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Changing Patterns of Infant Mortality and Maternal Fertility among Pumé Foragers and Horticulturalists

ABSTRACT National census data show that the modern demographic transition—the recent trend toward declining mortality and fertility—is well underway in most countries. A different picture emerges when data from small-scale societies in unindustrialized parts of the world are considered. Many of these small-scale societies are also adapting to rapid changes in their subsistence economies. In this article, we examine the relationship between the pace of acculturation, infant mortality, and fertility levels among Pumé foragers and horticulturalists, two related groups of native South Americans. During the earliest stages of acculturation, Pumé horticulturalists experience not only a rapid drop in infant mortality but also a rise in birth rates. An anthropological view of demographic transitions provides important insight into how small-scale societies are affected by exposure to the labor market economy and has practical applications to effective development initiatives and public health policies. [Keywords: infant mortality, fertility, foragers, South American Indians, Pumé]

MANY FORAGERS AND SUBSISTENCE agriculturalists are currently adapting to initial contact with the labor market economy. These populations concurrently often undergo rapid demographic change. Although important contributions have been made concerning the relationship between economic development and demographic patterns (Chu and Lee 2000; Drèze and Mamta 2001; Lloyd et al. 2000; Nag et al. 1978; Palloni et al. 1996), much of this discussion centers on populations that are already embedded in the labor-market economy, have access to contraception, or have undergone some decline in child mortality and fertility. Considerably less is known about demographic changes among foragers and subsistence agriculturalists who are experiencing permanent settlement and the introduction of food production, market foods, craft production, wage labor, vaccination, and health care for the first time.¹

Large-scale demographic changes are often explained within the context of the modern demographic transition: the trend over the last several centuries toward declining mortality and fertility. From national data, it appears that the demographic transition is well underway in most developing countries. However, a different picture emerges when data from small-scale societies in unindustrialized parts of the world are considered. In this article we introduce de-

mographic data from two ethnically related but economically contrasting groups of native South Americans. The Pumé (Yaruro) are a foraging and horticultural people indigenous to the savannas (*llanos*) of southwestern Venezuela (Besnerais 1948, 1954; Gragson 1989; Greaves 1997, 2006; Leeds 1961; Mitrani 1988; Petruccio 1939). We use individual reproductive histories to examine changes in infant mortality and fertility among recently acculturated Pumé horticulturalists compared to Pumé foragers (see Figure 1).² Our analytic goal is to distinguish between the effects that birth rate and child survivorship have on the potential for population growth. The Pumé data provide an empirical view into demographic changes in a small-scale society adapting to the first stages of acculturation. Such changes are often undetectable from national indices, yet they elucidate the effects that development initiatives and the earliest stages of economic acculturation have on pretransitional societies.

DEMOGRAPHIC EXPECTATIONS IN ECONOMICALLY TRANSITIONAL POPULATIONS

The demographic transition describes population growth responses to different fertility and mortality regimes. In the classic modern demographic transition model, during the pretransition stage fertility and mortality are both high,

AMERICAN ANTHROPOLOGIST, Vol. 109, Issue 4, pp. 713–726, ISSN 0002-7294 online ISSN 1548-1433. © 2007 by the American Anthropological Association. All rights reserved. Please direct all requests for permission to photocopy or reproduce article content through the University of California Press's Rights and Permissions website, <http://www.ucpressjournals.com/reprintInfo.asp>. DOI: 10.1525/AA.2007.109.4.713.



FIGURE 1. Savanna Pumé mother and child. (Photo courtesy of Oskar Berger)

keeping gains in population growth in check. During the second stage, mortality drops, primarily child mortality, but fertility remains high, precipitating rapid population growth. In the third stage, fertility also declines and population growth rates fall to pretransition levels. In contrast to pretransition levels, low growth following the transition is regulated by low fertility and low mortality. Although the effects of declining child mortality on the rapid population growth occurring in many transitional populations is well documented (Coale 1974; Livi-Bacci 2001; Pennington 1996), the causes of fertility decline and its relationship with child mortality is less straightforward.

Economists and demographers often model the relationship between economic development and the transition from high to low fertility in terms of the demand for children (Becker 1960; Becker and Lewis 1973; Bongaarts 2002; Easterlin 1978; Lee and Bulatao 1983; Szreter 1993). The demand for children is sensitive to, among other factors, changes in wealth flows across generations (Caldwell 1976, 1977); how wealth and status are intergenerationally brokered (Boone and Kessler 1999; Borgerhoff Mulder 1998; Rogers 1995); changes in parental investments in children's education, skill acquisition, health, nutrition, material goods, and other forms of child quality (Bulatao and Lee 1983; Kaplan 1996; Rosenzweig 1990); the economic contributions of children (Blurton

Jones et al. 1989; Kramer 2005; Mueller 1976; Vlassoff 1979); and the value of maternal education and wages rates (Drèze and Mamta 2001; Lloyd et al. 2000; Low et al. 2002). These diverse and often interrelated explanations for fertility reduction are linked through the concept of the opportunity cost of childbearing or the foregone benefit to a mother to spend her time and resources in other ways. A decline in fertility is predicted when the opportunity cost of childbearing increases because, for example, the payoff to invest in children's education or for mothers to engage in wage labor increases.

Much of what is known and debated about the demand for children and fertility decisions has been formulated with respect to populations that have some access to health care and contraception, are committed food producers, and are involved in the market economy through wage labor, cash cropping, and food purchase. At the national and regional level, fertility has fallen in developing nations, in many cases dramatically, from pretransitional levels of five to seven children. However, in small-scale societies, the earliest stages of acculturation may present a very different situation, one in which many hunter-gatherers and horticulturalists find themselves. Here we take a different tack and ask what happens during the first phases of acculturation when constraints on fertility are relaxed because the opportunity costs of childbearing either do not change or decline. Under these conditions we expect that child mortality will drop, but birth rates will remain at pretransition levels or even increase, having a punctuated effect on population growth.

The Pumé are an ideal population to use to test these expectations because foraging and horticultural communities differ with respect to subsistence, food reliability, consumption of market foods, and sedentism. As a single ethnic group inhabiting the same general environment, they provide critical analytic control through similar genetic background and disease exposure. Neither group has ready access to clinics, regular health care, or vaccination programs. This allows us to examine how infant mortality and fertility vary while holding access to modern health care effectively constant.

THE PUMÉ

The Pumé are a group of native South Americans who have inhabited the llanos of southwest Venezuela for at least the past several hundred years, where they were documented by early European explorers (Carvajal 1956; Gilij 1965; Gummilla 1963). Today there are about 7,000 Pumé. Those who live along the Capanaparo, Cinaruco, and Riecito Rivers reside in permanent villages and have a mixed subsistence base of fish, manioc horticulture, animal husbandry, wild foods, and occasional wage labor. In contrast, the Pumé who live in the savannas between these major river courses are mobile foragers, subsisting on hunting, fishing, wild root and mango collection, and, to a much lower extent, manioc horticulture. These differences in economy, mobility, and



FIGURE 2. River (squares) and savanna (circles) Pumé study communities.

lifestyle are recognized by the Pumé, who use the terms *savanna Pumé* and *river Pumé* to distinguish their communities (see Figure 2).

The river Pumé were first ethnographically described in the 1930s (Petrullo 1939) and then again in the 1960s (Leeds 1961, 1964). Subsequently, the majority of ethnographic work has focused on the largest and most acculturated Spanish-speaking river villages in the region. The savanna Pumé have been ethnographically documented through long-term time allocation studies by Ted Gragson in the 1980s (Gragson 1989) and Russell Greaves from the 1990s into the 2000s (Greaves 1997, 2006; Hilton and Greaves 2004). Greaves has worked in savanna Pumé community of Dora Aná since 1990. In 2005, a new demographic and economic project expanded study into several additional foraging and horticultural communities. The study villages are in close geographic proximity, situated within a 400-square-kilometer area and are no more than half a day's walk apart. The following describes the savanna and river Pumé as observed in the study communities during 2005 and 2006.

Savanna Pumé

In response to hyperseasonal fluctuations in rainfall, the savanna Pumé move several times throughout the year between dry and wet season camps. In one community, six main camps were documented during the 2004–05 seasonal round. During the six-month dry season, subsistence is centered on fish, which are concentrated in restricted pools and small segments of streams, and on mangos. Groves of introduced mangos trees, although distant, have been incorporated into the savanna Pumé foraging radius. Dry season camps are located adjacent to streams and lagoons for access to water. Related nuclear families live in clusters of ephemeral brush shades.

When the llanos flood during the wet season, the savanna Pumé move their camps to higher ground and families aggregate in more substantial thatch houses (Gragson 1989; Greaves 1997, 2006; Mitrani 1988). Fish are dispersed and difficult to locate during the wet season, and the resource base shifts to small game, wild roots, and manioc. Garden foods are consumed during part of the wet season, when they supply about 35–40 percent of daily calories. Gardens are small and bitter manioc is the only successfully cultivated food crop. Substantial amounts of wild roots are collected throughout the horticultural season (Gragson 1989; Greaves 1997) to supplement bitter manioc, which is a low-quality carbohydrate. Poor agricultural soils and low resource density and diversity contribute to the generally impoverished savanna Pumé diet. Nutritional stress, which can be extreme in some years, is most pronounced during the wet season when protein and fat are in short supply.

River Pumé

The river Pumé were semimobile until about fifty years ago. They now inhabit single villages year-round, although periodically they occupy temporary fishing camps during the dry season. Fish in the major rivers are larger, occur in greater density, and can be caught over longer periods of the year and in sufficient quantity to produce a surplus for trade. Soils adjacent to the rivers are more fertile than in the savanna interior, and river Pumé gardens are more extensive, producing higher returns and a greater variety of plant foods. Some river communities also raise small numbers of domesticated chickens and pigs. The river Pumé are well nourished compared to the savanna Pumé and experience little seasonal variance in food availability.

Historically, the river Pumé have had more contact with influences from outside the llanos than have the savanna Pumé. The rivers are the major transportation routes into the region during the wet season. Although no permanent roads exist in most of Pumé territory, temporary two-tracks follow the river courses, permitting some vehicular travel during the dry season.

Differences in Economic Acculturation

The migration of Venezuelan nationals into the region to establish small family ranches accelerated in the 1960s. Conflicts periodically erupt between the Pumé and ranchers over land and resource claims. Although the Pumé are concerned about encroachment on their traditional lands, tensions are tempered by the access ranches provide to market goods. Because the ranches are situated along the major rivers, opportunities for trade, wage labor, and access to market food are greater for the river Pumé as compared to the savanna Pumé. This contributes to reduced seasonal variation in food availability and lower food stress among the river Pumé.

Ranch work is occasional and sporadic: 47 percent of savanna men and 73 percent of river men report having spent at least one day over the past year in wage labor

(24 percent of savanna men and 63 percent of river men report having spent more than five days over the past year). No savanna women engage in wage labor. Very few river women occasionally work as domestics on local ranches. Labor is paid for in food and other consumables. The river Pumé generally earn higher wages and may occasionally receive cash as payment, which was not reported by any savanna Pumé during the 2005 economic survey.

A trade network between the savanna and river people likely has been in place since the Pumé have lived in the area. However, the nature of the commodities traded has changed over time. Small family groups travel between the river and savanna, visiting relatives and exchanging goods primarily during the dry season when movement is easy. Nonlocal goods (clothing, pasta, rice, metal tools, cookware, and soap), which are more common in river communities, are traded for raw materials from the savanna. Tools and clothing are well worn by the time they reach the savanna interior, where they are exchanged for arrowcanes, fiber, resin, weaving materials, and finished arrows.

Although savanna and river communities differ in their access to market foods and other goods, none of the five villages included in this study has a school, health clinic, store, electricity, or well water, nor are they able to be reached by a permanent road or scheduled transportation. The majority of both savanna and river Pumé are monolingual, with only four percent savanna and 24 percent river Pumé reporting a rudimentary understanding of Spanish. Very few river Pumé (three percent) and no savanna Pumé report having attended school.

Because of their proximity to major transportation routes, the river Pumé's contact with the regional and national economy is now increasing. In contrast, nominal economic change has occurred in savanna communities since the last long-term study (Greaves 1997). Although most government projects target the larger, more acculturated Pumé towns, the river study communities receive some periodic assistance. Most apparent during 2005–06 was the distribution of food through government-sponsored programs in river villages and the absence of such assistance in savanna communities.

Both the savanna and river Pumé live in a malarial environment. Other significant diseases in the region include measles, yellow fever, Chagas disease, tuberculosis, and other respiratory diseases (Kramer and Greaves 2005; Lizarralde and Seijas 1991). Diarrhea is a primary cause of children morbidity and mortality. Daily variance in food availability, seasonal malnutrition, and chronic intestinal parasite loads no doubt have a synergistic effect on higher morbidity and mortality at all ages among the savanna Pumé compared to the river Pumé. Neither the savanna nor river study communities routinely receive medical intervention and immunizations, nor do they have access to contraception. Health care visits are sporadic and more frequently target river communities. Although these visits are

occasional, they may nonetheless confer a positive effect on survivorship.

THE PUMÉ SAMPLE AND DATA COLLECTION

During the 2005 and 2006 fieldwork, censuses and reproductive histories were collected in three river horticultural and two savanna foraging Pumé villages. All households in each of the study communities participated in the data collection. The sample consists of 426 individuals: 203 males and 223 females. Interviews were conducted by Greaves in the Pumé language. Individuals were asked about their age and marital status, and then to list their siblings, parents, spouses, and children from each marriage and to indicate whether these individuals were living or deceased. The Pumé are forthcoming about previous marriages, children from previous marriages, deceased children, and spouses. Parents were asked to include infants who had died very young in their list of children. Because of the difficulty in obtaining consistent information about miscarriages, the following analyses include only full-term births in fertility measures.

Working with anthropological populations on demographic issues poses certain methodological challenges (Fricke 1994; Hill and Hurtado 1996; Howell 2000; Weiss 1975). The Pumé exemplify some of these problems. They live in small communities, do not keep vital records, differentiate ages by life stages rather than calendar years, and do not reckon social relationships in kin terms that distinguish biological from classificatory parents, siblings, and offspring. The villages included in this demographic survey range from 70 to 150 individuals. To compensate for the random fluctuation in vital rates inherent to small samples, the following analyses pool data from the two savanna villages to compare to the pooled data from the three river villages.

Constructing reliable reproductive histories depends on collecting precise ages and counts of children-ever-born to a mother. Parents can accurately report the ages of young children by moon or season counts up to four years. Because the Pumé do not keep written births or death records or have an absolute means for aging, several methods were used to improve the age estimates of older children and adults (Hill and Hurtado 1996; Howell 2000; Kramer 2005; Pennington and Harpending 1993). Rather than only interviewing the head-of-household, each household member old enough to respond (at least ten years of age and older) was interviewed about their parents, siblings, and children. Asking multiple relatives about kin relations and to list siblings and children in birth-order rankings provided a check for information consistency and whether further questioning was needed. Although only summary counts from national enumerations are available for most Pumé villages, detailed censuses (name, age, sex, and kin relation) were collected several times in the study communities during the mid-to-late 1980s and in the early 1990s (Greaves n.d.; Lizarralde n.d.). These provide a baseline to anchor ages of most individuals over the age of 12.

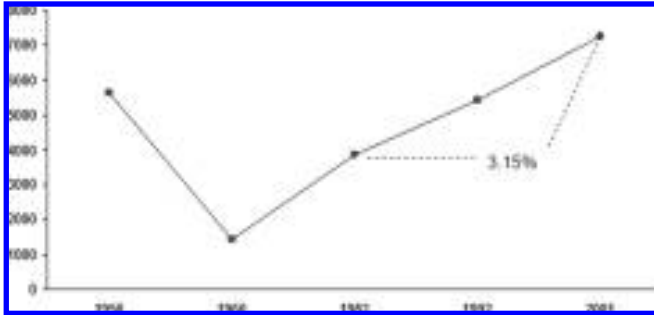


FIGURE 3. Pumé population growth 1950–2000. *Sources:* Based on aggregate data for all Pumé: 1950 census (Fuchs 1978, table 1); 1960 census (Fuchs 1978); 1982 census (Oficina Central de Estadísticas e Informática [OCEI] 1985); 1992 census (Oficina Central de Estadísticas e Informática [OCEI] 1995); and 2001 census (Instituto Nacional de Estadística-Apure 2001).

Multiple questioning and birth rank responses also were a useful check to verify that reproductive histories included a complete count of a mother's children. Pumé mothers assiduously list their children and whether deceased children were infants, young children, or subadults when they died, using developmental markers such as weaning, walking, talking, tooth eruption, and menses. However, documenting a specific age at death (rather than by developmental stage) was more problematic because the Pumé do not consistently recall ages or elapsed time beyond about four years. Deceased infants whose parents could not give age at death in moon counts were identified as children who were breastfeeding but not walking. Observationally, children with known ages begin to walk at one year old. Consequently, in the following analyses, mortality measures are based on frequencies across a mother's reproductive career rather than timing effects such as birth order and interval. To construct reliable age composition, fertility, and child mortality profiles, we build on the strengths of multiple censuses, initial rates recorded between censuses, and reproductive histories collected in 2005 and 2006. Because what is known about forager demography is limited to such few groups, we focus on intuitive empirical measures rather than model indices. All analyses were performed in SAS (ver. 9.1).

RETROSPECTIVE POPULATION TRENDS

Past indigenous censuses are available only as aggregate counts and show a dramatic decline in population from the 1950s to the 1960s (Besnerais 1954; Fuchs 1978), followed by an appreciable and continuing rise in growth beginning in the 1980s (see Figure 3). The magnitude of the drop in population from the 1950s to 1960s is likely because of incomplete census data. Comparable and reliable censuses were collected in 1982 (Lizarralde and Seijas 1991:10; OCEI 1985:38) and 1992 (OCEI 1995:32).³ These data indicate that population growth among the Pumé is occurring at a rate comparable to the fastest growing regions of the world. However, in the absence of village-based vital

rates, it raises the question of what dynamics underlie this growth and whether it is evenly distributed across Pumé communities.

Comparing the age composition of river and savanna communities is a heuristic means to observe general trends in fertility and mortality (see Table 1). As constructed from our 2005 demographic data, the broad base of the age-sex pyramid and the relatively higher representation of young children in river communities compared to savanna villages reflects the higher proportion of the population under the age of 15.⁴ Community type is significantly associated with age distribution ($\chi^2 = 11.1628$, $df = 1$, $p = .0008$), with river communities having a greater proportion of children relative to adults than savanna communities. Median age, another heuristic summary of a population's age structure, is 13 for river Pumé compared to 20 for the savanna Pumé.⁵

The lower median age, the comparatively broad-based pyramid, and higher proportion of the population under the age of 15 indicate that the river Pumé are a younger population. This is often interpreted as characteristic of a high fertility and fast growing population. However, populations also can grow younger through a shift in the age groups most affected by mortality changes (Namboodiri 1996). For example, when a mortality decline disproportionately affects younger ages, the number of young individuals alive in a population increases relative to older people. The age structure hints at either mortality or fertility differences between the savanna and river Pumé. In the next step, we clarify these trends.

Because previous reproductive history data and vital records do not exist, we cannot directly analyze diachronic patterns. Given that changes in mobility, subsistence, access to market foods, and wage labor are very recent among the river Pumé, it is reasonable to interpret these demographic contrasts as associated with the transition from a foraging to an increasingly acculturated way of life.

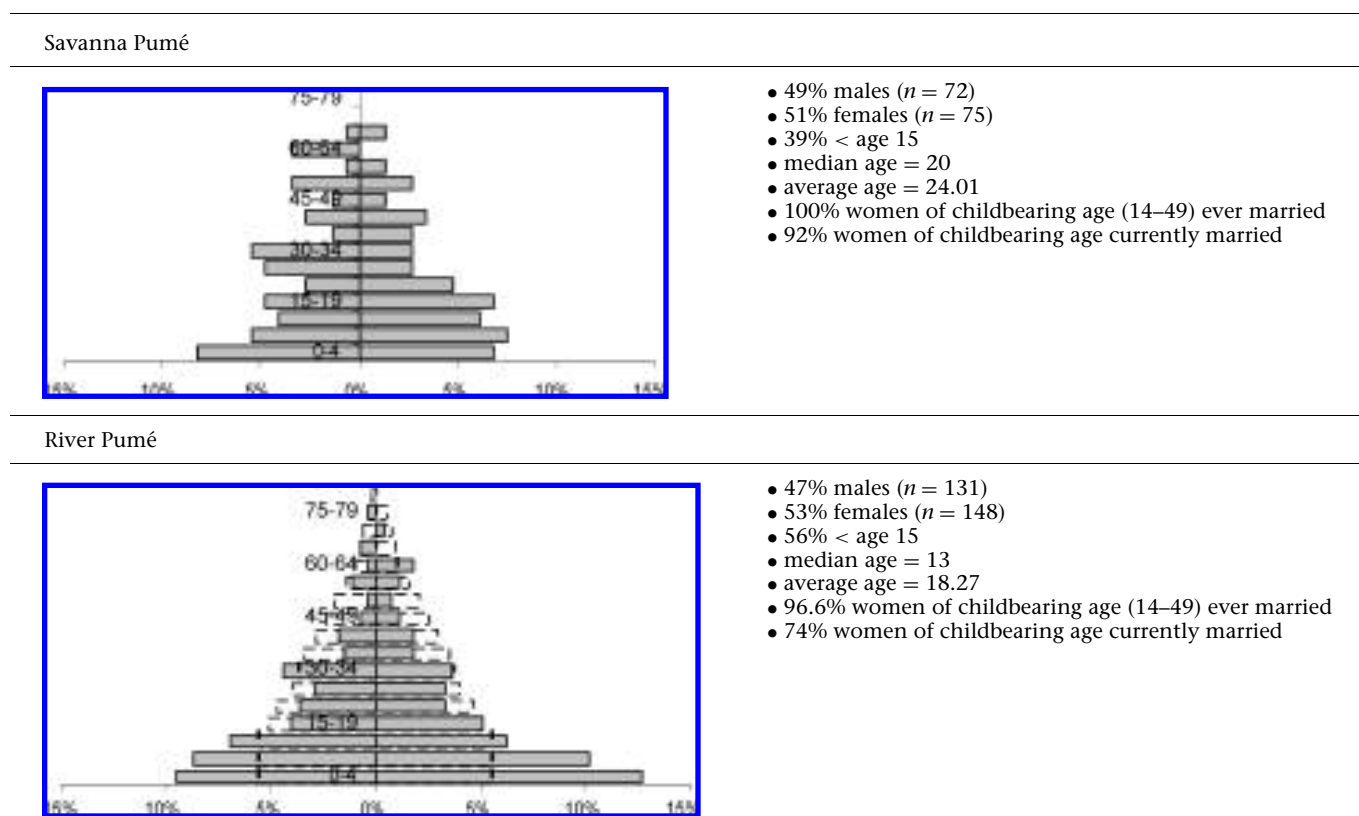
PUMÉ POPULATION DYNAMICS

In the following sections, we use several corroborating lines of evidence to investigate the dynamics underlying savanna and river population age structure. These include cohort and period fertility, parity progressions relative to infant mortality and birth intervals. When using small-scale data, unambiguous interpretation of a single result can be spurious. To avoid reliance on limited criteria, each of these measures approaches fertility and mortality from a slightly different perspective and together builds a comprehensive picture of savanna and river Pumé demographic trends.

Reproductive Environment

Although the savanna and river Pumé differ in subsistence, sedentism, and acculturation, their background reproductive conditions are similar. Pumé girls reach menarche at a young age: river girls at about age 13, and savanna girls at a slightly younger age (Kramer n.d.). Girls in both savanna and river Pumé communities marry young:

TABLE 1. Pumé age composition based on 2005 census data.



Note: Proportion of total population shown for males on right, females on left; Venezuelan age distribution shown on the river Pumé pyramid (World Health Organization 2006).

95 percent of girls marry by age 15. Girls may marry when premenstrual, although in such cases coital relations are not begun until after menarche. These early marriages often are brittle, and either partner may instigate divorce. Of girls ages 13–18, although 97 percent have been married, only 80 percent are currently married. The proportion of married women is higher among savanna Pumé, but the difference within age group is only significant among postreproductive women 45 and older ($p = .0391$). Primary sterility appears to be relatively uncommon. Within our sample of women 40 and older ($n = 34$), only one women has not given birth.

Serial monogamy is the predominate marriage pattern, although a small proportion of marriages are polygamous (see Table 2). Matrilocalty is common, and matrilineal form a strong social foundation among the Pumé. Inter-marriage occurs between savanna and river Pumé communities, but marriage partnerships more often are formed between village members or exogamously across savanna or river communities.⁶ Modern contraception is unavailable to both savanna and river Pumé women. Children are breastfed on demand, given supplemental foods at about six months, and fully weaned by two-and-a-half to three years old.⁷ Both the savanna and river Pumé are natural fertility populations, and given no substantial differences in marriage patterns, marital relations are

not expected to be an important source of variation in determining fertility patterns.

Fertility Patterns

Total fertility rates (TFR), because they are less sensitive to age structure than crude birth rates and general fertility rates, are the most ubiquitous measure to compare patterns across populations. A TFR, which can be thought of as the mean number of children born to a mother by the end of her reproductive career, can be constructed either as cohort or period rates.

The most accurate means to construct a cohort rate is to follow a group of women in the same birth or marriage cohort as they pass through their reproductive careers, documenting births and deaths as they occur. Because 30-year

TABLE 2. Pumé marriage patterns (number of times males and females report having been married and polygamously married either currently or in the past)

	Number of Marriages				Polygamously
	1	2	3	4+	
Savanna Pumé ($n = 94$)	74%	23%	1%	1%	11%
River Pumé ($n = 115$)	80%	17%	1%	2%	4%

TABLE 3. Indicators of fertility and mortality in Pumé communities.

Indicator	Savanna Pumé	River Pumé
Age-specific Fertility ^a		
15–19	1.143	1.214
20–24	1.875	1.889
25–29	1.500	1.778
30–34	1.333	1.273
35–39	1.000	1.000
40–44	0.556	0.600
Total Fertility Rate	7.407	7.754
Mean Number of Births ^b		
to women ≥ 15	4.88 (std = 3.28, <i>n</i> = 48)	4.86 (std 3.21, <i>n</i> = 65)
to mothers	5.32 (std = 3.06, <i>n</i> = 44)	5.11 (std = 3.07 <i>n</i> = 62)
Infant Mortality Rate ^c	346	132

^aPeriod rates are calculated as number of births over the past five years to savanna (*n* = 38) and river Pumé (*n* = 53) mothers.

^bDifferences between river and savanna groups are not significant (*p* = .9904 for mothers and *p* = .8581 for women).

^cDeaths per 1000 live births to savanna (*n* = 34) and river (*n* = 492) Pumé mothers 15–45.

longitudinal studies are impractical, cohort rates are most often collected by interviewing women in the same cohort about their parity to date. A cohort TFR is the completed fertility of women who are past reproductive age; it summarizes fertility conditions over a woman's 30-year reproductive career.

Period rates are constructed cross-sectionally from the numbers of births that have occurred over some period of time, usually within a calendar year, to women in different age groups. A period TFR, which is the sum of these age specific fertility rates (ASFR), estimates a woman's lifetime fertility based on this synthetic cohort. Period measures reflect current conditions and are used to project future population trends, assuming that those conditions will persist throughout a woman's reproductive career.

Period rates are constructed from censuses and summary counts of births for a population. Cohort rates are built from individual retrospective or longitudinal interview data. Each perspective captures a somewhat different view of fertility trends and is appropriate depending on the research question and the relative importance of period (historic events) or cohort (age effects) influences on fertility (Preston et al. 2001). Both are presented here for comparative purposes to give insights into the stability of vital rates and recent demographic trends.

Period ASFRs for both the river and savanna Pumé depict a characteristic fertility distribution where rates rise during the teens, reach a peak during the twenties, and then begin to fall (see Table 3). TFRs of 7.407 for savanna women and 7.754 for river women are high but within the range for other natural fertility populations (for overviews, see Bentley et al. 1993a; Campbell and Wood 1988). The Pumé TFRs are substantially higher than national levels (Venezuela's TFR = 2.7), which are determined primarily by low fertility in dense urban centers (87 percent of Venezuela's population lives in coastal centers; see Population Reference Bureau 2006). Mean number of births is similar for river and savanna females. Mean values are lower than TFRs because they average births over women of all ages,

not only those who have completed their reproductive careers.

Cohort fertility rates are shown in Figure 4. In most age groups, river women have slightly higher fertility, but those differences are not significant. For women 40 and older, savanna women have a cohort TFR of 7.4 (*n* = 16) and river women a TFR 7.28 (*n* = 18); the difference is not significant (*p* = .9060).

Period and cohort measures of fertility are equivalent when other demographic rates within a population remain fairly constant over time (Preston et al. 2001). For the savanna Pumé, the similarity between cohort (see Figure 4) and period (see Table 3) fertility suggests that mortality rates and the age pattern of childbearing have not appreciably changed in the recent past. In contrast, the river Pumé exhibit slightly higher period ASFRs for younger women and higher TFR compared to cohort estimates, suggesting that birth and death rates may have shifted in recent years.

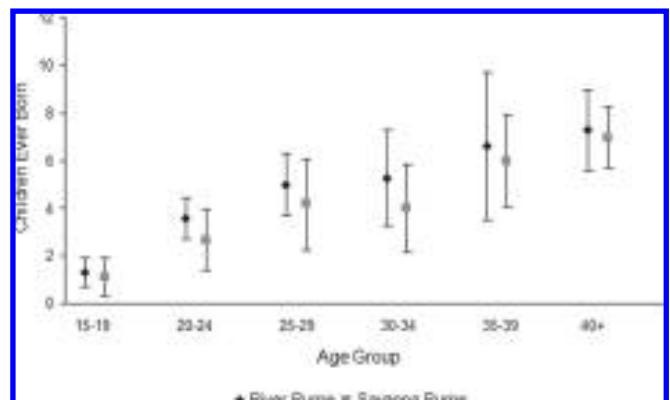


FIGURE 4. Age-specific completed fertility. A cohort rate constructed from the number of *children-ever-born* to river (*n* = 62) and savanna (*n* = 48) Pumé women. Error bars show confidence intervals.

TABLE 4. Infant mortality experience of Pumé mothers ages 15–25.

	# Infant Deaths per Mother			
	0	1	2	3
Savanna Pumé (<i>n</i> = 17)	35%	29%	24%	12%
River Pumé (<i>n</i> = 20)	65%	25%	10%	—

Infant Mortality

Significant differences emerge when we look at the child mortality experiences of Pumé mothers. The infant mortality rate (IMR)—relative frequency of deaths in the first year of life per 1,000 live births—is nearly three times greater among the savanna Pumé compared to the river Pumé (see Table 3). Of the few groups of mobile foragers for whom IMRs have been documented, the savanna rate (346) is higher than that for the Hadza and Ache (210 and 120, respectively) and similar to IMRs reported for the Agta and the Asmat (370 and 340, respectively; see Pennington 2001). The savanna Pumé IMR is slightly higher than rates reported for the Hiwi (Hill et al. 2007), foragers who live adjacent to Pumé territory along the Venezuelan–Colombian border. The river Pumé IMR of 132 represents a considerable drop in infant mortality compared to savanna forager rate but still far exceeds the national Venezuelan IMR of 19.6 (Population Reference Bureau 2006).

A closer look at infant mortality shows that many more river Pumé mothers never experience an infant death and far fewer experience multiple infant deaths than savanna mothers (see Table 4). The probability of an infant death is related to a mother's exposure to giving birth. To account for the possibility that young river mothers have fewer infant deaths because they have given birth to fewer children, mortality levels are tabulated with respect to parity (see Table 5). In this case, we limit the sample to 15- to 25-year-olds to increase data quality of pairing infant deaths to parity. At all parities, savanna mothers 15 to 25 are more likely to have had an infant death than river mothers. For example, by parity 2, 40 percent of river women have experienced at least one infant death, whereas 60 percent of savanna women have. By parity 5, only 50 percent of river

TABLE 5. Proportional distribution of infant mortality per woman by parity for Pumé mothers ages 15–25.

# Infant Deaths	Parity ^a				
	1	2	3	4	5
Savanna Pumé (<i>n</i> = 17)					
0	.67	.40	.33	.25	—
1	.33	.40	.33	—	.50
2+	—	.20	.33	.75	.50
River Pumé (<i>n</i> = 20)					
0	.80	.60	.50	.75	.50
1	.20	.20	.25	.25	—
2+	—	.20	.25	—	.50

^aNo woman 15–25 has had more than five children.

mothers have had at least one infant death, whereas all savanna women have. Holding parity constant, the disparity in infant mortality between the savanna and river Pumé is substantial.

Because previous reproductive history data do not exist, we cannot directly measure how recently infant survival has improved among the river Pumé. Infant mortality figures presented here are based on the last five years of a woman's reproductive history, when recall is at its best. The rates are expected to reflect general secular trends. A measles outbreak did occur 20 years ago, with losses greatest in the larger river communities (Lizarralde and Seijas 1991). Although few measles deaths occurred in the study communities, in small populations this could have noticeable effects. Interviews and reproductive histories indicate that no epidemics, famines, or episodic mortality events have occurred in the last five years.

In sum, infant mortality is considerably lower among the river Pumé and remains very high, at pretransition levels, among the savanna Pumé. The higher ASFRs at younger ages and the higher period compared to cohort TFR suggest that a shift in childbearing patterns is also occurring among the river Pumé. One means to further examine this trend and discern between the effects that birth rate and child survivorship have on population growth is to look more closely at the biological relationship between infant mortality and fertility.

CHANGES IN INFANT MORTALITY AND BIRTH RATES

The biological mechanisms linking infant mortality and birth interval length provide an indirect means to evaluate the extent to which the river fertility rate is attributable to a change in the pace of reproduction distinct from the biological effects that lowered infant mortality has on fertility. Studies consistently demonstrate that, in natural fertility breast-feeding populations, the average duration of a birth interval is substantially shorter following an infant death than when an infant survives because of the positive effect that lactation has on postpartum amenorrhea and subfecundity (Chowdhury et al. 1978). For example, studies among noncontracepting, historic European populations show that the physiological effect of an infant death reduced the length of a birth interval by as much as ten months (Knodel 1978). An extensive cross-cultural study found that birth intervals are on average 60 percent longer following the survival of a child than an infant death (Grummer-Strawn et al. 1998). Furthermore, the effect of breast-feeding accounted for most of this difference. Birth control, the level of women's education level, and wage labor participation tend to be associated with decreased periods of lactation. However, none of these factors are present among the Pumé and therefore do not influence birth interval length.

Birth interval length is estimated from the number of live births over the past five years and years-at-risk of pregnancy. For Pumé mothers 15 to 40, savanna women have a

TABLE 6a. GLM model results testing the effect of community type on *children-ever-had* after controlling for age and infant deaths for Pumé mothers 15–40 ($n = 73$).

Variable	Parameter Estimate	Pr > t
Intercept	−3.07043	.0003
Age	0.23610	<.0001
Infant deaths	0.68658	.0016
Community type	0.77764	.0846

Note: Model $R^2 = .5706$, $p \leq .0001$.

live birth on average every 3.1 years (42 births, 130 years-at-risk $n = 28$) and river women have a live birth on average every 2.87 years (70 births, 201 years-at-risk $n = 44$). The pattern is similar for women ages 15 to 25. River women have slightly shorter birth intervals on average, suggesting that the biological effect of lowered mortality on lengthening birth intervals has been more than offset by an increase in the pace of child bearing.⁸

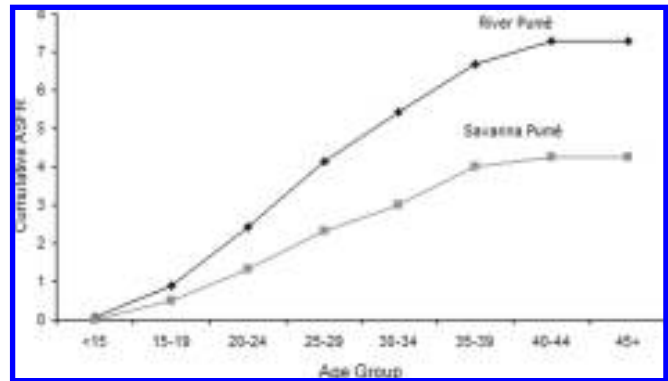
To assess whether fertility based on a mother's infant mortality experience varies between river and savanna women, we construct a multivariate general linear model (GLM) controlling for mother's age and infant deaths. Seventy-three mothers ages 15 to 40 were included in the model. Results show that fertility increases with infant mortality experience and age. But whether a woman is from a savanna or river village (community type) falls out of the model as insignificant in explaining variation in children-ever-born (see Table 6a). Community type, however, is significant in explaining variation in the number of surviving children (see Table 6b). After controlling for age, river women have significantly more surviving children ($p = .0006$).

A decline in infant mortality can affect population growth in two confounding ways. First, because the interval to the next birth is longer when a child survives, it can be negatively associated with fertility. Among the river Pumé, a decline in infant mortality is demonstrable but has not led to longer birth intervals and lower fertility. Second, the drop in infant mortality increases the number of children who survive to reproduce in the next generation. To examine the potential effect that differences in child survivorship may have on population growth, we construct a period ASFR of surviving children (see Figure 5). Given the assumption underlying the construction of period rates that current conditions will persist throughout a woman's repro-

TABLE 6b. GLM model results testing the effect of community type on *surviving children* controlling for age for Pumé mothers 15–40 ($n = 73$).

Variable	Parameter Estimate	Pr > t
Intercept	−2.73984	.0004
Age	0.17791	<.0001
Community type	1.37338	.0006

Note: Model $R^2 = .4728$, $p \leq .0001$.

**FIGURE 5.** Age-specific surviving Pumé fertility: a period rate constructed from surviving children born to women over the past five years ($n = 113$ females 14 and older).

ductive career, river women have a TFR of 7.27 surviving children and savanna women have a TFR of 4.25 surviving children.

By standardizing for the probability of surviving to age 15, an estimated 79 percent of the increase in the river Pumé TFR compared to the savanna Pumé can be attributed to gains in children surviving to reproductive age and 21 percent to an increase in birth rates. Thus, the effect of fertility levels on population growth is disproportionately greater among the river Pumé both because of gains in child survival and to an increase in the pace of reproduction.

DISCUSSION

Demographic transition research has placed central importance on fertility reduction, and specifically its relationship to child survivorship (Cheland 2001; Doepke 2005; Montgomery and Cohen 1998; Notestein 1953; Preston 1978). Because infant mortality is a strong predictor of fertility decline as developed nations pass through demographic transition (Heer and Smith 1968; Schultz 1976), as mortality declined, fertility was expected to fall, as parents had fewer children to achieve a target family size of surviving children (Freeman 1963). Continued research indicated that the relationship is far from straightforward (Cantrelle et al. 1978; Taylor et al. 1976; van de Walle 1986). In some cases mortality decline does not appear to be a precondition to the fertility decline, and in many populations fertility did not fall as quickly as anticipated (Lindert 1980; Montgomery and Cohen 1998).

Implicit in many discussions about child loss and fertility is the assumption that lower fertility is universally desired. Yet, some of the highest fertility rates documented in natural fertility populations occur when traditional societies undergo initial economic transition (Early and Headland 1998; Hill and Hurtado 1996; Kramer and McMillan 2006). The Pumé results add to these studies by demonstrating that population growth during the earliest stages of economic acculturation occurs through not only higher child survival but also an increase in birth rates. Rapid

population growth as an outcome of death rates dropping more quickly than birth rates is well documented. However, a rise in birth rates as a distinct trend is underreported (Dyson and Murphy 1985; Kramer and McMillan 2006; Romaniuk 1980). It is, however, a potentially important component of population growth and perhaps not an uncommon consequence of economic development, the introduction of government assistance, and other development initiatives.

When constraints on fertility are relaxed and there is no concomitant rise in the opportunity costs of childbearing, parents appear to maintain or even further reproductive effort. In the absence of the means to achieve target fertility levels or structures supporting a reduction in the demand for children (e.g., increased wage rates, returns to formal education or to investment in skill or improved social status; see Becker 1981; Blurton Jones et al. 1989; Caldwell 1983; Hill and Kaplan 1999; Kramer 2005), river Pumé mothers do not downwardly adjust their fertility levels. Although river mothers have experienced a significant decline in infant mortality, this does not account for all of rise in fertility. This suggests that during the early stages of acculturation, period effects are introduced that not only ease constraints on child mortality but also make conditions more favorable for mothers to increase birth rates.

Period Effects on Child Survivorship and Fertility

The savanna and river Pumé live in the same environment, are genetically related, and have led comparable lives until recently. They are now distinguished by important differences in their contact with influences outside their subsistence economy. As the river Pumé transition economically, they experience period effects that have a positive influence on both child survivorship and birth rates.

Until recently the river Pumé were seasonally mobile, but they are now sedentary and more reliant on horticulture. Although it is widely held that circumstances associated with food production and sedentism have a positive effect on fertility because the constraints of foraging mobility on birth rates are relaxed, cross-cultural empirical data do not support this expectation (Kramer and Boone 2002; Pennington 2001). If sedentism is indeed a decisive factor affecting TFRs, we would expect horticulture to be a clear landmark in fertility increase. However, a number of cross-cultural studies show that horticulturalists do not have significantly greater fertility (Bentley et al. 1993b; Campbell and Wood 1988), suggesting that sedentism alone does not account for an increase in river Pumé fertility.

Neither savanna nor river Pumé villages have clinics or are regularly visited by health care workers, and we can hold exposure to modern health care effectively constant. For example, of children aged ten years and younger, 38 percent of savanna children and 48 percent of river children report ever having received a vaccination; this difference is not significant ($\chi^2 = 1.1088$, $df = 1$, $p = .2923$). This supports other findings that initial gains in survivorship are due less

to medical intervention or vaccination than to the results of improvements in food supply, living standards, and the introduction of simple items such as soap that vastly improve sanitation conditions (Finch and Crimmins 2005; McKeown 1977). Although neither group is regularly visited by health care workers, the river Pumé overwhelmingly benefit from the limited health care that does reach the area, and even sporadic medical attention can make a difference in mortality rates.

The most far-reaching period influence, however, is food supply. The greater reliance on horticulture, fishing, market foods, and government assistance buffers the river Pumé against the pronounced daily and seasonal variation in food supply common in savanna communities. This affects both fertility and mortality in several significant ways.

First, children—especially young children at the age of weaning—are particularly susceptible to shortfalls in food supply. Greater accessibility of agricultural and market foods improves the diets of young children, less through absolute availability than by reducing the periodicity and amplitude of nutritional stress. Cross-cultural evidence suggests that among traditional populations, improved children's diets can introduce substantial gains in survival (Pennington 1992, 1996). Second, fluctuations in daily food availability and seasonal nutritional stress can affect female reproductive function. Although the specific biological mechanisms are not fully understood, periodic variation in adequate nutrition alters the energy budget available to allocate to lactation and to the resumption of reproductive function following a birth (Jasienska 2001; Lunn et al. 1984; Rosetta 1995; Sellen 2000). Resolving shortfalls in food supply may affect the duration of postpartum subfecundity and help explain the shorter birth intervals among the river Pumé. Third, although young nursing infants are buffered to some extent from disease and malnutrition, after supplemental foods are introduced at about six months, maternal condition does affect infant health and well-being. Lactation under suboptimal dietary conditions, which savanna women experience for half of each year, can lead to substantial weight loss in lactating women (Sellen 2000). Anthropometric data collected in 2006 show that savanna women experience a body mass decline during their prime reproductive years. Repetitive cycles of pregnancy and lactation may compound the effects of annual nutritional stress. Savanna women undergo a mean weight decrease of eight percent (~4.4 kilos) during the wet season. River women have greater access to market foods, are considerably better nourished, are relatively plumper than savanna women, and do not experience an equally severe seasonal weight loss.

Maternal energy depletion can have long-term effects on both maternal and infant health (Little et al. 1992). Nursing infants are particularly susceptible to gastrointestinal diseases after they are introduced supplementary foods. Infants exclusively fed breast milk are at considerably reduced risk of diarrhea compared to infants who are introduced to

supplementary foods (Brown 2003). Furthermore, infants with inadequate weaning diets can suffer growth faltering after six months (Sellen 1998).

Last, dietary condition has a synergetic relationship with disease resistance not only for children but also adults. Although infectious disease is endemic to both savanna and river Pumé, seasonal malnutrition and daily variance in food supply exacerbates morbidity among the savanna Pumé. Long-term historic studies of cohorts show that adults who have greater exposure to infectious disease at young ages have higher rates of morbidity and mortality (Bengtsson and Lindström 2003; Finch and Crimmins 2004), which affects the mortality profile of reproductive-aged women and population growth potential. In relation to development goals, data from a longitudinal study with the Tsimane of Bolivia demonstrate that when individuals seek medical attention only under dire situations and it takes several days to travel to clinics, medical intervention preferentially benefits adults, not children (Gurven et al. 2007).

Current demographic changes among subsistence foragers and horticulturalists living within nation states often go undetected because reliable censuses do not exist, individual data are unavailable, or populations are too small for dynamics to be discernible by national and regional indices. Yet such communities are frequently the recipient of development initiatives designed from regional or national trends. Viewing demographic changes in light of the Pumé economic transition can direct better informed development initiatives, health care policies, and government assistance, which are more likely to achieve their desired goals and have long-term benefits for indigenous populations.

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NOTES

Acknowledgments. Foremost we thank the Pumé of Doro Aná, Yaguri, Charakoto, Rosario, Chaparralito, and Chainero for their generosity in providing us with food and shelter and spending long hours talking to us about their families. We are grateful to Drs. Roberto Lizarralde (Universidad Central de Venezuela), Ted Gragson (University of George, Athens), and Haydée Seijas (Universidad Central de Venezuela) for their previous census research among the Pumé, which was invaluable in constructing our age estimates. Much appreciation to Dr. Roberto Lizarralde, Dr. Werner Wilbert (Instituto Venezolano de Investigaciones Científicas), Daisy Barreto, and Kleisner Correa (Salud Indígena) for graciously sharing their knowledge of Pumé-government relations and assisting with Venezuelan research logistics. We much appreciate our discussions with Hilly Kaplan and Jane Lancaster about the Pumé demographic situation. We also thank the AA reviewers for their comments in helping to solidify this article. The 2005–06 research on which these analyses are based was funded by the National Science Foundation (0349963). The initial two-year study among the savanna Pumé in 1992–94 was funded by from the L. S. B. Leakey Foundation and an NSF dissertation improvement grant awarded to Russell Greaves and Lewis Binford (DBS-9123875).

1. By *subsistence societies*, we mean those in which food and other goods are largely produced by the household rather than purchased, and little or no surplus is generated for trade or cash.
2. Although migration also is a factor in population growth, minimal net out- or in-migration occurs in the five Pumé study villages.
3. The indigenous census data from 2001 are problematic and remain unpublished.
4. One way to compensate for the small sample sizes is to increase the size of the age classes from one year to five years. Some of the bumps and troughs in the age pyramid could be a feature of the inevitable irregularities in age representation in small samples (but see Weiss and Smouse 1976 for small populations experiencing growth). The greater relative representation of young people (0–14) in the river Pumé could indicate higher historic mortality among 15–29 years old, but this is unlikely. Thirty-one percent of Venezuela's population, as shown in Table 1, is under the age of 15 (Population Reference Bureau 2006).
5. This compares to a median age of 24.7 for Venezuela (UN Population Fund 2006).
6. As marriage patterns affect a net loss or gain on a population age structure owing to migration, most marriages occur between individuals from within the five study villages.
7. Premasticated adult food is introduced first, followed by small portions of soft food such as mangos. By the age of two, children are eating small whole fish with bones.
8. In a sample of Pumé mothers between the ages of 15–29 years, within each five-year age group, both the savanna and river Pumé mothers who had greater infant mortality experience have had more births. However, in neither case do women make up for their losses through additional births, corroborating S. H. Preston's (1978) original finding and L. M. Grummer-Strawn and colleagues' (1998) later reassessment that under conditions of high infant mortality parents do not achieve one-to-one replacement through subsequent births. Although mothers who have one or more infant death have more live births, regardless of whether they are savanna or river mothers, at the population level, far fewer river women experience these high levels of mortality.

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