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Pastoral Sedentarization and Its Effects on Children's Diet, Health, and Growth Among Rendille of Northern Kenya

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Throughout the arid regions of Africa formerly mobile pastoral populations are becoming sedentary. Although pastoral sedentarization is encouraged by international development agencies and national governments as solutions to food insecurity, poor health care, and problems of governance, it has not been demonstrated that abandoning the pastoral way of life, and particularly children's access to milk and other livestock products, is beneficial to the health and well-being of pastoral populations. This paper reports the results of a 3-year study of one pastoral and four settled Rendille communities of northern Kenya based on data from 17 repeated bimonthly surveys of childhood dietary, growth, and morbidity patterns and household level economic strata. Bivariate analysis of 5,535 measurements from 488 children from birth to 9 years revealed that age-specific height and weight measurements for the pastoral community are uniformly heavier and taller than children from the sedentary villages. Multivariate analysis using Generalized Estimating Equations methodology showed that the amount of milk consumed was always a statistically significant determinant of child weight and height growth, regardless of drought or non-drought times and breastfeeding status. Other significant determinants of child growth include morbidity and poverty, both associated with sedentary communities. These results indicate that international

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development assistance should not neglect improvements in livestock production and support of pastoral movements in Africa's arid lands.

KEY WORDS: pastoralism; sedentarization; child growth; East Africa.

INTRODUCTION

The adoption of sedentism by formerly mobile African pastoralists increased dramatically in the late twentieth century as a result of sharp economic, political, demographic, and environmental changes. Although the majority of pastoralist households remains committed to the raising of livestock in the savannas and desert regions of East Africa (Kenya, Tanzania, Uganda), Northeast Africa (Somalia, Ethiopia, Sudan, Egypt), and West Africa (Senegal, Mali, Niger, Chad, Nigeria), many formerly pastoral families have settled near towns or riverine and highland areas to pursue alternate economic strategies including cultivation, agro-pastoralism, or urban wage labor.

Pastoralists settle for a variety of reasons, both in response to "pushes" away from the pastoral economy and to "pulls" of urban or agricultural life. For example, Maasai in southern Kenya have lost grazing lands due to the growth of agricultural and pastoral populations, privatization of land for commercial farms and ranches, and the expansion of tourist game parks, causing many pastoralists to combine sedentary maize cultivation with animal raising (Campbell, 1999; Galaty, 1992; McCabe *et al.*, 1992). In the more arid and less densely populated north of Kenya where Rendille live, pastoralist families settled in response to the environmental stress of drought and famine combined with political violence of livestock raiding and ethnic conflict (Fratkin, 2001).

Sedentarization is the process of formerly nomadic populations settling into nonmobile communities, and applies to foraging populations, livestock keeping pastoralists, and other occupational or ethnic groups that were formerly mobile such as Roma (Meir, 1997; Salzman, 1980). Sedentarization is neither a recent event nor a unidirectional process. Fulbe pastoralists in West Africa have long-standing ties to sedentary agricultural villages and mercantile towns where many former pastoralists took up sedentary agriculture while keeping livestock herds with pastoral relatives (Bayer and Waters-Bayer, 1994). Certain Maasai groups in East Africa, including the Arusha, took up agriculture in the nineteenth century (Spear, 1997), while others such as LChamus oscillated between cultivation and livestock production depending on particular historical circumstances (Little, 1992). By the late twentieth century pastoralists faced increasing pressures of land crowding, population growth, and competition with both farming and

pastoral populations, but have also settled near towns to market milk, meat, and livestock, as well as take advantage of new opportunities in wage labor, education, and access to health care (Fratkin, 2001; Little, 1994; Roth, 1991, 1996; Salih *et al*., 1995).

The settling of nomadic or semi-sedentary pastoralists in Africa has been advocated by multilateral and bilateral development agencies, religious missions, conservation groups, and national governments, who deem nomadic pastoralism wasteful or unproductive, and who promote permanent settlement as beneficial to integrating pastoralists into the national economy, assimilating marginal populations, forging of national identity, and improving their material well-being (see Dyson-Hudson, 1991; Kituyi, 1990). International donors such as the World Bank and USAID have encouraged the privatization of formerly communal range lands and the establishment of individual ranches (Galaty, 1994; Hodgson, 1999; World Bank, 1984), although these policies are being rethought as western ranching models have shown little success in East Africa (Scoones, 1994; World Bank, 1997). Likewise, national governments in Africa have been concerned with settling pastoralists as a means of better controlling and taxing them and inhibiting cross-border migrations (Bayer and Waters-Bayer, 1994). Finally, some NGOs involved in famine relief work have encouraged poor pastoralists to settle permanently at famine relief points, in order to deliver food and social services, but also to separate pastoral populations from their nomadic lifestyle, which is seen as primitive and irrational (Fratkin, 1992; Hogg, 1982).

Despite these interventions, it is not clear what the costs and benefits of sedentarization are to pastoralists. Several studies point to socioeconomic problems of impoverishment and destitution for pastoralists who settle (Hogg, 1986; Little, 1985) which may particularly affect women (Talle, 1988). Others point to increased marketing benefits (Ensminger, 1991; Sato, 1997; Zaal and Dietz, 1999) including those to women selling milk and agricultural products (Fratkin and Smith, 1995; Little, 1994; Smith, 1998, 1999; Waters-Bayer, 1988). Several studies report negative health consequences of pastoral sedentarization, including poorer nutrition, inadequate housing, lack of clean drinking water, and higher rates of certain infectious disease including malaria, bilharzia, syphilis, and AIDS, despite better access of settled populations to formal education and health care (Chabasse *et al.*, 1985; DeLuca, 1996; Fratkin *et al.*, 1999; Hill, 1985; Nathan *et al.*, 1996).

Over the period September 1994 to June 1997, we, a cultural anthropologist (Elliot Fratkin), a demographic anthropologist (Eric Roth), and a medical researcher (Martha Nathan, MD), conducted longitudinal research examining the biosocial concomitants of sedentism for Rendille pastoralists of Marsabit District, northern Kenya. We compared the effects of differing

economic strategies on the diet, health, and nutrition of five communities ranging from fully nomadic through agro-pastoral to irrigation agriculturalists. In doing so we raised and addressed two related research questions: (1) what are the biosocial consequences of different types of sedentism for these formerly mobile pastoralists and, (2) how can these consequences be measured?

Previous Research on Pastoral Sedentarization and Its Effect on Health and Nutrition

Ecological, economic, and sociological research on pastoralism has grown substantially in the past few decades (for reviews see Fratkin, 1997; Galaty and Johnson, 1990; Scoones, 1994). Research on pastoral sedentarization has also increased, particularly on problems of development and social change (Fabietti and Salzman, 1996; Galaty *et al.*, 1981; Meir, 1997; Salzman, 1980; Salzman and Galaty, 1990). In contrast, there remains relatively little written on the health and nutritional aspects of pastoral sedentarization. In the early 1980s Allan Hill (Hill, 1985) organized multidisciplinary studies comparing the health and nutrition of sedentary and pastoral groups in Mali. Results from one specific study within this large project on Sahelian community health demonstrated that nomadic groups featured higher rates of tuberculosis, brucellosis, syphilis, trachoma, and child mortality (children 5 years and under), which they attributed to differences in health care services (Chabasse *et al.*, 1985). At the same time this study indicated that settled agricultural populations had higher rates of bilharzia, intestinal helminths and other parasites, and higher malaria and anemia rates, which the authors attributed to their proximity to riverine locations. The study did not look at the process of sedentarization within a single community where health and nutritional outcomes for nomadic versus settled communities could be compared for the same ethnic group.

The South Turkana Ecosystem Project of the late 1980s carried out extensive research on the ecology, health, nutrition, and fertility of nomadic Turkana of north-west Kenya (Galvin, 1985, 1992; Gray *et al.*, 2002; Little, 1997, 2001, 2002; Little *et al.*, 1988, 1993; Little and Leslie, 1999; Shell-Duncan, 1993, 1995) and also examined health and nutrition among settled farming Turkana populations (Campbell *et al.*, 1999). Overall, researchers found that settled Turkana experienced reduced fertility, increased morbidity, (particularly from malaria) and increased child mortality. Settled children under 5 showed more growth stunting than nomadic children, although settled children over 5 were heavier, a finding attributed to a greater role of carbohydrates in their diet, particularly for chidren receiving supplemental

feeding in schools. Nomadic Turkana women were taller, heavier, and had lower blood pressure than settled women.

Dietary change represents a fundamental difference between mobile pastoral and settled communities. Pastoral diets generally are characterized as high in protein but low in calories, with marked seasonal variation in both protein and energy content (Galvin, 1985, 1992; Galvin and Little, 1999; Little *et al.*, 1993; Nathan *et al.*, 1996; Nestel, 1986; Shell-Duncan, 1995). For northern Kenya times of dietary stress occur at the ends of the two dry seasons (November–March and May–August) when livestock pasture becomes scarce, in turn limiting both drinking water and milk availability for human consumption. During dry periods, small stock are increasingly sold to purchase foods including grains (maize meal or *posho*) and other carbohydrates (e.g., sugar to mix with tea). Nonetheless, the milk-based, high-protein diet of pastoralists is considered adaptive in a highly seasonal environment with limited resources for dietary energy (Galvin and Little, 1999). The positive ramifications of a pastoralist high-protein diet may be particularly significant for infants, pregnant women, and lactating mothers, all of whom are at high risk of nutritional stress (Panter-Brick, 1998). Since protein is an indispensable nutrient for reproductively active pastoral women as well as for infants and growing children (Galvin and Little, 1999), the potential protein loss associated with agricultural sedentism may have a negative impact on maternal nutritional health.

Market integration of rural producers in Africa may have both positive and negative consequences on child health and nutrition. Sales of agricultural commodities may diminish child nutrition when they lead to substitution of high calorie or protein foods for cheaper, poorer ones (Lappé and Collins, 1977). However, other studies report improved child nutrition associated with commercial agriculture when combined with subsistence production, as shown in various production strategies of Taita farmers of Kenya (Fleuret and Fleuret, 1991). Likewise, Ensminger's (1992) study of the economic transformation of Orma of Kenya found increased residence in market centers and agricultural commercialization associated with improved nutritional markers (weight-for-height) for adults and male children, but not for female children.

Today in settled communities of formerly mobile pastoralists certain families may have a wider economic resource base, such as those engaged in the commercial livestock economy and those who take up cash-crop agriculture. This allows these families not only to alleviate seasonal fluctuation of food availability but also to widen the variety of food in their diet. Typically, there are contrasting seasonal patterns of nutritional stress for agriculturists and pastoralists. Critical periods for agriculturists coincide with food shortages and high-labor demands associated with farming during the

preharvesting season (Simondon *et al.*, 1993, p. 166). Families with sufficient agricultural and/or pastoral resources can even out seasonal stresses associated with each subsistence mode. By contrast, poorer families who rely on smaller pastoral or agricultural holdings for their subsistence and cash income are more likely to experience seasonal stresses distinct from those of wealthier families.

Pastoral Sedentarization in Marsabit District, Northern Kenya

Marsabit District is Kenya's largest, most arid, and least inhabited district with 121, 478 people occupying 61,296 square kilometers. The district borders Ethiopia in the north, Wajir District in the east, Isiolo District in the southeast, Samburu District in the southwest, and Lake Turkana and Turkana Districts in the west. Mean annual rainfall varies from 200 mm in the lowlands to 1000 mm in the highlands. As shown in Fig. 1, the majority of the district is made up of vast lowland scrub desert ranging from 400- to 700-m latitude. This is interspersed with several mountain ranges and hills including Marsabit Mountain (1545 m), an isolated volcano in the center of the district and location of the district capital of Marsabit town. There are no permanent rivers in the district, but mountain run-offs provide temporary surface water in the lowlands and the highlands have several permanent lakes and pools. Roughly 80% of the district's population are livestock pastoralists, 10% are highland farmers, 5% are in commerce trade, and 5% are salaried employees in district administration, police, and nongovernment organizations (Republic of Kenya, 1991).

Until recently, the majority of Marsabit's District's population practiced mixed species pastoralism, living principally off camels or cattle, as well as raising goats and sheep. This population includes Boran cattle keepers (pop. 36,447), Gabra camel herders (pop. 30,213), Rendille camel herders (pop. 23, 585), Samburu (Ariaal) mixed cattle and camel herders (5,887), and Sakuye camel pastoralists (pop. 1,856) (figures are from the 1989 Kenya census, the last to report ethnic categories). These pastoral groups also keep large flocks of goats and sheep which are used principally for trade and meat. Large stock have more value, both in terms of food production and market exchange, although camels are kept primarily for milk and baggage transport while cattle are kept for milk, meat, and market exchange. In addition, there are several small agricultural populations including Burji farmers (pop. 6000) originally from Ethiopia who were encouraged by the British to settle on Marsabit Mountain to provide food for police and road construction crews in the 1930s (Fratkin, 1998).

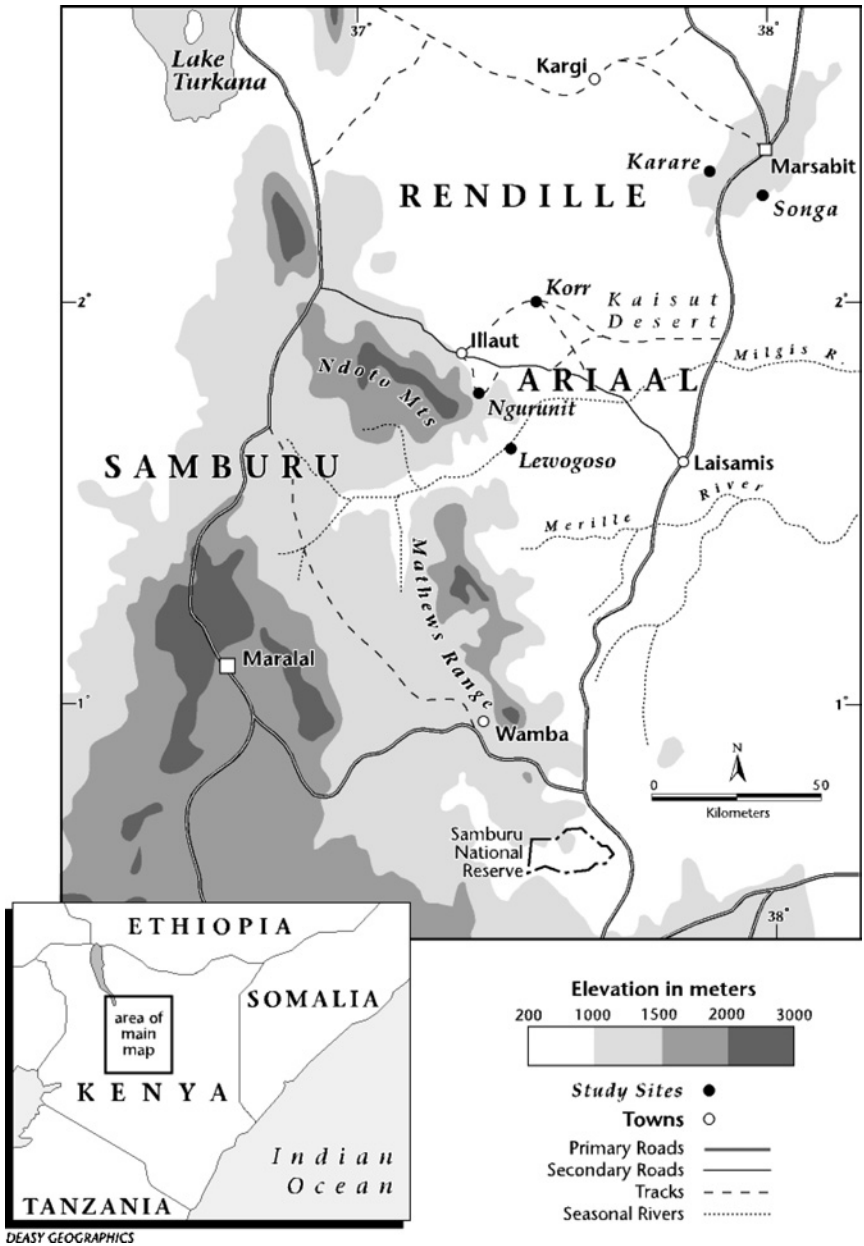

Fig. 1. Map of study communities in northern Kenya.

Sedentarization is a recent phenomenon in Marsabit District. Unlike Maasai who settled and participated in the market economy for most of the twentieth century, northern Kenya has remained both isolated and undeveloped for much of this time. This situation changed dramatically after a long series of droughts beginning in 1971, when both religious missions and international development agencies encouraged the settling of impoverished pastoralists in famine relief centers and agricultural projects.

Drought was recorded in Marsabit District for 8 years between 1900–1970 (1919–22, 1928–29, 1934, 1945, 1949, 1960); the same number of drought years occurred in the following 30 years (1971, 1975–76, 1980, 1983–84, 1992, 1996, and 2000) (Marsabit District Annual Reports, 1974–1999; O'Leary, 1990). Northern Kenya did not suffer the severe famines that occurred in Ethiopia during the 1970s and 1980s, although many animals were lost during drought periods (Roth, 1990, 1996). While the majority of the district's residents continue to live as livestock pastoralists, many reduced their mobility and moved closer to lowland towns, to have access to famine relief foods and social services, particularly health care and education, and to seek safety from increased interethnic raiding, which has become more deadly due to the flow of small arms into the region from civil wars in Ethiopia, Somali, and Sudan.

Many Marsabit pastoralists who began to settle in the 1970s were attracted initially to famine-relief centers in the lowlands and agricultural schemes on Marsabit Mountain established principally by religious organizations. Following the drought of 1971, the Catholic Church assumed responsibility in Marsabit District for distributing relief supplies of corn, rice, and soybean flour, which were donated by international relief agencies including USAID, UNICEF, and CARE. Concentrating on the low-lying pastoral areas, the Catholic Church reached Gabra through Maikona and North Horr and Rendille through Laisamis. The Laisamis Catholic mission also began mobile food distribution to Rendille pastoralists at two wells in the Kaisut Desert, Korr and Kargi, which soon attracted Rendille, primarily women, older men, and children too small to herd livestock in distant camps.

In 1973, a coalition of religion groups (the National Christian Churches of Kenya (NCCK), African Inland Church (AIC), CARE, and the Catholic Mission Marsabit) encouraged impoverished Rendille pastoralists to settle on new agricultural schemes on Marsabit Mountain to learn and practice maize and vegetable agriculture as an alternative to pastoralism. By the 1990s, these communities were well-established agricultural enclaves of 2,000 people each including the Rendille communities of Naskikawe and Kitaruni (near the Ariaal community of Karare) and Songa (in the Marsabit Forest Reserve 17 km below Marsabit town), along with three

other communities occupied by Boran, who are traditional enemies of the Rendille. These farming communities resemble those of other Kenyan agriculturalists in which former pastoralists have become more individualized and integrated in commercial markets selling maize, kale (*sukuma wiki*), peppers, squash, and fruit (Smith, 1998, 1999).

While the agricultural settlements on Marsabit Mountain attracted destitute pastoralists, many lowland pastoralists who still kept livestock, particularly Rendille, moved closer to towns and roads for security and social services including health care, education, and periodic famine relief. An estimated 6,000 of 12,000 Rendille live within 20 km of Korr and Kargi, towns that developed from the Catholic Church food distribution points at well sites in the Rendille lowlands. Although Rendille living here still keep significant herds of camels, small stock, and some cattle, these cannot be maintained in the arid areas around towns, and are herded for most of the year in distant camps managed by young men. Consequently, in sedentary communities comprised of married women, elderly men, and small children diet changed from predominantly milk to maize meal (*posho*) as the staple food. Rendille living near the lowland towns, or on Marsabit Mountain in agricultural or agro-pastoral communities, have access to health dispensaries, schools, and shops, but there are few jobs available.

Diet, Health, and Childhood Growth in Marsabit District

A prevalent theme in our investigation of Rendille sedentarization is that it constitutes an ongoing process consisting of constraints and opportunities, attracting both wealthy and poor members of the pastoral community. Sedentarization has yielded a number of beneficial effects including improved access to drinking water, education, health care, and to a market economy (Fratkin, 1998; Roth, 1991; Smith, 1998, 1999). But pastoral sedentarization also has generated widening disparities in wealth distribution and access to food resources, a process reported among other settling pastoralists (Hogg, 1986; Little, 1985). Another result appears to be declining nutritional child health in newly formed sedentary communities, as evidenced by poor age-specific height and weight measurements when compared to similar aged samples from pastoral populations (Brainard, 1990; Fratkin *et al.*, 1999; Little, 2001; Little *et al.*, 1993; Nathan *et al.*, 1996).

One way to evaluate the success of newly settled populations is by assessing whether their transition to sedentism provides adequate nutrients, thereby maintaining their health, biological function, and productive capacity, especially during times of dietary stress (Huss-Ashmore, 1993, pp. 202, 215). In the Rendille case this task is complicated by different subsistence

strategies adopted by Rendille communities in their transition to sedentism. Some communities subsist primarily off their livestock herds as mobile pastoralists, while sedentary communities such as Korr depend on famine relief foods. Other communities, such as Songa on Marsabit Mountain have become full-time agriculturists. Because of such diverse local economies, we chose maternal–child health, measured via morbidity, nutrition, and child growth, as the vital currency for appraising the biosocial consequences of sedentism.

In this perspective the sensitivity of human growth processes to the environment is seen as "one mechanism by which our species adapts" (Johnston and Little, 2000, p. 40). Poor adaptive response to environmental change is evidenced by childhood growth faltering," i.e., slowing of growth curves (Stinson, 2000, p. 447). This phenomenon was originally termed "auxological epidemiology" by Tanner (1981), who traced its original academic application to studies of the growth and development of British factory children in the nineteenth century. Today growth faltering is globally associated with elevated risks of morbidity and mortality (Pelletier, 1994) or, as succinctly stated by Martorell (1989, p. 18) "good growth means good health." In addition, Martorell (1989, p. 19) points out that growth retardation is an early warning sign of deteriorating child health, since the *process* of being small is also associated with cognitive and functional impairment.

We employed this perspective in previous analyses of Rendille child health (Fratkin *et al.*, 1999; Nathan *et al.*, 1996) based on cross-sectional data. However, as cautioned by Panter-Brick (1998, p. 75), "A cross-sectional view of growth status offers us little information regarding the processes by which children fail to thrive." Here we examine longitudinal data spanning a 3-year period to examine the processes of child growth, nutrition, and morbidity among these formerly mobile northern Kenyan pastoralists.

In our previous work we proposed that sedentarization would affect Rendille child growth in two ways. The first would be via dietary change, with sedentary groups drinking less milk as a result of their separation from household livestock herds, which are maintained outside sedentary centers in mobile animal camps called *fora.* The second would be through an increase in density-dependent infectious diseases, with greater population density in sedentary communities acting as reservoirs for infectious pathogens. These potential pathways of biosocial change invoke the well-documented model known as the *nutrition–morbidity synergism*, originally formulated by Scrimshaw *et al.* (1968), and described by Pelletier (1994, p. 409) as, "the view that malnutrition adversely affects a person's ability to resist and/or respond to infection, and infection adversely affects a person's

ability to utilize energy and nutrients obtained from the diet." Results from our previous cross-sectional analyses partially supported these hypotheses. Children from sedentary communities drank significantly ($p < 0.01$) less milk than pastoral children, but they did not show significant ($p > 0.05$) differences in morbidity rates for a variety of common childhood diseases (acute respiratory infections, fever, and diarrhea).

In addition to these pathways, we also predicted that socioeconomic differentiation arising from sedentarization, and delineated in earlier livestock-based analyses (cf. Fratkin and Roth, 1990, 1996; Roth, 1990, 1996) would translate into varying levels of childhood malnutrition. This prediction was not supported, as our cross-sectional data revealed that household economic levels had no effect upon levels of childhood malnutrition. Now armed with longitudinal data we focus again upon the nutrition–morbidity framework and examine the ramifications of dietary change, morbidity patterns, and economic differentiation in different ecological conditions over time. In addition we explore possible effects of increased parental investment in boys found in schooling and other aspects of the strongly patriarchal Rendille life (Fratkin *et al.*, 1999; Roth, 1991, 2000).

Our multiyear longitudinal data set is unique among pastoralist research, in Africa or elsewhere. Much previous research, including Hill's (1985) study on the health and diets of pastoral and agricultural communities in Mali, are based on one, or at most two seasonal periods. The Southern Turkana Ecological produced two excellent longitudinal health and nutritional studies (Galvin, 1985; Shell-Duncan, 1995), both based on 1 year of data collection in a drought period. In contrast, as shown in Fig. 2, mean monthly rainfall data for our multiple year study show the expected East African bimodal rainfall pattern for 1995 followed by drought in 1996 and 1997. Thus we were able to monitor seasonal changes in diet, health, and growth across both drought and non-drought years. These longitudinal data allow us to examine growth patterns for Rendille children in two related manners. We begin with a bivariate analysis based on age-specific anthropometric indicators. This is followed by a multivariate study of possible underlying determinants of childhood growth.

MATERIALS, METHODS, AND STUDY AREA

To monitor child diet, growth, and health we selected five Rendille communities, four sedentary (Korr, Karare, Ngrunit, and Songa) and one mobile (Lewogoso) in Marsabit District, northern Kenya. Their locations are shown in Fig. 1. These communities are summarized below.

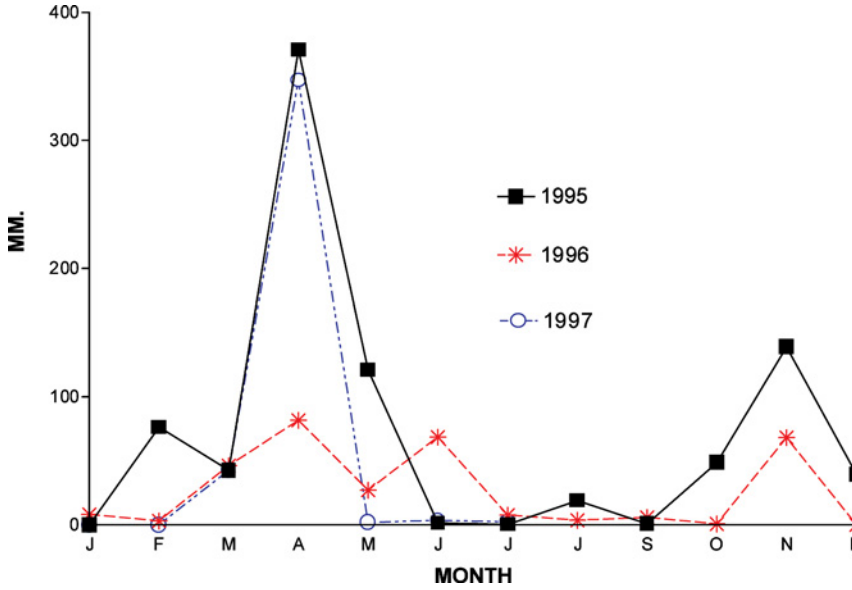

Fig. 2. Monthly rainfall in Marsabit District, 1995–97.

1. *Lewogoso* is a mobile camel-, cattle-, and small-stock-keeping Ariaal Rendille settlement of approximately 250 people practicing mixed-species husbandry. This community has been extensively studied (Fratkin, 1998) and forms a control community for the comparison of the sedentary villages.
2. *Ngrunit* is a sedentary agro-pastoral community of approximately 1,200 people located in a forested valley in the Ndoto Mountains made up of Rendille, Ariaal, Samburu, and Dorobo peoples. This community has a church, school, and small dispensary but is isolated and not well integrated into marketing activities. Residents raise vegetables in their gardens and market livestock.
3. *Korr* is a new town in the arid lowlands of the Kaisut Desert below Marsabit Mountain created initially by the Catholic Diocese to feed destitute Rendille during the famine of the 1970s. Today Korr has a sedentary population of about 6,000, with adjacent seminomadic Rendille settlements. Korr has poor marketing facilities, although the town provides a local market, mainly represented by small stock sales, for surrounding pastoralists (Roth, 1991, 1996).
4. *Karare* is a settled highland community on Marsabit Mountain 17 km from Marsabit town, the district capital. Its 2,000 residents are primarily Ariaal (Samburu/Rendille mix) who both keep cattle

herds and raise dryland maize. Karare has access to good marketing facilities as well as a large urban population in Marsabit town and is located on the major truck road from Nairobi to Addis Ababa. Karare women sell milk on a regular basis to Marsabit townspeople (Fratkin and Smith, 1995; Roth *et al.*, 2001).

5. *Songa* is a sedentary highland agricultural community on Mt. Marsabit of 2,000 people, founded by American Protestant missionaries from the African Inland Church in 1973 in a forest on Marsabit Mountain for destitute Rendille. Practicing drip irrigation agriculture, Songa's population grows vegetables for sale in Marsabit town (Smith, 1998).

Every 2 months from September 1994 to June 1997, teams of two Rendille enumerators per community surveyed 40 mothers and their children in each of these five communities, gathering information on diet, morbidity, and taking anthropometric measurements (total 202 women and 488 children). Maternal and childhood ages were determined by referral to mothers' immunization records or children's birth papers when possible, and when those were unavailable, by reference to a historic events calendar developed and used in previous Rendille studies in consultation with Rendille field assistants.

To reconstruct dietary patterns a detailed 24-hr dietary recall was performed for mothers and children. Each mother was asked to name foods consumed the previous day by themselves and each of their children. These were recorded separately for morning, afternoon, and evening meals, and included servings of milk, meat, starch (including cooked maize-meal, termed *posho*, porridge made with milk, or whole maize, rice, or wheat-based *chapati* bread), fat, tea, sugar, fruit (e.g., mango, papaya, bananas), or green vegetables, including local kale (in Kiswahili, *sukumu wiki*). Frequency of servings was reported rather than actual amounts consumed (e.g., calories or volume) which were not possible to observe or otherwise measure. An important exception was estimation of the amount of milk consumed based on standard metal cups widely used in the area, such that "one small cup" was listed as one cup, "one large cup" as 1.5 cups and milk served with tea or porridge estimated at 0.25 cups. This scheme introduced standardization to the most important Rendille food source.

Mothers and children were weighed using a CMS hanging scale for children less than 2 years of age and via SECA digital scale for mothers and children over 2. Before weighing began for the project we weighed articles of Rendille dress and clothing, e.g., skirts, skin dresses, strings of beads and determined average weights for specific items. These were deducted from the weight measurements for both mothers and children, depending upon

their apparel each survey date. Heights were determined using a Shorr measuring board. Maternal triceps skinfold thickness (TSF) was measured with a Holtain caliper (Frisancho, 1990), and mid-arm circumferences were obtained via a Roche disposable tape.

Eight Rendille and Ariaal assistants were hired for the 3-year period, working in pairs to conduct the surveys in the same community over the course of the study (one pair surveyed two communities, the others one community each). Initial monitoring of local assistants by the project manager (Fratkin) was repeated at the beginning of each year, and supervised at each survey episode by the team supervisor. While we did not undertake formal tests for interobserver error, for some measurements, exemplified by TSF, observers took three readings and then used the average.

Morbidity data were gathered by asking mothers: (1) the number of days each child was ill in the past month and, (2) the category of disease, e.g., diarrhea, fever and/or respiratory infections ("colds" or "cough"). These three types of illnesses are well known, and mothers showed no problem recalling how many days in a month they were ill.

Finally, families were assigned to one of the three economic strata — poor, middle, and rich — based upon a composite measure of household wealth, livestock holding, wage income, remittances, and household expenditures. For pastoralists, wealth was determined according to the number of animals they owned (indicating both levels of food and access to income) and sold. This was standardized using the concept of Tropical Livestock Units (TLU), based on the Dahl and Hjort (1976, p. 224) scheme in which 1 TLU is the equivalent of 250 pounds of dressed meat, so that 1 TLU = 1 camel, 0.8 cow, or 10 goats/sheep. Pastoral households were classified as "poor" if they owned less than 4.5 TLUs per capita, "middle" if 4.5–7.0 TLU/per capita, and rich if they owned more than 7.0 TLU/per capita. The agricultural community of Songa was stratified based on cash income (poor <US$10 per month, middle as $10–50 per month, and rich if they earned incomes above $50 per month). The criteria for wealth stratification were confirmed by using "indigenous wealth-ranking" methodology developed by Grandin (1983) and successfully applied by Roth (1999) to Rendille households, in which individuals are ranked by a consensus of village men and women including native enumerators. Famine relief, largely in the form of maize and beans distributed by local missions, was available to all study communities. While availability was less for the nomadic community because of distance to distribution points "poor" did not necessarily reflect lack of access to food.

Anthropometric measurements from the five communities produced a total of 5,535 measurements from 488 children from birth to 9 years old (selected as children less than 6 years at the beginning of the 3-year study).

Table I. Age-Specific Measurements of Five Sample Communities

Age in Months	Lewogoso	Ngrunit	Songa	Karare	Korr	Total
0–11	114	202	110	177	162	765
12–23	184	211	161	181	170	907
24–35	215	203	198	173	212	1,001
36–47	187	121	191	161	155	815
48–59	190	109	191	193	191	874
60–71	171	82	146	187	164	750
72+	54	9	108	184	68	423
Total	1,115	937	1,105	1,256	1,122	5,535

In Table I measurements are grouped by community and child's year of age, with the final age category lumping a small group of children aged 6+ years.

We used the computer program EPI-INFO (Center for Disease Control, 1997) to transform sex-specific measures of weight-by-age and height-by-age into standard deviation (Z scores) according to the formula from Stinson (2000, p. 443):

$$Z = \frac{\text{Individual subject score-median reference value}}{\text{Standard deviation in reference population}} \tag{1}$$

This program uses growth reference curves developed by the National Center for Health Statistics (Hamill *et al.*, 1979) and recommended by the World Health Organization (1986) for use in Third World countries. Measurements below two negative standard deviations (-2 Z scores) from the median of the reference population were considered to represent mild-to-moderate malnutrition (World Health Organization, 1986), and to constitute evidence of growth faltering. Specifically, children falling below -2 SD for weight can be considered "wasted," while those below -2 SD for height can be classified as "stunted" (WHO Expert Committee, 1995).

To investigate the determinants of childhood growth patterns we employed Generalized Estimating Equations (GEE) methodology using the SAS® GENMOD program (Statistical Analysis System, 1997). GEE was developed by Liang and Zeger (1986) as a regression modeling approach to deal with correlated data, exemplified here by our longitudinal repeated measures methodology. These repeated measures from any one individual or cluster of individuals are correlated with each other and are therefore no longer independent. Generalized Estimation Equations estimates the correlation between a single individual or cluster's response and provide a correct estimate of each effect's variance. GEE methodology is most commonly employed when the dependent variable is discrete (Allison, 1999, pp. 184–188). Therefore, for this analysis, malnutrition was coded as a dichotomous dependent variable (0 = malnourished, 1 = well-nourished)

for each child every time he/she was surveyed. As throughout, measurements falling below two negative standard deviations from the median of the reference population (<−2 S.D.) were considered to represent mild-to-moderate malnutrition, or "stunting" for height and "wasting" for weight (World Health Organization, 1986).

ANALYSIS AND RESULTS

Longitudinal Patterns of Child Growth

Patterns of child growth based on weight-for-age and height-for-age *Z* scores are shown in Figs. 3 and 4, respectively for the first five age intervals, denoting birth to age 5. These reveal dramatically large differences in the growth patterns of pastoral versus settled children. Age-specific height and weight scores for the pastoral Lewogoso community are always higher than same-aged measurements from the sedentary villages. For the latter, growth faltering, characteristic of many African populations (cf. Eveleth and Tanner, 1990; Little and Leslie, 1999), occurs in both height and weight measures. In contrast this is found only for weight-for-age in the pastoral Lewogoso children, and not nearly to the same extent.

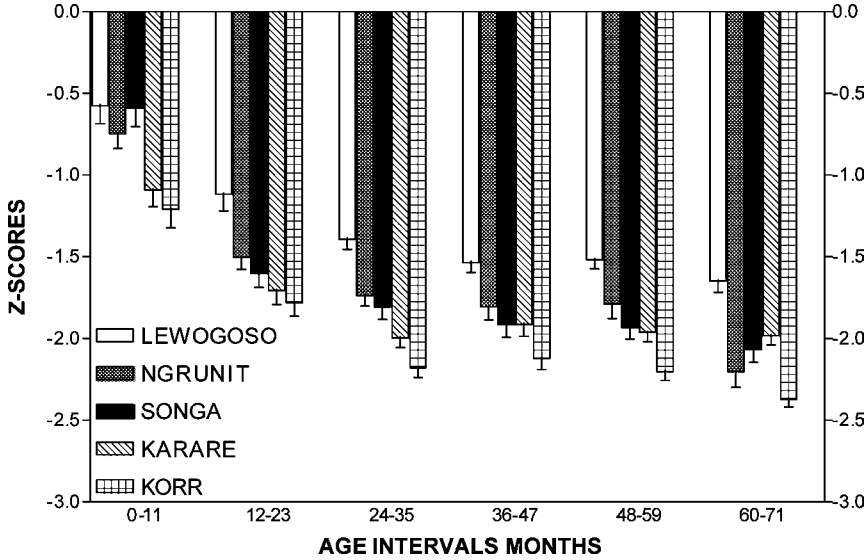

Fig. 3. Weight-by-age *Z* scores, all five communities, means and standard errors of the mean.

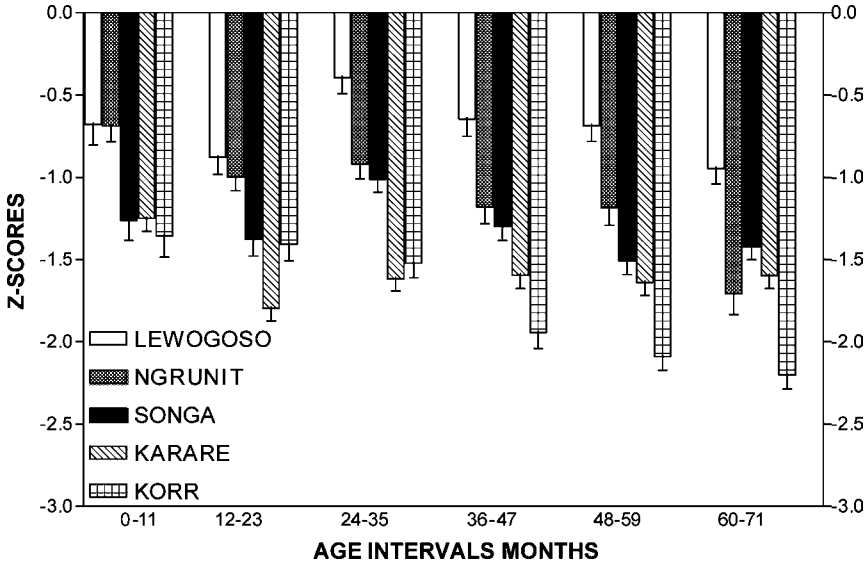

Fig. 4. Height-by-age *Z* scores, all five communities, means and standard errors of the mean.

The underlying differences between the sedentary and pastoral samples are more clearly shown in Figs. 5 and 6. These convert the continuous *Z* score values for both weight-for-age and height-for-age into their respective discrete measures of "wasting" (below -2 *Z* scores for weight) and "stunting" (below -2 *Z* scores for height) for pastoral Lewogoso and the pooled sample of sedentary communities, omitting in both cases the final catch-all category. Presented in this fashion the resulting curves reveal similar patterns. For example, in Fig. 4 wasting rates increase steeply until the third age period (24–35 months) and then remain relatively stable. With respect to stunting as shown in Fig. 6, both curves exhibit sharp increases for the second age period (12–23 months) followed by a decrease in the next (ages 24–35 months). Yet despite similarities in the timing of malnutrition, these data clearly show far lower rates of both wasting and stunting at all ages for children in pastoral Lewogoso compared to the sedentary sample.

Accounting for the Differences

Our next task was to account for the large, consistent differences between children from nomadic and sedentary communities. Previous

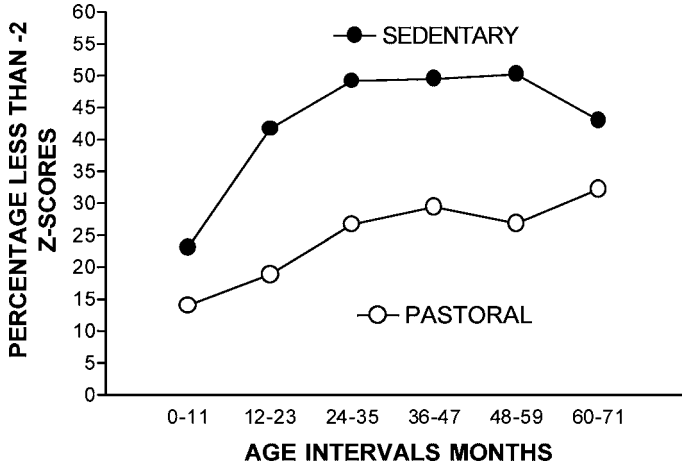

Fig. 5. Measures of malnutrition for weight-by-age, pastoral versus sedentary samples, wasting defined as below −2 *Z* scores.

cross-sectional analyses revealed that these differences arose primarily from dietary change, with milk remaining the staple of the pastoral samples, but replaced by grains in the sedentary groups. As shown in Fig. 7, our earlier cross-sectional results are replicated in these longitudinal data. Pooling

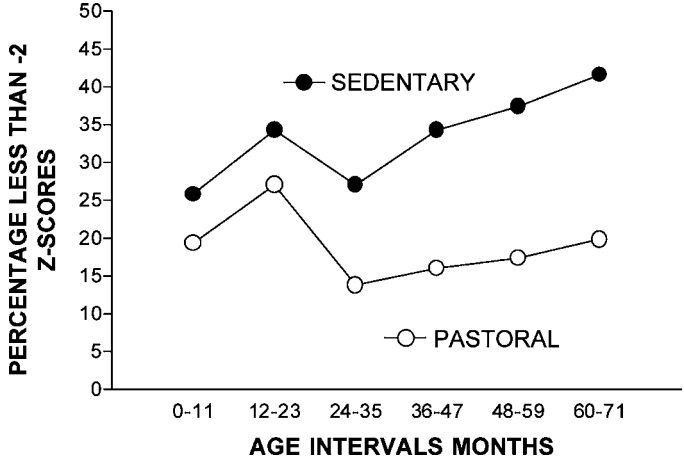

Fig. 6. Measures of malnutrition for height-by-age, pastoral versus sedentary samples, stunting defined as below −2 *Z* scores.

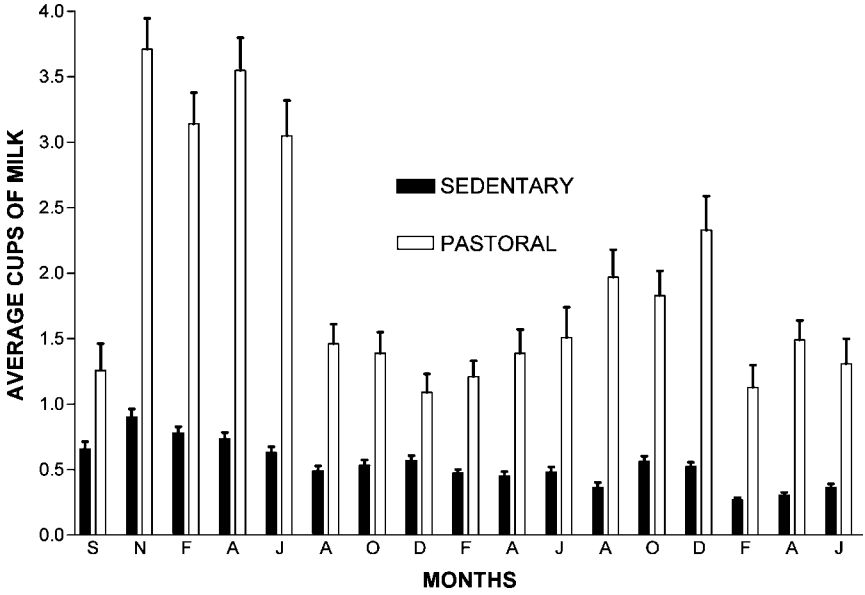

Fig. 7. Daily cups of milk over study period, pastoral versus sedentary samples, means and standard errors of the means.

the sedentary groups again, Fig. 7 shows daily average milk intake measured in cups for pastoral and sedentary children across the study period. This reveals pastoral children having up to three times the average cups of milk relative to children from the four sedentary communities. These large differences remain throughout the study period, even during the drought periods of 1996/7 when milk intake fell for Lewogoso.

To examine the effect of morbidity Fig. 8 again contrasts a combined sedentary sample with children from pastoral Lewogoso, in this case presenting data pooling reported average days ill with fever, diarrhea, and colds over each 2-month sampling interval. Here the contrast between sedentary and nomadic communities is not as dramatic as for milk consumption, and is harder to interpret. For example, only twice in the 17 measurements was the average number of sick days higher for Lewogoso than for the pooled sedentary sample. Yet for many cases these differences are not large.

To examine the relative effect of dietary and morbidity patterns upon childhood malnutrition and to consider additional factors we used GEE methodology. Along with measures of milk consumption and morbidity we considered household economic status, mother's breastfeeding status, and

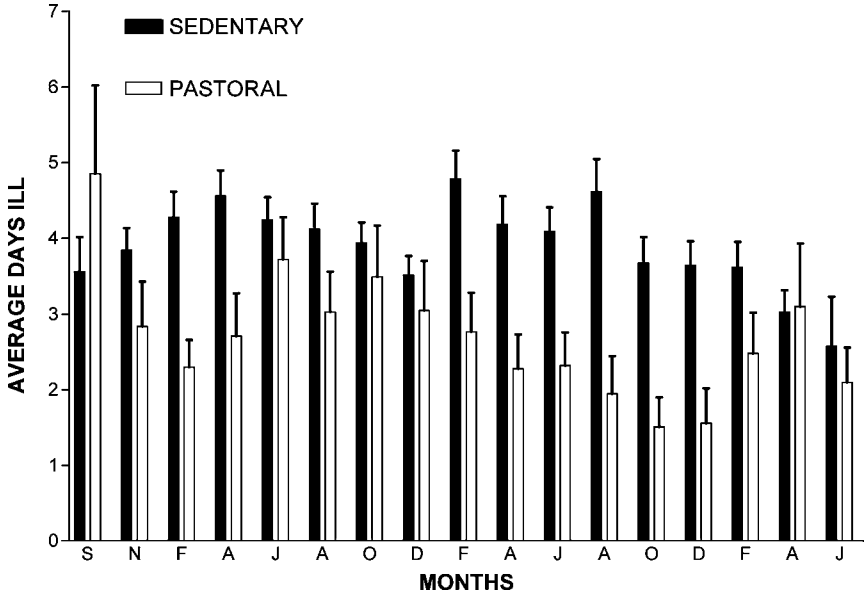

Fig. 8. Days ill over study period, pastoral versus sedentary samples, means and standard errors of the means.

offspring sex as independent variables capable of affecting growth patterns. Household economic status can reflect unequal access to food, while breast-feeding provides protection via maternal immunities as well as a source of nutrition. Sex of offspring is relevant to possible cultural biases in child health care stemming from the Rendille custom of primogeniture (cf., Roth, 2000).

In Table II GEE analysis of the pooled five communities based on all seven age categories is presented separately for weight-by-age and height-by-age. For each run dichotomous and continuous independent variables include the following:

(1) *SEX* — this was converted into a dummy variable coded "0" for males and "1" for females.
(2) *WEALTH* — interviewees were asked to rank their household, as well as their neighbors as either, "Rich," "Sufficient," and/or "Poor." For the present studies different criteria of wealth for sedentary agricultural communities and pastoral Lewogoso (cash income versus animal ownership) led to dichotomizing this variable into "Poor" and "Other" (combining the Rich and Sufficient" strata) groups.

Table II. Analysis of GEE Parameter Estimates, All Five Communities, Total Study Period

Parameter	Estimate	SE	Z	Prob.
Weight-for-age				
Intercept	−0.1456	0.1416	−1.03	0.3037
Breastfed: Yes	−0.6562	0.1311	−5.01	<0.0001
Illness	0.0272	0.0074	3.68	0.0002
Milk	−0.2307	0.0454	−5.08	<0.0001
Wealth: Poor	0.5838	0.1518	3.85	0.0001
Sex: Male	−0.2037	0.1499	−1.36	0.1743
Height-for-age				
Intercept	−0.7954	0.1680	4.74	<0.0001
Breastfed: Yes	0.0183	0.1570	0.12	0.9073
Illness	0.0123	0.0069	1.80	0.0725
Milk	−0.1457	0.0492	−2.96	0.0030
Wealth: Poor	0.5076	0.1438	2.77	0.0056
Sex: Male	−0.3306	0.1803	−1.87	−0.0620

(3) *MILK* — a continuous variable recording cups of milk consumed in the past 24 h.
(4) *ILLNESS* — a continuous variable denoting days ill with diarrhea, respiratory disease, and/or fever in the past 30 days.
(5) *BREASTFEEDING* — coded as a dichotomous variable, e.g., "breastfeeding — yes/no." This variable serves two purpose. First it represents the nutrition–infection synergism as breast milk contains both nutrients and maternal antibodies. Second it serves to partially model the age effect noted in the previous bivariate analyses of age and Z scores, where growth faltering was associated with increasing age in the sedentary communities.

Table II present results, expressed as the GEE parameter estimations associated with *malnutrition*, for height- and weight-for-age measurements for all five communities over the entire study period. Table II (top-half) shows data for the weight-by-age analysis. With the exception of the Sex variable, all independent variables were highly ($p < 0.0001$) statistically significant. As expected, days ill (Illness) was positively associated with wasting ($Z = 3.68$, $p < 0.0002$), while milk consumed (Milk) was even more strongly negatively associated with malnutrition ($Z = -5.08$, $p < 0.0001$). Breastfeeding children were negatively associated with wasting ($Z = -5.01$, $p < 0.0001$), illustrating the beneficial nutritional and anti-infection properties of mother's milk. Economic status (Wealth) showed families from the poor stratum positively associated with wasting ($Z = 3.85, p < 0.0001$). Finally, while not statistically significant, the Sex variable ($Z = -1.36, p = 0.1743$) shows a negative association between boys and malnutrition, indicating that girls are more often wasted.

Many of these relationships hold when considering height-by-age, or stunting, as shown in Table II (bottom-half). Thus Milk retains a strong negative association ($Z = -2.96, p = 0.003$), while poor households represented by the Wealth variable still feature a highly significant positive association ($Z = 2.77, p = 0.0056$). Although retaining the same algebraic signs as in the weight-by-age analysis, both days ill (Illness, $Z = 1.80, p = 0.0725$) and the variable denoting male children (Sex, $Z = -1.87, p = 0.0620$) are statistically nonsignificant, although both are close to the α 0.05 level. Breastfeeding (yes) is nonsignificant for stunting.

As in our 1996 analysis of cross-sectional growth data we next separated weaned children from those still breastfeeding to assess the effects of independent variables when children no longer benefited from maternal nutrition and immunity. We further subdivided this sample of weaned children into survey times characterized by the East African bimodal rainfall pattern and following periods of drought and abnormally heavy rainfall, to see how the independent variables fared under differing environmental conditions. In this scheme the first eight sampling times (September 1994 until December 1995) represented the period of bimodal rainfall pattern (see Fig. 2), while the remaining nine sampling times were either characterized by drought conditions (from February 1996 until February 1997), or by the excessively heavy rainfall (>300 mm) in April 1997.

Tables III and IV present results for these analyses. In Table III, representing non-drought and normal rainfall conditions, the most important independent variables are Milk and Wealth. The former is strongly negatively related to malnutrition for both weight ($Z = -3.56, p < 0.0001$) and height ($Z = -2.52, p < 0.001$). Poverty, coded for by the Wealth variable, is positively associated with malnutrition for both weight ($Z = 4.15, p < 0.0001$) and height ($Z = 3.67, p < 0.0001$). Days ill (Illness) and male children, the

Table III. Analysis of GEE Parameter Estimates, Normal Rainfall

Parameter	Estimate	SE	Z	Prob.
Weight-for-age				
Intercept	−0.2835	0.1806	−1.57	0.1165
Illness	0.0138	0.0115	1.20	0.2321
Milk	−0.2100	0.0590	−3.56	0.0004
Wealth: Poor	0.8533	0.2058	4.15	<0.0001
Sex: Male	−0.3517	0.2033	−1.73	0.0837
Height-for-age				
Intercept	−0.7995	0.2020	−3.96	<0.0001
Illness	0.0067	0.0103	0.65	0.5134
Milk	−0.1522	0.0604	−2.52	0.0118
Wealth: Poor	0.8532	0.2327	3.67	0.0002
Sex: Male	−0.3543	0.2317	−1.53	−0.1262

Table IV. Analysis of GEE Parameter Estimates, Drought, and Heavy Rainfall

Parameter	Estimate	SE	Z	Prob.
Weight-for-age				
Intercept	−0.0229	0.1968	−0.12	0.9073
Illness	0.0405	0.0126	3.20	0.0014
Milk	−0.2996	0.0961	−3.12	0.0018
Wealth: Poor	0.6348	0.2171	2.92	0.0035
Sex: Male	−0.2437	0.2099	−1.16	0.2456
Height-for-age				
Intercept	−0.7520	0.2321	−3.24	0.0012
Illness	0.0200	0.0118	1.69	0.0907
Milk	−0.3811	0.1384	−2.75	0.0059
Wealth: Poor	0.4822	0.2574	1.87	0.0610
Sex: Male	−0.4406	0.2510	−1.76	−0.0792

latter represented by the Sex variables, are not significantly associated with either measure of malnutrition.

Turning to Table IV which present GEE results during drought and heavy rainfall times, Milk is again significantly negatively associated with malnutrition, measured by both weight ($Z = -3.12, p = 0.0018$) and height ($Z = -2.75$, $p = 0.0059$). In contrast, days ill (Illness) is only significant in the analysis of weight-by-age ($Z = 3.20$, $p = 0.0014$). The Wealth variable again shows poor families associated with malnutrition, significantly so for weight-for-age ($Z = 2.92$, $p = 0.0018$), and close to the α 0.05 level for height-for-age ($Z = 1.87$, $p = 0.0610$). While Sex is not statistically significant for either measure, as in all previous analyses it retains a negative algebraic sign, indicating that girls, relative to boys, are more susceptible to malnutrition.

SUMMARY AND DISCUSSION

Examination of longitudinal growth data collected over a 3-year period among Rendille and Ariaal populations in Marsabit District, northern Kenya revealed far poorer growth patterns for children from four sedentary Rendille communities, relative to same-aged children from the pastoral community of Lewogoso. Overall, viewing child growth as an indicator of population health and environmental adaptation (Panter-Brick, 1998), and noting the ill-effects associated with poor growth patterns and resulting small size worldwide (Martorell, 1989; Pelletier, 1994) the sample of children from the pastoral community of Lewogoso can be considered far better adapted to their environment than children from sedentary communities.

As in our previous cross-sectional studies pastoral children's diet featured significantly more milk throughout the entire study period. This finding is hardly surprising since pastoral communities such as Lewogoso have daily access to milk animals, while sedentary communities often are separated from their herds, which spend considerable time in distant *fora* camps far away from the sedentary community. GEE analysis of both breastfeeding and weaned children, with the former separated into times featuring periods of expected rainfall patterns as well as periods of drought and abnormal rainfall levels, always showed milk consumption significantly and negatively associated with both wasting and stunting. We also found morbidity and poor households positively associated with childhood malnutrition. Since sedentism is associated with decreased childhood milk consumption, increased morbidity and household impoverishment, these findings also consistently point to maladaptive biological consequences of sedentism for Ariaal and Rendille children. We also note that these results correspond to those derived from Shell-Duncan and Obiero's (2000) cross-sectional analysis of Rendille childhood growth and health patterns.

At the same time that we make the above observations, we recognize that sedentarization confers both benefits and constraints. In terms of policy implications the real question now is how to reconcile these negative biological findings with other possibly beneficial social consequences of Rendille sedentarization. Included among these benefits are increased access to public education, health facilities, and larger markets, and changing female involvement in all three (Fratkin *et al.*, 1999; Fratkin and Smith, 1995; Roth, 1991). All these factors have the potential to positively influence childhood health. Yet in our opinion at present they do not outweigh the negative childhood health consequences of sedentarization. Indeed, the fact that the pastoral Ariaal sample exhibits better growth patterns in both wet and dry years argues strongly for the pastoral existence as a stronger and more flexible adaptation to the cyclical droughts and accompanying famines that historically and currently characterize East Africa.

Unfortunately, many international development agencies' programs focused on curtailing pastoral movements and abandoning mobile pastoralism, such as USAID projects among the Maasai emphasizing privatization of their range lands and commercialization of pastoral production (Galaty, 1994; Hodgson, 1999). The challenge for the future will be to develop policies that ensure child health under conditions of rapid socioeconomic change represented by the transition from nomadic pastoralism to sedentism, while supporting the persistence of the adaptive pastoral lifestyle.

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