Place. *Journal of Anthropological Archaeology* 1:5–31.
- Binford, L. R., and J. W. J. Chasko
- 1976 Nunamiut Demographic History: A Provocative Case. In *Demographic Anthropology: Quantitative Approaches*, edited by E. B. W. Zubrow, pp. 63–143. University of New Mexico Press, Albuquerque.
- Blurton Jones, N.
- 1986 Bushman Birth Spacing: A Test for Optimal Birth Intervals. *Ethology and Sociobiology* 8:183–203.
- 1987 Bushman Birth Spacing: Direct Tests of Some Simple Predictions. *Ethology and Sociobiology* 8:183–203.
- 1989 The Costs of Children and the Adaptive Scheduling of Births: Towards A Sociobiological Perspective on Demography. In *The Sociobiology of Sexual and Reproductive Strategies*, edited by A. E. Rasa, C. Vogel, and E. Voland, pp. 265–283. Chapman and Hall, London.
- 1994 A Reply to Dr. Harpending. *American Journal of Physical Anthropology* 93:391–397.
- Blurton Jones, N., K. Hawkes, and P. Draper
- 1994a Differences between Hadza and !Kung Children's Work: Original Affluence or Practical Reason? In *Key Issues in Hunter-Gatherer Research*, edited by E. S. Burch Jr. and L. J. Ellana, pp. 189–215. Berg, Oxford.
- 1994b Foraging Returns of !Kung adults and Children: Why didn't !Kung Children Forage? *Journal of Anthropological Research* 50:217–248.
- Blurton Jones, N. G., K. Hawkes, and J. F. O'Connell
- 1989 Modelling and Measuring Costs of Children in Two Foraging Societies. In *Comparative Socioecology of Mammals and Man*, edited by V. Standen and R. Foley, pp. 367–390. Blackwell, Oxford.
- Blurton Jones, N. G., and R. M. Sibly
- 1978 Testing Adaptiveness of Culturally Determined Behavior. In *Human Behaviour and Adaptation*, edited by N. Blurton Jones and V. Reynolds, pp. 325–248. Symposia of the Society for the Study of Human Biology, Vol. 18. Harvard University Press, Cambridge.
- Blurton Jones, N. G., L. C. Smith, J. F. O'Connell, K. Hawkes, and C. Kamazura
- 1992 Demography of the Hadza, An Increasing and High-Density Population of Savanna Foragers. *American Journal of Physical Anthropology* 89:159–181.
- Campbell, K. L., and J. W. Wood
- 1988 Fertility in Traditional Societies. In *Natural Human Fertility: Social and Biological Determinants*, edited by P. Digory, M. Potts, and S. Teper, pp. 33–69. Macmillan, London.

- Carr-Saunders, A.  
1922 *The Population Problem: A Study in Human Evolution*. Clarendon, Oxford.
- Cech, D., and S. T. Martin  
1995 *Functional Movement Development across the Life Span*. W. B. Saunders, Philadelphia.
- Clastrès, P.  
1972 The Guayaki. In *Hunters and Gatherers Today*, edited by M. G. Bicchieri, pp. 138–174. Waveland Press, Prospect Heights, Illinois.
- Draper, P.  
1976 Social and Economic Constraints on Child Life among the !Kung. In *Kalahari Hunter-Gatherers*, edited by R. B. Lee and I. DeVore, pp. 199–217. Harvard University Press, Cambridge.
- Ellison, P. T.  
1990 Human Ovarian Function and Reproductive Ecology: New Hypotheses. *American Anthropologist* 92:933–952.
- Fiedel, S. J.  
1999 Older than We Thought: Implications of Corrected Dates for Paleoindians. *American Antiquity* 64:95–115.
- Frison, G. C., and L. C. Todd  
1986 *The Colby Mammoth Site*. University of New Mexico Press, Albuquerque.
- Goodyear, A. C.  
1989 A Hypothesis for the Use of Cryptocrystalline Raw Materials among Paleoindian Groups of North America. In *Eastern Paleoindian Lithic Resource Use*, edited by C. Ellis and J. L. Lothrop, pp. 1–10. Westview Press, Boulder.
- Handwerker, W. P.  
1983 The First Demographic Transition: An Analysis of Subsistence Choices and Reproductive Consequences. *American Anthropologist* 85:5–27.
- Harpending, H.  
1994 Infertility and Forager Demography. *American Journal of Physical Anthropology* 93:385–390.
- Hassan, F. A.  
1981 *Demographic Archaeology*. Academic Press, New York.
- Haury, E. W.  
1953 Artifacts with Mammoth Remains, Naco, Arizona. *American Antiquity* 19:1–14.
- Haury, E. W., E. B. Sayles, and W. W. Wasley  
1959 The Lehner Mammoth Site, Southeastern Arizona. *American Antiquity* 25:2–42.
- Hawkes, K., K. Hill, and J. F. O'Connell  
1982 Why Hunters Gather: Optimal Foraging and the Ache of Eastern Paraguay. *American Ethnologist* 9:379–398.
- Hawkes, K., J. F. O'Connell, and N. G. Blurton Jones  
1995 Hadza Children's Foraging: Juvenile Dependency, Social Arrangements, and Mobility among Hunter-Gatherers. *Current Anthropology* 36:688–700.
- Hayden, B.  
1972 Population Control among Hunter/Gatherers. *World Archaeology* 4:205–221.
- Haynes, C. V. Jr., D. J. Donahue, A. J. T. Jull, and T. H. Zebel  
1984 Application of Accelerator Dating to Fluted Point Paleoindian Sites. *Archaeology of Eastern North America* 12:184–191.
- Haynes, C. V. Jr.  
1966 Elephant-Hunting in North America. *Scientific American* 214:104–112.  
1971 Time, Environment, and Early Man. *Arctic Anthropology* 8:3–14  
1980 The Clovis culture. *Canadian Journal of Anthropology* 1(1):115–121.  
1992 Contributions of Radiocarbon Dating to the Geochronology of the Peopling of the New World. In *Radiocarbon after Four Decades*, edited by R. E. Taylor, A. Long, and S. Kra, pp. 355–374. Springer-Verlag, New York.
- 1993 Clovis-Folsom Geochronology and Climatic Change. In *From Kostenki to Clovis: Upper Paleolithic - Paleo-Indian Adaptations*, edited by O. Soffer and N. D. Praslov, pp. 219–236. Plenum Press, New York.
- Hemmings, E. T., and C. V. Haynes Jr.  
1969 The Escapule Mammoth and Associated Projectile Points, San Pedro Valley, Arizona. *Journal of the Arizona Academy of Science* 5:184–188.
- Hemmings, E. T.  
1970 *Early Man in the San Pedro Valley, Arizona*. Unpublished Ph.D. dissertation, University of Arizona, Tucson.
- Hester, J. J.  
1972 *Blackwater Locality No. 1: A Stratified Early Man Site in Eastern New Mexico*. Publication No. 8. Fort Burgwin Research Center, Rancho de Taos, New Mexico.
- Hester, J. J., and J. Grady  
1977 Paleoindian Social Patterns on the Llano Estacado. In *Paleo-Indian Lifeways*, edited by E. Johnson, pp. 78–96. The Museum Journal, Vol. 17. West Texas Museum Association, Lubbock, Texas.
- Hewlett, B. S.  
1991a Demography and Childcare in Preindustrial Societies. *Journal of Anthropological Research* 47:1–37.  
1991b *Intimate Fathers: The Nature and Context of Aka Pygmy Paternal Infant Care*. University of Michigan Press, Ann Arbor.
- Hill, K., and A. M. Hurtado  
1996 *Ache Life History: The Ecology and Demography of a Foraging People*. Aldine de Gruyter, New York.
- Hofman, J. L.  
1994 Paleoindian Aggregations on the Great Plains. *Journal of Anthropological Archaeology* 13:341–370.
- Howell, N.  
1976 The Population of the Dobe Area !Kung. In *Kalahari Hunter-Gatherers*, edited by R. B. Lee and I. DeVore, pp. 137–151. Harvard University Press, Cambridge.
- 1979 *Demography of the Dobe !Kung*. Academic Press, New York.
- Hurtado, A. M., and K. R. Hill  
1987 Early Dry Season Subsistence Ecology of Cuiva (Hiwi) Foragers of Venezuela. *Human Ecology* 15:163–187.  
1990 Seasonality in a Foraging Society: Variation in Diet, Work Effort, Fertility, and Sexual Division of Labor among the Hiwi of Venezuela. *Journal of Anthropological Research* 15:163–187.
- Irwin, C.  
1989 The Sociocultural Biology of Netsilingmiut Female Infanticide. In *The Sociobiology of Sexual and Reproductive Strategies*, edited by A. Rasa, C. Vogel, and E. Voland, pp. 234–264. Chapman and Hall, London.
- Keeley, L. H.  
1995 Protoagricultural Practices among Hunter-Gatherers: A Cross-Cultural Survey. In *Last Hunters First Farmers*, edited by T. D. Price and A. B. Gebauer, pp. 243–272. School of American Research Press, Santa Fe.
- Kelly, R. L.  
1983 Hunter-Gatherer Mobility Strategies. *Journal of Anthropological Research* 39:277–306.  
1995 *The Foraging Spectrum*. Smithsonian Institution Press, Washington, D.C.
- Kelly, R. L., and L. C. Todd  
1988 Coming into the Country: Early Paleoindian Hunting and Mobility. *American Antiquity* 53:231–244.
- Kitagawa, H., and J. van der Plicht  
1998 Atmospheric Radiocarbon Calibration to 45,000 Yr B.P.:

- Late Glacial Fluctuations and Cosmogenic Isotope Production. *Science* 279:1187–1190.
- Konner, M., and C. Worthman  
1980 Nursing Frequency, Gonadal Function, and Birth Spacing among !Kung Hunter-Gatherers. *Science* 207:788–791.
- Lee, R. B.  
1972 Population Growth and the Beginnings of Sedentary Life among the !Kung Bushmen. In *Population Growth: Anthropological Implications*, edited by B. Spooner, pp. 319–342. The MIT Press, Cambridge.
- 1979 *The !Kung San: Men, Women, and Work in a Foraging Society*. Cambridge University Press, Cambridge.
- Leonhardy, F. C.  
1966 *Domebo: A Paleo-Indian Mammoth Kill in the Prairie-Plains*. Contributions of the Museum of the Great Plains, Lawton, Oklahoma.
- MacDonald, D. H.  
1999 Modeling Folsom Mobility, Mating Strategies, and Technological Organization in the Northern Plains. *Plains Anthropologist* 44:141–161.
- MacDonald, D. H., and B. S. Hewlett  
1999 Reproductive Interests and Forager Mobility. *Current Anthropology* 40:501–523.
- Martin, P. S.  
1973 The Discovery of America. *Science* 179:969–974.
- Meltzer, D. J.  
1993a Pleistocene Peopling of the Americas. *Evolutionary Anthropology* 1:157–169.
- 1993b Is There a Clovis Adaptation? In *From Kostenki to Clovis: Upper Paleolithic: Paleo-Indian Adaptations*, edited by O. Soffer and N. D. Praslov, pp. 293–310. Plenum Press, New York.
- 1995 Clocking the First Americans. *Annual Review of Anthropology* 24:21–45.
- 1997 Monte Verde and the Pleistocene Peopling of the Americas. *Science* 276:754–755.
- 1999 Comment on “Reproductive Interests and Forager Mobility” by D. H. MacDonald and B. S. Hewlett. *Current Anthropology* 40:519–520.
- Meltzer, D. J., D. K. Grayson, G. Ardila, A. W. Barker, D. F. Dincauze, C. V. Haynes Jr., F. Mena, L. Nuñez, and D. J. Stanford  
1997 On the Pleistocene Antiquity of Monte Verde, Southern Chile. *American Antiquity* 62:659–663.
- Morris, B.  
1982 *Forest Traders: A Socio-Economic Study of the Hill Pandaram*. London School of Economics Monographs on Social Anthropology No. 55. The Athlone Press, Totowa, New Jersey.
- Mosimann, J. F., and P. S. Martin  
1975 Simulating Overkill by Paleoindians. *American Scientist* 63:304–313.
- O’Connell, J. F., and K. Hawkes  
1981 Alyawara Plant Use and Optimal Foraging Theory. In *Hunter-Gatherer Foraging Strategies*, edited by B. Winterhalder and E. A. Smith, pp. 99–125. University of Chicago Press, Chicago.
- Pennington, J. A. T.  
1989 *Bowes and Church’s Food Values of Portions Commonly Used*. Harper and Row, New York.
- Pennington, R., and H. Harpending  
1988 Fitness and Fertility among Kalahari !Kung. *American Journal of Physical Anthropology* 77:303–319.
- Sellards, E. H.  
1952 *Early Man in America: A Study in Prehistory*. University of Texas Press, Austin
- Smith, E. A., and S. A. Smith  
1994 Inuit Sex-Ratio Variation: Population Control, Ethnographic Error or Parental Manipulation? *Current Anthropology* 35:595–624.
- Spielmann, K. A.  
1989 A Review: Dietary Restrictions on Hunter-Gatherer Women and the Implications for Fertility and Infant Mortality. *Human Ecology* 17:321–345.
- Stanford, D.  
1978 Some Clovis Points. Paper presented at the 5th Biennial Meeting of the American Quaternary Association, Edmonton, Alberta
- Steele, J., J. Adams, and T. Sluckin  
1998 Modelling Paleoindian Dispersals. *World Archaeology* 30:286–305.
- Storck, P.  
1991 Imperialists without a State: The Cultural Dynamics of Early Paleoindian Colonization as Seen from the Great Lakes Region. In *Clovis: Origins and Adaptations*, edited by R. Bonnichsen and K. L. Turnmire, pp. 153–162. Center for the Study of the First Americans, Corvallis, Oregon.
- Sutherland, D. H., R. A. Olshen, E. N. Biden, and M. P. Wyatt  
1988 The Development of Mature Walking. *Clinics in Developmental Medicine* 104/105
- Tankersley, K. B.  
1991 A Geoarchaeological Investigation of Distribution and Exchange in the Raw Material Economies of Clovis Groups in Eastern North America. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 285–303. University Press of Kansas, Lawrence.
- Taylor, R. E., C. V. Haynes Jr., and M. Stuiver  
1996 Clovis and Folsom Age Estimates: Stratigraphic Context and Radiocarbon Calibration. *Antiquity* 70:515–525.
- Webb, Esmée and David Rindos.  
1993 The Mode and Tempo of the Colonization of Empty Landmasses: Sahul and the Americas Compared. In *Rediscovering Darwin: Evolutionary Theory and Archaeological Explanation*, edited by C. M. Barton and G. A. Clark, pp. 233–250. Archeological Paper No. 7. American Anthropological Association, Arlington, Virginia.
- Whitley, D. S., and R. I. Dorn  
1993 New Perspectives on the Clovis vs. pre-Clovis Controversy. *American Antiquity* 58:626–647.
- Wilmsen, E.  
1978 Seasonal Effects of Dietary Intake on Kalahari San. *Federation Proceedings* 37:65–72.
- Winterhalder, B., and C. Goland  
1993 On Population, Foraging Efficiency, and Plant Domestication. *Current Anthropology* 34:710–715.
- Wood, J. W.  
1990 Fertility in Anthropological Populations. *Annual Review of Anthropology* 19:211–242.
- World Health Organization  
1985 *Energy and Protein Requirements*. World Health Organization, Geneva.
- Young, D., and R. Bonnichsen  
1984 *Understanding Stone Tools: A Cognitive Approach*. Center for the Study of Early Man, University of Maine, Orono.

---

Received April 27, 1999; accepted September 16, 1999;