

HUMAN ECOLOGY
An Interdisciplinary Journal

Vol. 19, No. 2

June 1991

CONTENTS

Special Issue: Human Foragers in Tropical Rain Forests

| | |
|--|-----|
| Introduction: Have Hunter-Gatherers Ever Lived in Tropical Rain Forest Independently of Agriculture? <i>Thomas N. Headland and Robert C. Bailey</i> | 115 |
| Foraging in Tropical Rain Forests: The Case of the Penan of Sarawak, East Malaysia (Borneo) <i>J. Peter Brosius</i> | 123 |
| The Possibility of Independent Foraging in the Rain Forest of Peninsular Malaysia <i>Kirk Endicott and Peter Bellwood</i> | 151 |
| Hunting in Lowland, Tropical Rain Forest: Toward a Model of Nonagricultural Subsistence <i>Peter D. Dwyer and Monica Minnegal</i> | 187 |
| Wild Yams Revisited: Is Independence from Agriculture Possible for Rain Forest Hunter-Gatherers? <i>Serge Bahuchet, Doyle McKey, and Igor de Garine</i> | 213 |
| Making a Living in the Tropical Forest: Yuqui Foragers in the Bolivian Amazon <i>Allyn MacLean Stearman</i> | 245 |
| The Tropical Rain Forest: Is It a Productive Environment for Human Foragers? <i>Robert C. Bailey and Thomas N. Headland</i> | 261 |

BRANDEIS UNIVERSITY

DEC 09 1992

LIBRARY

**HUMAN
ECOLOGY**

An Interdisciplinary Journal

- Bjornsson, B. (1971). *The Lutheran Doctrine of Marriage in Modern Icelandic Society*. Universitetsforlaget, Oslo.
- Brookfield, H. C. (1972). Intensification and disintensification in Pacific agriculture: A theoretical approach. *Pacific Viewpoint* 15: 38-48.
- Dewar, R. E. (1984). Environmental productivity, population regulation, and carrying capacity. *American Anthropologist* 86: 601-614.
- Finsson, H. (1796). Um mannfackkum af hallaerum a Islandi [On population decline in famine years]. *Rit thess Konunglega Islenzka Laerdomslista-Felags* 14: 30-226.
- Fridriksson, S. (1972). Grass and grass utilization in Iceland. *Ecology* 53(5): 785-796.
- Gjerstet, K. (1924). *History of Iceland*. Macmillan, New York.
- Goubert, P. (1960). *Beauvais et les Beauvaisis*. Ecole Pratiques des Hautes Etudes, Paris.
- Gunnarsson, G. (1980). A study of causal relations in climate and history with emphasis on the Icelandic experience. In *Meddelande Fraan Ekonomisk-Historiska Institut*. Lunds Universitet 17, Lund.
- Ho Ping-ti (1959). *Studies on the Population of China, 1368-1953*. Harvard University Press, Cambridge.
- Jackson, E. L. (1982). The Laki eruption of 1783: Impacts on population and settlement in Iceland. *Geography* 67(1): 42-50.
- Kirch, P. V. (1984). *Evolution of Polynesian Chiefdoms*. Cambridge University Press, New York.
- McGovern, T. H., Bigelow, G., Amorosi, T., and Russell, D. (1988). Northern islands, human error, and environmental degradation: A view of social and ecological change in the medieval North Atlantic. *Human Ecology* 16(3): 225-270.
- Ogilvie, A. (1985). The past climate and sea-ice record from Iceland, Part 1: Data to A.D. 1780. *Climatic Change* 6: 131-152.
- Rafnsson, S. (1984). Bufe og byggd vid Lok Skaftarelda og Modurhardinda Skaftareldum 1783-1784. Haskoli Islands, Reykjavik.
- Sen, A. (1981). *Poverty and Famine*. Oxford University Press, Oxford.
- Thorarinsson, S. (1969). The Lakagigar eruption of 1783. *Bulletin Volcanologique* 33(3): 910-929.
- Thorarinsson, S. (1979). On the damage caused by volcanic eruptions with special reference to tephra and gases. In Sheets, P. D., and Grayson, D. K. (eds.), *Volcanic Activity and Human Ecology*. Academic Press, New York, pp. 125-160.
- Fomasson, R. (1977). A millennium of misery: The demography of the Icelanders. *Population Studies* 31: 405-425.
- Fomasson, R. (1980). *Iceland: The First New Society*. University of Minnesota Press, Minneapolis.
- Furnbull, C. (1972). *The Mountain People*. Simon and Schuster, New York.
- Vasey, D. E. (1992). *An Ecological History of Agriculture: 10,000 B.C.-A.D. 10,000*. Iowa State University Press, Ames.
- Valford, C. (1970). *Famines of the World: Past and Present*. B. Franklin, New York.
- Vylie, J. (1987). *The Faroe Islands: Interpretations of History*. University Press of Kentucky, Lexington.

Age and Sex Differences in the Impact of Seasonal Energy Stress Among Andean Agriculturalists

William R. Leonard¹

It has been widely argued that children and females are most severely affected during periods of food scarcity. This proposition is tested using dietary and anthropometric data from the Andean community of Nuñoa, Peru. Contrary to expectation, children (ages 12 years and under) are relatively protected from seasonal food scarcity while adults experience severe caloric stress. Anthropometric measures of nutritional status corroborate the dietary analysis, indicating significantly better nutritional status in children. Sex differences in dietary adequacy are not evident. Adult males, however, have significantly poorer measures of nutritional status than adult females. These differences in dietary adequacy and nutritional status reflect adaptations to marked seasonality in work demands and energy availability.

KEY WORDS: energetics; seasonality; nutritional status; adaptation; Peru.

INTRODUCTION

Seasonal fluctuations in food availability have exerted persistent stress on human populations throughout our evolutionary history and continue today to present significant problems to rural populations throughout the world. Although anthropologists have long recognized "seasonal hunger" among subsistence-level populations (Richards, 1939), they have only recently begun to examine the problem in a rigorous and systematic way (de Garine and Harrison, 1988; Huss-Ashmore, 1988; Ferro-Luzzi, 1990).

¹School of Human Biology, University of Guelph, Guelph, Ontario N1G 2W1, Canada.

Consequently, we still know very little about variation in biological and behavioral responses to fluctuations in food availability.

Within a population, it is unlikely that food scarcity affects all sectors of the population equally. Age and sex have been cited as two particularly important axes of variation. Some observers have argued, for example, that children are the most severely affected group during periods of food scarcity since the limited resources must be preferentially allocated to the more "productive" members of the household (Gross and Underwood, 1971; Schofield, 1974; Chen *et al.*, 1979). A similar argument has been made for a general "male bias" in food allocation during times of stress (i.e., preferential allocation to the "producers" of the household) (den Hartog, 1972; Chen *et al.*, 1981; Nelson, 1986). Yet, despite the perception that food is generally preferentially allocated to adults and males during periods of scarcity, very little quantitative data have been collected to evaluate this issue. Indeed, several recent studies have indicated that adult and male biases in food allocation may not be as prevalent as previously thought (Basu *et al.*, 1986; Brahman *et al.*, 1988; Wheeler and Abdullah, 1988; Leonard, 1989).

Thus, the purpose of this paper is explicitly to test the hypothesis that children and women in an agricultural population of the Peruvian Andes are subjected to greater levels of caloric deprivation than adult males. Dietary and anthropometric data are used to determine if there are age and sex differences in caloric adequacy and physical nutritional status (i.e., measures of body size and composition) in this population. The results are then compared with those from other populations in order to generate an ecological model of variation in adaptive responses to seasonal food stress.

METHODS

Research Location

This work was conducted in the Andean (Quechua-speaking) community of Nuñoa, Peru. The community is located in the *altiplano* region of the southern highlands at an elevation of 4000 m (13,100 ft) and has a population of about 4500 individuals (Carey, 1988). Most households within this community participate in small-scale farming and animal herding as well as off-farm wage labor or commercial activities. The primary crops grown in this area are several varieties of tubers and cereals. The five Andean tubers grown in the Nuñoa district are *oca* (*Oxalis tuberosa*), *papa isas* (*Ucullus tuberosa*), *izaños* (*Tropaeolum tuberosum*), and the *dulce* and *amarga* potatoes (*Solanum andigenum* and *S. curtilobaum*, respectively). Cereal grains include the indigenous Chenopods, *quinoa* (*Chenopodium qui-*

noa) and *cañihua* (*C. pallidicaule*), as well as Old World species such as barley (*Hordeae spp.*) and wheat (*Triticum spp.*) (Thomas and Winterhalder, 1976). Domesticated animals include the *llama*, *alpaca*, and sheep, which graze in areas unsuitable for agriculture.

Precipitation in the southern Peruvian *altiplano* averages 830 mm/yr and is almost entirely limited to September through April (Thomas and Winterhalder, 1976). This restricted distribution of rainfall over the course of the year severely limits agricultural production. All planting occurs between late September and November at the beginning of the wet season. The crops are harvested in late April through early June when the dry season begins.

Given the highly seasonal nature of agricultural production, resource exchange and food storage techniques have traditionally been quite important in the Peruvian highlands (Werge, 1979; Masuda *et al.*, 1985). In Nuñoa, the production of freeze-dried potatoes (e.g., *chuño*, *moraya*) after the harvest is still widely practiced. These items, along with dried *llama* and *alpaca* meat (*charqui*), compose a significant portion of the diet during the lean periods of the year (Leonard, 1988).

The present study was carried out between January and August of 1985. It was planned to take place over a period when food availability could be expected to vary significantly (i.e., the last few months before the harvest through the post-harvest). Due to late frosts, cereal production in Nuñoa was poor in 1985. Production of potatoes and other tubers, on the other hand, was above average.

Sample and Measures

These data were collected in the context of a larger study that examined the biosocial responses to illness in this population (Thomas *et al.*, 1988). Seasonal health and demographic surveys were conducted in 1983–1984 on a random sample of 96 Nuñoan households (11% of the total population) (Leonard, 1987; Leatherman, 1987; Thomas *et al.*, 1988; Carey, 1988). Of these, a subsample of 33 households was targeted for more intensive time allocation (Tucker, 1987) and nutritional (Leonard, 1987) surveys in 1985.

The present study examines dietary and anthropometric data from 26 Nuñoan households of lower socioeconomic status (SES) that were monitored from January through August of 1985. Lower SES families were defined as those with a head of household who did not have a steady source of off-farm income (Leonard and Thomas, 1988, 1989). Analyses were carried out only on those individuals for whom there were both dietary and complete anthropometric data ($n = 101$) (cf. Leonard and Thomas, 1988).

Individual daily food consumption was monitored by direct food weighings. Prior to each meal, the amounts of each food item were weighed. During the meal itself, individual portions and amounts unconsumed were weighed as well. Caloric and nutrient intakes were calculated using standard nutritional tables for Andean food items (Wu Leung and Flores, 1961; Collazos *et al.*, 1975; Ministerio de Previsión y Salud Pública, 1979).

Anthropometric measures included height, weight, mid-arm circumference and triceps, and subscapular skinfold thicknesses. Age and sex-specific means and standard deviations for these measures are presented in Table I. All individuals were measured in their homes with clothes but without shoes. Corrections for the weight of clothing were made using the procedure outlined by Frisancho (1969) from his previous anthropometric study of this population.

RESULTS

Energy Consumption and Dietary Adequacy

There are dramatic caloric reductions during the last few months before the harvest in Nuñoa. During the pre-harvest months, daily energy intakes (mean \pm SE) for adult males and females are 1468 ± 83 and 1327 ± 65 kcal/day, respectively, as compared to 2068 ± 158 and 1919 ± 170 kcal/day during the post-harvest period ($t\sigma = 3.36$, $p < 0.01$; $t\phi = 3.26$, $p < 0.01$). Figure 1 shows the seasonal changes in average daily caloric intakes for all age/sex cohorts. Note that for each cohort, energy intake during the post-harvest is greater than that of the pre-harvest. However, the magnitude of these changes, both absolutely and relatively, is far greater in adults than in children. The adolescent pattern appears to be more similar to that of the adults. However, this latter pattern remains somewhat equivocal because of the small sample size in this age cohort.

It therefore appears that children experienced relatively *less* seasonal energy stress than adults. To test explicitly this proposition, daily energy requirements for each member of the sample were estimated following the general protocol outlined by Leslie *et al.* (1984). Information on age, sex, and body composition were used to estimate resting metabolic requirements (Torún, 1984). Energy costs of daily activities, thermoregulation and reproductive factors (i.e., pregnancy and lactation) were estimated from data presented in Leslie *et al.* (1984, Tables I, IV, and V). From estimates of daily energy expenditure, caloric adequacy for individuals in the sample was calculated as:

Table I. Anthropometric Characteristics of a Sample of 101 Individuals from Nuñoa, Peru^a

| Age group | Sex | n | Height (cm) | Weight (kg) | Skinfold ^b (mm) | Arm circ. ^c (cm) | A.M.A. ^d (cm ²) |
|-----------|-----|----|------------------|----------------|----------------------------|-----------------------------|--|
| 2-3 | m/f | 10 | 84.9 \pm 5.1 | 12.7 \pm 1.6 | 15.1 \pm 2.8 | 14.8 \pm 0.8 | 10.9 \pm 1.0 |
| 4-6 | m/f | 15 | 100.9 \pm 5.5 | 16.6 \pm 2.7 | 12.9 \pm 3.3 | 15.8 \pm 1.3 | 13.9 \pm 1.9 |
| 7-9 | m/f | 12 | 115.9 \pm 7.2 | 21.6 \pm 3.4 | 12.1 \pm 2.7 | 16.7 \pm 1.0 | 16.3 \pm 1.7 |
| 10-12 | m/f | 10 | 123.9 \pm 7.2 | 27.3 \pm 3.3 | 14.2 \pm 3.8 | 18.3 \pm 1.0 | 19.9 \pm 1.8 |
| 13-15 | f | — | — | — | — | — | — |
| 16-19 | f | 1 | 150.0 | 44.3 | 17.1 | 21.5 | 27.3 |
| 20-40 | f | 18 | 147.4 \pm 5.9 | 50.3 \pm 4.8 | 23.5 \pm 5.6 | 24.2 \pm 1.3 | 33.9 \pm 2.7 |
| 41-70 | f | 7 | 142.2 \pm 5.6 | 45.5 \pm 5.8 | 20.9 \pm 5.2 | 23.2 \pm 2.0 | 32.6 \pm 4.4 |
| 13-15 | m | 5 | 142.9 \pm 12.7 | 34.7 \pm 4.6 | 13.2 \pm 1.8 | 19.9 \pm 1.2 | 24.2 \pm 3.8 |
| 16-19 | m | 3 | 156.8 \pm 4.2 | 53.3 \pm 3.3 | 16.3 \pm 2.6 | 23.7 \pm 0.9 | 36.9 \pm 2.1 |
| 20-40 | m | 11 | 155.2 \pm 3.6 | 54.2 \pm 5.0 | 13.5 \pm 3.0 | 25.5 \pm 1.6 | 45.2 \pm 7.1 |
| 41-70 | m | 9 | 156.3 \pm 6.5 | 57.4 \pm 6.5 | 13.9 \pm 4.3 | 25.8 \pm 1.3 | 45.8 \pm 4.5 |

^a Values are given as Mean \pm SD.

^b Sum of triceps and subscapular skinfold thicknesses.

^c Mid-arm circumference.

^d Cross-sectional upper arm muscle area.

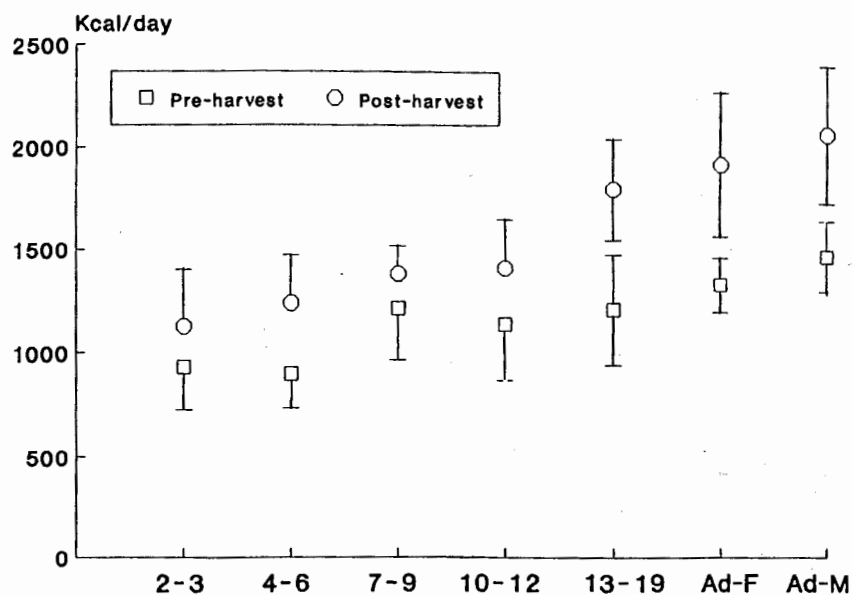
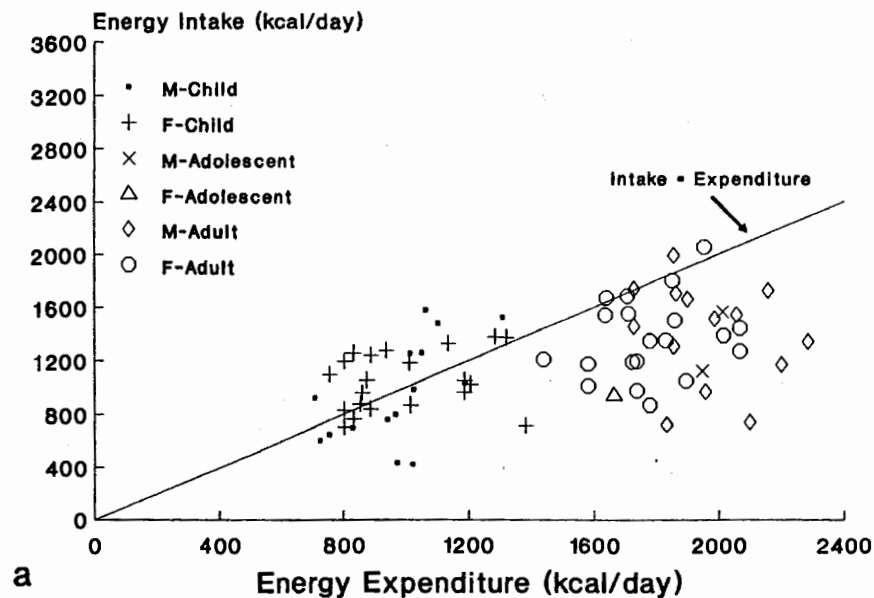


Fig. 1. Daily energy consumption (kcal) during pre- and post-harvest periods for a sample of individuals from Nuñoa, Peru. Values are given as means with the 95% confidence intervals.

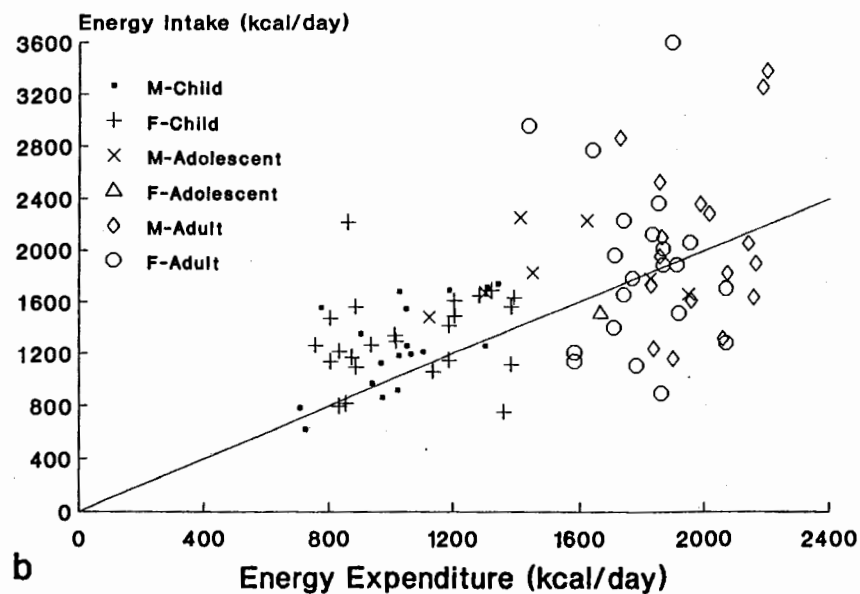
$$\text{Adequacy} = \frac{[\text{Daily Energy Intake}]}{[\text{Predicted Energy Expenditure}]}$$

Data on individual caloric intakes and expenditures for the pre- and post-harvest periods are presented in Figs. 2a and b. Daily energy intakes are plotted against predicted energy requirements for each of the seasonal samples. The solid lines delimit the thresholds for caloric balance (i.e., Intake = Expenditure). From these graphs, two points are quite clear: (1) energy stress is much more pronounced during the pre-harvest phase, and (2) adolescents (13–19 yr) and adults (20 yr and older) are subjected to greater caloric deprivation than children (2–12 yr).

Table II provides a summary of the data presented in Figs. 2a and b showing the mean caloric adequacy for children (ages 2–12 yr) and adults (20 yr and older) during the pre- and post-harvest periods, respectively. Note that during the post-harvest period, both cohorts, on average, exceed their daily energy requirements (1.26 and 1.06), and do not significantly differ. Dietary consumption during the pre-harvest, however, is adequate



a



b

Fig. 2. Plot of energy intake vs. energy expenditure (kcal/day) during the (a) pre- and (b) post-harvest periods for a sample of individuals from Nuñoa, Peru. Solid lines delimit the threshold for meeting caloric needs. Thus, individuals above the line are in positive energy balance, while those below the line are in negative balance. Note that during the pre-harvest period, caloric adequacy is much higher in children than it is in adolescents and adults.

Table II. Comparison of Caloric Adequacy in Nuñoan Children and Adults During the Pre- and Post-harvest Periods^a

| Sample | Children | | | Adults | | |
|---------------------|----------|------|------|----------|-------------------|------|
| | <i>n</i> | Mean | SE | <i>n</i> | Mean | SE |
| Pre-harvest: | | | | | | |
| Males | 15 | 0.98 | 0.08 | 14 | 0.72 ^b | 0.06 |
| Females | 21 | 1.08 | 0.06 | 20 | 0.77 ^c | 0.04 |
| Total | 36 | 1.04 | 0.05 | 34 | 0.74 ^c | 0.03 |
| Post-harvest | | | | | | |
| Males | 18 | 1.23 | 0.07 | 17 | 1.04 | 0.08 |
| Females | 24 | 1.29 | 0.08 | 21 | 1.08 | 0.10 |
| Total | 42 | 1.26 | 0.06 | 38 | 1.06 | 0.07 |

^a Caloric Adequacy = [Daily Energy Intake]/[Predicted Energy Requirements].

^b Significant difference between children and adults, $p < 0.05$.

^c Significant difference between children and adults, $p < 0.001$.

only among the children (1.04 times predicted needs), while the intakes of adults are less than 75% of their predicted needs and are significantly lower than those of the children ($t = 4.98$, $p < 0.001$).

The same patterns are evident when the child-adult comparisons were restricted to individuals of the same sex. Caloric adequacy at pre-harvest is significantly greater in young boys than in men (0.98 vs. 0.72; $t = 2.50$, $p < 0.05$). Likewise, young girls have a more adequate pre-harvest diet than women (1.08 vs. 0.77; $t = 4.60$, $p < 0.001$).

Sex differences in caloric adequacy, on the other hand, are not apparent in either of the cohorts. As seen in Table II, caloric intakes for boys and girls under age 12 are comparable, averaging 98% and 108% of predicted needs, respectively, during the pre-harvest period ($t = 1.17$; n.s.) and 123% vs. 129% ($t = 0.57$; n.s.) after the harvest. Similarly, adult males and females do not differ in dietary adequacy during either seasonal phase (0.72 vs. 0.77 [$t = 0.75$; n.s.] at pre-harvest; 1.04 vs. 1.08 [$t = 0.28$; n.s.] at post-harvest).

Therefore, contrary to expectations, children appear to be relatively protected from pre-harvest food scarcity, while adolescents and adults appear to experience higher levels of caloric stress. There is, however, no evidence of a male bias in nutritional adequacy. In fact, adult males, the group most often viewed as being "preferentially fed," have the lowest caloric adequacy of the four cohorts examined in Table II.

Table III. Comparison of Anthropometric Measures of Nutritional Status Between Nuñoan Children and Adults^a

| Measure | Children | Adults |
|------------------|-------------------------------------|-------------------------------------|
| | (<i>n</i> = 47; $\bar{X} \pm SE$) | (<i>n</i> = 45; $\bar{X} \pm SE$) |
| Weight-for-age | -0.89 \pm 0.14 | -1.20 \pm 0.11 ^b |
| Height-for-age | -2.16 \pm 0.22 | -2.20 \pm 0.14 |
| Weight-for-ht | +0.28 \pm 0.14 | -0.44 \pm 0.07 ^c |
| Sum of skinfolds | -0.55 \pm 0.16 | -1.30 \pm 0.08 ^c |
| Arm muscle area | -1.16 \pm 0.07 | -0.99 \pm 0.11 |

^a Anthropometric measures of nutritional status (weight-for-age, height-for-age, weight-for-height [BMI], sum of triceps and subscapular skinfolds, and arm muscle area) are standardized as Z-scores relative to U.S. norms presented in Frisncho (1990).

^b Significant difference between children and adults, $p < 0.05$.

^c Significant difference between children and adults, $p < 0.001$.

Anthropometric Measures of Nutritional Status

The physical implications of these food allocation patterns are evaluated using the anthropometric data. To assess relative nutritional status, the anthropometric measures were standardized as Z-scores (standard deviation units) relative to U.S. age- and sex-specific norms established by Frisncho (1990).

Table III presents five measures of nutritional status for children and adults: weight-for-age, height-for-age, weight-for-height, sum of triceps, and subscapular skinfolds and mid-arm muscle area. For three of the five anthropometric measures, the children are significantly closer to their U.S. counterparts than the adults. For summed triceps and subscapular skinfold thicknesses, a good measure of overall caloric/nutrient reserves, Nuñoan children average 0.55 standard deviation units below their U.S. peers, while the adults are about 1.3 SD units below their U.S. counterparts ($t = 4.22$, $p < 0.001$). Likewise for weight, children have a mean Z-score of -0.89 vs. -1.20 for adults ($t = 1.92$, $p < 0.05$). Weight-for-height shows the same pattern with children averaging above the 50th U.S. percentile ($Z = +0.28$), while adults fall almost half a standard deviation below their U.S. counterparts ($Z = -0.44$, $t = 4.46$, $p < 0.001$). Physical status of the children is thus demonstrably better than that of adults, corroborating the results from the dietary data.

Similarly, Table IV demonstrates the general lack of a sex difference in growth patterns for children ages 12 and under. Z-scores of height-for-age, weight-for-age, weight-for-height, and sum of skinfolds do not significantly differ between males and females. Arm muscle area is the measure

Table IV. Comparison of Anthropometric Measures of Nutritional Status Between Male and Female Nuñoan Children and Adults^a

| Measure | Children | | Adults | |
|--------------|-------------------------------------|---------------------------------------|-------------------------------------|---------------------------------------|
| | Male (n = 21; $\bar{X} \pm SE$) | Female (n = 26; $\bar{X} \pm SE$) | Male (n = 20; $\bar{X} \pm SE$) | Female (n = 25; $\bar{X} \pm SE$) |
| Weight-age | -1.17 ± 0.16 | -0.67 ± 0.21 | -1.55 ± 0.15 | -0.92 ± 0.14 ^c |
| Height-age | -2.39 ± 0.30 | -1.98 ± 0.30 | -2.28 ± 0.18 | -2.13 ± 0.20 |
| Weight-ht | +0.24 ± 0.18 | +0.32 ± 0.21 | -0.70 ± 0.11 | -0.25 ± 0.08 ^c |
| Sum skinfold | -0.35 ± 0.25 | -0.71 ± 0.20 | -1.43 ± 0.10 | -1.20 ± 0.13 |
| A.M.A. | -1.33 ± 0.10 | -1.01 ± 0.09 ^b | -1.59 ± 0.12 | -0.51 ± 0.08 ^c |

^a Anthropometric measures of nutritional status (weight-for-age, height-for-age, weight-for-height [BMI], sum of triceps and subscapular skinfolds, and arm muscle area) are standardized as Z-scores relative to U.S. norms presented in Frisancho (1990).

^b Significant difference between boys and girls, $p < 0.05$.

^c Significant difference between adult men and women, $p < 0.01$.

that differs significantly, with *males* showing lower relative musculature (-1.33 vs. -1.01; $t = 2.37$, $p < 0.05$). These results are therefore consistent with our finding that there was little difference in dietary adequacy between male and female children, particularly during times of stress.

As for the adults, the anthropometric measures indicate that males are being subjected to more severe stress. Table IV shows that for three of the measures of nutritional status (weight-for-age, weight-for-height, and arm musculature) men are significantly worse than women. Most notable is the difference in relative musculature which is more than a full standard deviation unit ($Z = -1.59$ vs. -0.51 ; $t = 7.85$, $p < 0.001$).

Seasonal fluctuations in body weight for adult males and females averaged 1.8 and 1.2 kg, respectively, or roughly 2.5–3.5% of body weight. Females tend to lose the weight as fat, as was seen by the large changes in upper arm fat (seasonal change in arm fat area = 2.42 cm²). Males, on the other hand, show declines in lean muscle mass, as evidenced by the changes in arm muscle area (seasonal change = 1.49 cm²) (Leonard and Thomas, 1989). Both the magnitude of declines and the tendency for females to lose fat while males lost lean tissue are consistent with previous work on energy-stress populations of Latin America (Stini, 1972, 1975) and Africa (Rosetta, 1986). Females also show an age-related decline in body fatness as triceps skinfold measures are negatively correlated with age among the women of this sample ($r = -0.455$, $p \leq 0.02$). This decline is probably attributable to the cumulative metabolic costs of pregnancy and lactation combined with effects of seasonal food scarcity.

Overall, differences in anthropometric measures of nutritional status are consistent with those seen in dietary adequacy. Children have substantially better nutritional status than adults. Sex differences in physical status are not evident in the children's cohort. Among adults, however, males have poorer nutritional status than females, with reduced muscularity of adult males being particularly notable.

DISCUSSION

These results can be understood by looking at how they fit within the context of the subsistence ecology of this population. In particular, two characteristics of the subsistence economy seem to be relevant. First, there is a lack of well-defined sexual or age-related division of labor. In other words, there are very few subsistence tasks that necessitate male labor (Thomas, 1973). At harvest time all family members except the youngest children help out in the field. Herding the animals and collecting fuel for

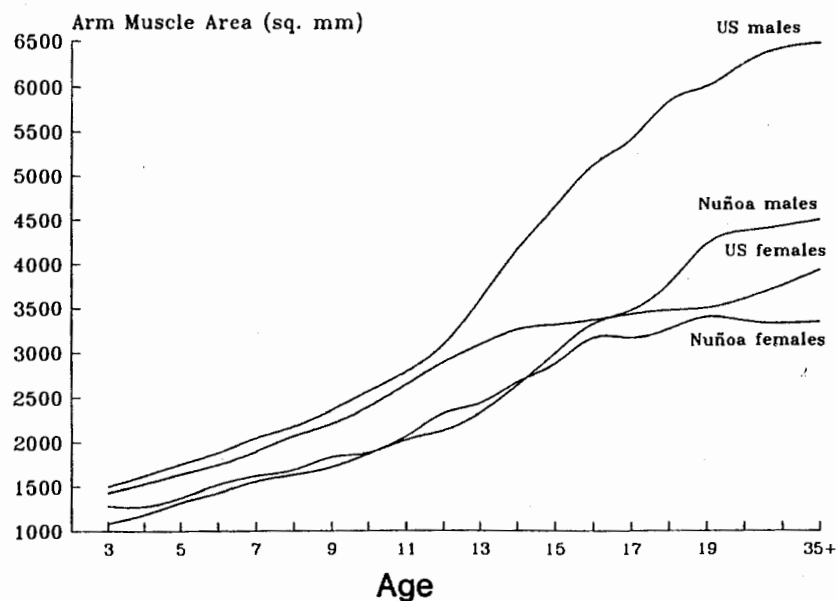


Fig. 3. Comparison of mid-arm muscle area for males and females of Nuñoa and U.S. samples. The data indicate differential reduction of muscle mass in adult Nuñoan males—males fall below the 5th percentile relative to U.S. norms whereas females fall between the 25th and 50th percentile. Nuñoa data are from Leatherman (1987) and U.S. data are from Frisancho (1990).

cooking fires is generally the responsibility of older children (age 9–12; Tucker, 1987). One of the few tasks that truly requires the strength of adult males is the preparation of fields for planting.

The second, corollary aspect, of this economy is the high seasonality of adult (particularly male) work requirements with periods of high labor demand being very restricted. Specifically, the pre-harvest period is a time of very low agricultural work requirements with more time being spent sleeping and in low energy activities such as spinning wool. Critical year-round household maintenance activities such as herding animals and collecting fuel for cooking fires are carried out by children (Leonard and Thomas, 1989).

Therefore, by reducing their activity and drawing on their own physical reserves during times of food scarcity the adults (particularly males) are able to protect their children from severe energy stress. The biological cost of this strategy, however, is evident in Fig. 3 which compares arm muscle area from a sample of over 1500 Nuñoan residents (Leatherman, 1987)

to the U.S. reference values compiled by Frisancho (1990). Note that throughout childhood (under age 12 yrs), there is little sexual dimorphism in muscularity in either the U.S. or Nuñoan samples. During the adolescent years, however, Nuñoan males depart much more sharply from their U.S. counterparts than do the Nuñoan females. Among Nuñoan adults, male muscularity falls below the 5th U.S. percentile while females fall between the 25th and 50th percentiles. Hence, severe seasonal energy stress among adolescents and adults appears to be contributing to delayed maturation and reduced sexual dimorphism in muscularity (cf. Frisancho and Baker, 1970; Leonard *et al.*, 1990).

Stini (1972, 1975) has argued that reduction of male muscularity during periods of nutritional stress represents an adaptive strategy for “scaling down” populational energy requirements. Since muscle tissue is more metabolically active than adipose tissue (i.e., has a larger blood supply and uses more oxygen), reduced muscularity in males serves to substantially reduce the total energy requirements of the largest members of the population. Such reductions, however, place limitations on male strength and working capacity (Spurr, 1984), and therefore would seem to be “adaptive” only under conditions in which the subsistence economy *does not* place a premium on male strength (i.e., well-defined sexual division of labor), as is the case in Nuñoa. Under conditions that dictate well-defined division of subsistence activities, we therefore expect to find preferential feeding of males to promote pronounced sexual dimorphism in muscularity.

The first set of conditions appear to be evident among African pastoral populations as well as Andean agriculturalists. These populations display great flexibility in household social organization in adapting to environments characterized by low productivity and unpredictability (for the Andes, see Thomas, 1979; Guillet, 1983; for African pastoralists, see Galvin, 1985). In both groups, children and adolescents are responsible for several aspects of household production, most notably the herding of livestock. Moreover, the pattern of preferential food allocation and higher nutritional status in children has recently been reported for several African pastoral groups (Benefice *et al.*, 1984; Galvin, 1985)² and other Andean populations (Graham, 1987).

The second set of conditions seem to be found among populations of southern India where agriculture is dependent upon the seasonal rains of the monsoons (Maclachlan, 1983; Stini, 1988). Maclachlan (1983) has argued that among the Yaavahalli villagers of the Kolar district of southern

²Galvin's (1985) results on the Turkana pastoralists of Kenya are strikingly similar to those presented in this paper in that: (1) children have more adequate diets, (2) nutritional status is significantly better among children, and (3) physical status, particularly muscularity, is poor among adult males.

India, high nutritional status of adult males (i.e., large body size and high muscularity) is critical to the survival of the population since agricultural activities require great strength and working capacity. According to Maclachlan's thesis, adaptation to seasonal constraints involves socio-cultural practices that accentuate male/female differences in activity patterns and body composition. Under these conditions one would expect that adolescent and adult males would receive preferential food allocation. Recent work by Edmundson and Edmundson (1988) in a similar monsoon-based agricultural region of India confirm this: energy consumption and nutritional status were found to be substantially better in adult males than in adult females.

In sum, these comparative data clearly indicate that there is considerable variation in the ways in which subsistence-level populations cope with seasonal fluctuations in food availability and labor requirements. Similarly, there is not a consistent male or adult bias in the impact of food scarcity across populations. Rather, it appears that intra-population variation in nutritional stress is a direct correlate of a population's adaptation to its particular environmental constraints.

CONCLUSIONS

In conclusion, it is evident that within this Andean agricultural community adults, rather than children, are subjected to higher levels of seasonal caloric stress. Children have a more adequate pre-harvest diet and better physical nutritional status than adults. Sex differences in nutritional adequacy or physical status are not apparent among children. Among adults, however, males appear to be subjected to greater amounts of stress as evidenced by their very low pre-harvest energy intakes (averaging only 72% of predicted needs) and poor measures of nutritional status.

The differential impact of nutritional stress on this population is explained in terms of an integrated strategy in response to seasonal food scarcity (Fig. 4). Under conditions of seasonal energy stress, adult dietary consumption declines sharply and produces reduced activity levels and a negative caloric balance. The children's diet, on the other hand, is relatively more adequate, allowing them to maintain a positive caloric balance while continuing to carry out critical household activities such as pasturing animals and collecting fuel. Thus, minimizing seasonal fluctuations in energy intake for children: (1) helps maintain adequate nutritional status among the most physiologically vulnerable members of the population (Frisancho, 1981), and (2) allows for important household chores to be carried out at the least energetic cost to the household (Thomas, 1976). The cost of this

Responses to Seasonal Food Stress

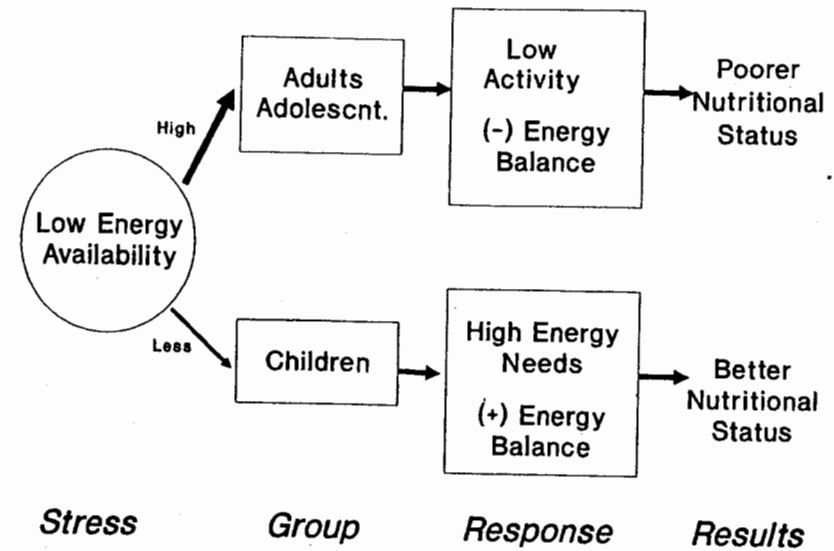


Fig. 4. The flow diagram depicts the adaptive strategies used by small farmers in Nuñoa, Peru in response to seasonal food stress. During periods of pre-harvest food scarcity, adults and adolescents are subjected to severe caloric deprivation whereas children are relatively protected. Adults and adolescents responded to this stress by reducing daily activities and utilizing fat and muscle stores for energy. Children, on the other hand, were better able to carry out their daily activities while maintaining positive caloric balance. Overall, such a strategy allows for critical activities (e.g., herding the animals, collecting fuel) to be maintained at the least energetic cost to the household. Moreover, it produces relatively higher nutritional status in children who are developmentally immature and thus more susceptible to environmental insults.

strategy, however, is poor nutritional status in adolescents and adults (particularly males) of this population.

ACKNOWLEDGMENTS

This research was supported by grants from the National Science Foundations (BNS-8306-186, to B. Thomas), Rackham Graduate School, the University of Guelph Research Board, the Wenner-Gren Foundation (#5318), and the Natural Sciences and Engineering Research Council of Canada.

REFERENCES

- Basu, A., Roy, S. K., Mukhopadhyay, B., Bharati, P., Gupta, R., and Majumber, P. P. (1986). Sex bias in intrahousehold food distribution: Roles of ethnicity and socioeconomic characteristics. *Current Anthropology* 27: 536-539.
- Benefice, E. S., Chevassus, A., and Barral, H. (1984). Nutritional situation and seasonal variations for pastoralist populations of the Sehel (Senegalese Ferlo). *Ecology of Food and Nutrition* 14: 229-247.
- Brahmam, G. N. V., and Sastry, J. G., and Rao, N. P. (1988). Intra-family distribution of energy—an Indian experience. *Ecology of Food and Nutrition* 22: 125-130.
- Carey, J. W. (1988). Health, Social Support and Social Networks in a Rural Andean Community of Southern Peru. Ph.D. dissertation, University of Massachusetts, Amherst.
- Chen, L. C., Chowdhury, K. M. A., and Huffman, S. L. (1979). Seasonal dimensions of energy-protein malnutrition in rural Bangladesh: The role of agriculture, dietary practices and infections. *Ecology of Food and Nutrition* 8: 175-187.
- Chen, L. C., Huq, E., and D'Souza, S. (1981). Sex bias in the family allocation of food and health care in rural Bangladesh. *Population Development Review* 7: 55-70.
- Collazos, C., White, P. H., White, H. S., Viñas, E., Alvistur, E., Uriqueta, R., Vasquez, J., Dias, C., Quiroz, A., Roca, A., Hegsted, D. M., Herrera, N., Fachin, A., Robles, N., Hernandez, E., and Bradfield, R. B. (1975). *La Composición de los Alimentos Peruanos (Quiuta Ed.)*. Ministerio de Salud, Lima.
- de Garine, I., and Harrison, G. A. (eds.) (1988). *Coping with Uncertainty in Food Supply*. Oxford University Press, Oxford.
- den Hartog, A. P. (1972). Unequal distribution of food within the household. *Nutrition Newsletter* 10: 8-17.
- Edmundson, W. C., and Edmundson, S. A. (1988). Food intake and world allocation of male and female farmers in an impoverished Indian village. *British Journal of Nutrition* 60: 433-439.
- Ferro-Luzzi, A. (ed.) (1990). Biology of adaptation to seasonal cycling of energy intake. *European Journal of Clinical Nutrition* 44(Suppl. 1): 1-125.
- Frisancho, A. R. (1969). Human Growth, Physique and Pulmonary Function at High Altitude: A Field Study of a Peruvian Quechua Population. Ph.D. dissertation, Pennsylvania State University, University Park, Pennsylvania.
- Frisancho, A. R. (1981). *Human Adaptation: A Functional Interpretation*. University of Michigan Press, Ann Arbor.
- Frisancho, A. R. (1990). *Anthropometric Standards for the Assessment of Growth and Nutritional Status*. University of Michigan Press, Ann Arbor.
- Frisancho, A. R., and Bakter, P. T. (1970). Altitude and growth: A study of the patterns of physical growth of a high altitude Quechua population. *American Journal of Physical Anthropology* 32: 279-292.
- Galvin, K. (1985). Food Procurement, Diet, Activities, and Nutrition of the Ngisonyoka Turkana Pastoralists in an Ecological and Social Context. Ph.D. dissertation, State University of New York, Binghamton.
- Graham, M. A. (1987). Seasonal variation and hunger in Andean households. *American Anthropological Association Abstracts* 1987: 183.
- Gross, D. R., and Underwood, B. A. (1971). Technological change and caloric costs: Sisal agriculture in northeastern Brazil. *American Anthropologist* 73: 725-740.
- Guillet, D. (1983). Toward a cultural ecology of mountains: The central Andes and the Himalayas compared. *Current Anthropology* 24: 561-574.
- Huss-Ashmore, R. (ed.) (1988). Coping with seasonal constraints. *MASCA Research Papers* 5: 1-141.
- Leatherman, T. L. (1987). Illness, Work and Social Relations in the Southern Peruvian Highlands. Ph.D. dissertation, University of Massachusetts, Amherst.
- Leonard, W. R. (1987). Nutritional Adaptation and Dietary Change in the Southern Peruvian Andes. Ph.D. dissertation, University of Michigan, Ann Arbor.

- Leonard, W. R. (1988). Nutritional strategies in the rural Andes and their impact on growth, development and mortality. *Homo* 39: 65-78.
- Leonard, W. R. (1989). Protection of children from seasonal nutritional stress in an Andean agricultural community. *European Journal of Nutrition* 43: 597-602.
- Leonard, W. R., and Thomas, R. B. (1988). Changing dietary pattern in the Peruvian Andes. *Ecology of Food and Nutrition* 21: 245-263.
- Leonard, W. R., and Thomas, R. B. (1989). Biosocial responses to seasonal food stress in highland Peru. *Human Biology* 61: 65-85.
- Leonard, W. R., Leatherman, T. L., Carey, J. W., and Thomas, R. B. (1990). Contributions of nutrition versus hypoxia to growth in rural Andean populations. *American Journal of Human Biology* 2: 613-626.
- Leslie, P. W., Bindon, J. R., and Baker, P. T. (1984). Caloric requirements of human populations: A model. *Human Ecology* 12: 137-162.
- MacLachlan, M. D. (1983). *Why They Did Not Starve*. ISHI, Philadelphia.
- Masuda, S., Shimada, I., and Morris, C. (eds.) (1985). *Andean Ecology and Civilization*. University of Tokyo Press, Tokyo.
- Ministerio de Previsión Social y Salud Pública (1979). *Tabla de Composición de los Alimentos Bolivianos*. Instituto Nacional de Laboratorios de Salud, La Paz.
- Nelson, M. (1986). The distribution of nutrient intake within families. *British Journal of Nutrition* 55: 267-277.
- Richards, A. (1939). *Land, Labour, and Diet in Northern Rhodesia: An Economic Study of the Bemba Tribe*. Oxford University Press, Oxford.
- Rosetta, L. (1986). Sex differences in seasonal variations of the nutritional status of Serere adults in Senegal. *Ecology of Food and Nutrition* 18: 231-244.
- Shofield, S. (1974). Seasonal factors affecting nutrition in different age groups and especially pre-school children. *Journal of Development Studies* 11: 22-40.
- Spurr, G. B. (1984). Physical activity, nutritional status, and physical work capacity in relation to agricultural productivity. In Pollitt, E., and Amante, P. (eds.), *Energy Intake and Activity*. Alan R. Liss, New York, pp. 207-261.
- Stini, W. A. (1972). Reduced sexual dimorphism in upper arm muscle circumference associated with protein-deficient diet in a South American population. *American Journal of Physical Anthropology* 36: 341-352.
- Stini, W. A. (1975). Adaptive strategies of human populations under nutritional stress. In Watts, E. S., Johnston, F. E., and Lasker, G. W. (eds.), *Biosocial Interrelations in Population Adaptation*. Mouton, The Hague, pp. 19-41.
- Stini, W. A. (1988). Biocultural strategies for coping with drought. In Huss-Ashmore, R. (ed.), *Coping with Seasonal Constraints*. MASCA Research Papers, Vol. 5, University of Pennsylvania, Philadelphia, pp. 21-28.
- Thomas, R. B. (1973). Human adaptation to a high Andean energy flow system. *Occasional Papers in Anthropology No. 7*. Pennsylvania State University, University Park.
- Thomas, R. B. (1976). Energy flow at high altitude. In Baker, P. T., and Little, M. A. (eds.), *Man in the Andes*. Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, pp. 379-404.
- Thomas, R. B. (1979). Effects of change on high mountain adaptive patterns. In Webber, P. J. (ed.), *High-Altitude Geoecology*. Westview Press, Boulder, Colorado, pp. 139-188.
- Thomas, R. B., and Winterhalder, B. P. (1976). Physical and biotic environment of southern highland Peru. In Baker, P. T., and Little, M. A. (eds.), *Man in the Andes*. Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, pp. 21-59.
- Thomas, R. B., Leatherman, T. L., Carey, J. W., and Haas, J. D. (1988). Biosocial consequences of illness among small scale farmers: A research design. In Collins, K. J., and Roberts, D. F. (eds.), *Capacity for Work in the Tropics*. Cambridge University Press, Cambridge, pp. 249-276.
- Torún, B. (1984). Physiological measurements of physical activity among children living under free-living conditions. In Pollitt, E., and Amante, P. (eds.), *Energy Intake and Activity*. Alan R. Liss, New York, pp. 159-184.

- Tucker, C. M. (1987). The Contributions of Children to Household Production in an Andean Community. M. A. thesis, University of Massachusetts, Amherst.
- Werge, R. W. (1979). Potato processing in the central highlands of Peru. *Ecology of Food and Nutrition* 7: 229-234.
- Wheeler, E. F., and Abdullah, M. (1988). Food allocation within the family: Response to fluctuating food supply and food needs. In de Garine, I., and Harrison, G. A. (eds.), *Coping with Uncertainty in Food Supply*. Oxford University Press, Oxford, pp. 437-451.
- Wu Leung, W-T., and Flores, M. (1961). *Food Composition Tables for Use in Latin America*. National Institute of Health, Bethesda, MD.

Herd Composition in an Aymara Community of the Peruvian Altiplano: A Linear Programming Problem

Lawrence A. Kuznar¹

A model of herd management is presented for Aymara alpaca herders in the south central Andes. Linear programming methods and subjective utility values are used to model how pastoralists choose the size of their herd and the species they raise. These decisions are modeled in light of the land and labor resources available to pastoralists, and the products Andean herders must derive from their herds (meat, wool, and dung). The model predicts typical herd size in the community of Chinchillape, and has implications for social and economic changes seen in the Andes today. Specifically, pastoralists in Chinchillape are pursuing maximizing strategies, optimizing herd value by concentrating on alpacas, and decreasing the proportion of llamas in their herd in response to expanding transportation systems. Finally, results of the models indicate that sheep are a very poor option for Andean herders. This explains the reluctance of indigenous herders to adopt sheep herding in some areas of the Andes.

KEY WORDS: Andes; pastoralism; Aymara, linear programming; utility theory.

INTRODUCTION

Anthropologists have proposed ecological models of Andean adaptations (Baker, 1979; Thomas, 1973; Bush, 1977), and computer simulations have been employed to examine how environment and population interact in Andean ecosystems (McRae, 1982). While these models have been successful in elucidating the ecological relationships between human subsistence systems, population, and the environment, they have not examined how these factors

¹Department of Sociology-Anthropology, Indiana University-Purdue University at Fort Wayne, 2101 E. Coliseum Boulevard, Fort Wayne, Indiana 46805.