

UC Davis

UC Davis Previously Published Works

Title

Effects on Household Labor of Temporary Out-migration by Male Household Heads in Nicaragua and Peru: an Analysis of Spot-check Time Allocation Data Using Mixed-effects Models

Permalink

<https://escholarship.org/uc/item/3nk9z4tp>

Journal

Human Ecology, 41(2)

ISSN

0300-7839 1572-9915

Authors

Koster, Jeremy M
Grote, Mark N
Winterhalder, Bruce

Publication Date

2013-02-16

DOI

10.1007/s10745-012-9549-5

Peer reviewed

Effects on Household Labor of Temporary Out-migration by Male Household Heads in Nicaragua and Peru: an Analysis of Spot-check Time Allocation Data Using Mixed-effects Models

Jeremy M. Koster · Mark N. Grote · Bruce Winterhalder

Published online: 16 February 2013
© Springer Science+Business Media New York 2013

Abstract When adult males are temporarily away from the household, observational evidence suggests cross-cultural and intra-cultural variation in the effects of their absence on the labor of other household members. In subsistence-based economies, we predict that other adolescent or older members will work more in essential production activities that otherwise would be performed by the missing men. We test this hypothesis using spot-check time allocation datasets from rural Nicaragua and Peru and the methodology of mixed-effects statistical models. In Nicaragua, we find that the absence of male household heads rarely necessitates substitute labor by household co-residents, apparently because men typically time their absences to coincide with the non-peak agricultural season. In Peru, the absence of male household heads results in increased men's work by co-residents only under unusual circumstances, as households apparently rely on other strategies to mitigate for the loss of labor. In addition to the comparative empirical analysis of the two cases, we show how mixed-effects models allow for individual heterogeneity and data structures that confound more familiar statistical techniques and occasionally produce spurious results. Mixed-effects modeling techniques will be necessary if we are to realize the analytic potential of the extensive, standardized time allocation datasets gathered by anthropologists.

Keywords Time allocation · Spot check · Scan sampling · Migration · Labor · Cross-cultural · Mixed-effects modeling

Electronic supplementary material The online version of this article (doi:10.1007/s10745-012-9549-5) contains supplementary material, which is available to authorized users.

J. M. Koster (✉)
University of Cincinnati, Cincinnati, OH, USA
e-mail: jeremy.koster@uc.edu

M. N. Grote · B. Winterhalder
University of California, Davis, CA, USA

Introduction

Among ecological anthropologists, studies of time allocation have frequently contributed to debates about marriage and the division of labor by sex and age (Lee 1979; Hill *et al.* 1985; Hurtado *et al.* 1985; Hawkes *et al.* 1997; Gurven *et al.* 2009; Kramer 2009). Whereas initial research focused primarily on individual-level demographic characteristics as independent predictors of behavior, Gurven and Kaplan (2006) emphasize that time allocation decisions often depend on the abilities and activities of other group members, particularly household co-residents. Following Becker (1991), households can be viewed much like firms that maximize group-level utility, with specialization and coordination among household members that reflect the complementarity of their skills and potential contributions. For example, women's work might be especially compatible with childcare and breastfeeding (Brown 1970; Hurtado *et al.* 1992; Gurven *et al.* 2009). Men's work, by contrast, often seems to reflect their greater strength and productive skills acquired via experience (Murdock and Provost 1973; Gurven and Kaplan 2006; Hooper 2011).

Despite its theoretical importance, relatively few empirical studies have addressed the ways in which an individual's behavior is contingent on the simultaneous activities and proximity of household co-residents (Paolisso and Hames 2010). Exceptions to this generalization include studies of cooperative labor among husbands and wives (Johnson and Johnson 1975), variation in paternal effort when mothers are present or absent (Winking *et al.* 2009), and the effects of temporarily absent fathers on the subsistence labor of boys (Bock 2002). This latter research, which suggests that boys in rural Botswana spend more time herding and less time in school when their fathers are conducting wage labor elsewhere, is especially interesting given the apparent variation

in the effects of co-resident fathers on the health and reproduction of older offspring in small-scale societies (Gibson 2008; Scelza 2010; Gray and Anderson 2010; Winking *et al.* 2011; see Shenk *et al.* (2013) for the importance of distinguishing the temporary absence of male migrant laborers from absences related to death or desertion).

Insight into the contributions of men can be gained by investigating the effects of their temporary absence on the time allocation of household co-residents. A working hypothesis is that co-residents must compensate for the absence of male household heads by providing substitute labor, thus leading co-residents to conduct more “men’s work.” In urban and market-based economies, analogous research suggests that the temporary migration of adult men typically results in reduced wage labor participation by household members who remain behind, although it is not clear if non-migrating household members devote more time to leisure or to household chores, childcare, and subsistence labor (Rodriguez and Tiongsong 2001; Booth and Tamura 2009; Lokshin and Glinskaya 2009). With the noteworthy exception of Bock’s (2002) aforementioned research in Botswana, this question has apparently received little attention from ethnographers working in small-scale societies.

To collect accurate, representative behavioral data, anthropologists since the 1970s have employed observational methods that are well-suited for documenting subsistence and domestic labor (Johnson 1975; Gross 1984). While prevailing methods produce datasets that are ideal for tests of intra-household coordination, these datasets rarely conform to conventional statistical assumptions. If the household is the unit of observation, interdependence in the activity schedules of the members means that sample points are not independent (Johnson and Behrens 1989). Repeated observations of an individual’s activities may entail temporal or other forms of sample dependence. Individual and household data may be affected by latent heterogeneity as a consequence of unique circumstances or habits of individuals and families that are reflected consistently in their activities but not captured by predictor variables. Until recently, many behavioral researchers using time allocation data have either avoided statistical measures (e.g., Fratkin and Smith 1995), or they have used standard statistical methods intended for independent and exchangeable observations (e.g., Bock 2002). More appropriate methods for time allocation datasets were either not yet developed or not widely known in the social science community.

Mixed-effects models (also called *multi-level* or *hierarchical* models) flexible enough to correct for and, indeed, make analytic use of the unique features of time allocation datasets are becoming common in bio-medical studies (see Merlo *et al.* 2005). Computer routines for fitting these models are becoming standard in statistical software packages such as R and Stata®.

To capitalize on these statistical advances while focusing on intra-household behavioral adaptations, we here analyze two spot-check, time allocation datasets with the goal of making two kinds of contributions: (1) a substantive ethnographic analysis and comparison of two cases of socio-economic activity in households experiencing the temporary absence of male household heads, and (2) a methodological demonstration of appropriate statistical tools for analyzing “spot check” time allocation data.

Study Sites

Arang Dak, Nicaragua

The research in Nicaragua was based in Arang Dak, an indigenous Mayangna and Miskito community that is located along the Lakus River, a tributary of the Coco River in the Bosawas Biosphere Reserve (see Koster 2008b for a map of the study area). Like many indigenous inhabitants of the lowland Neotropics, the residents of Arang Dak are swidden horticulturalists who rely on bananas and manioc as staple crops, supplemented by rice, beans, and corn (Koster 2011). The primary sources of dietary protein include hunted game, fish, and domesticated animals, namely cattle, pigs, and fowl (Koster 2008a). Hunting is almost exclusively male-oriented, but both males and females of all ages engage in fishing (Koster 2007).

Panning for gold in the streams that surround the community is a common money-making activity for men, but women also pan for gold, often accompanied by male relatives. Other local sources of income include teaching in the community school, the sale of crops or animal products, small-scale trading of imported consumer goods, and short-term wage opportunities as agricultural laborers.

For a variety of reasons, men in Arang Dak are often away from the community, especially during lulls in the agricultural calendar. Occasionally accompanied by other household members, some men seek wage labor opportunities on road construction projects in neighboring regions. Every few months, the schoolteachers must travel several days to pick up their paychecks. The men who maintain small stores periodically visit communities along the Coco River to replenish their supplies of consumer goods. Successful gold prospectors make similar trips to capitalize on higher exchange prices of gold in those communities. A number of development and conservation projects are active in the region, and men travel to participate in workshops, service, and training opportunities. Men also visit relatives and friends in neighboring watersheds, frequently stopping to capitalize on trading and wage labor opportunities along the way.

Cuyo Cuyo, Peru

The research in Peru was based in the District of Cuyo Cuyo, located on the eastern escarpment of the southern Peruvian Andes (see Goland 1993a for a map of the study area; Goland 1993b; Larme 1993; Recharte 1993; and Graham 1999 for ethnographic background). The project focused on ten households in each of two communities: Ura Ayllu and Puna Ayllu. Although the Spanish/Quechua speaking residents of these communities exhibit broadly similar subsistence strategies, there are some noteworthy differences associated with variation in altitude. Most of the land exploited by residents of Ura Ayllu is located between 2,600 and 4,200 m above sea level. In addition to broad beans and the tuberous crops that are planted at higher elevations, most notably potatoes and oca (*Oxalis tuberosa*), households in Ura Ayllu also produce corn in the lower elevations. By contrast, the lands used by residents of Puna Ayllu range between 3,500 and 4,500 m in altitude. As suggested by its name, most of the territory of Puna Ayllu (82 %) is comprised of grasslands that are above the altitudinal limit for agriculture. These grasslands are used primarily for herding alpaca and llama, which are relatively less important in Ura Ayllu. Residents of Puna Ayllu also grow potatoes, oca, and several secondary crops.

To obtain cash, most households rely on gold mining. The men in Ura Ayllu typically migrate to gold fields in the tropical lowlands of Madre de Dios, occasionally accompanied by older offspring. The trip requires a weeklong journey by truck. By contrast, most households in Puna Ayllu relocate to a secondary settlement that lies on the high plain above the agricultural areas of their territory. This mining settlement is approximately 5–6 h on foot from Puna Ayllu. Because placer mining is the prevailing technology in the Amazonian gold fields as well as the high Puna, gold mining in both settings is largely restricted to the rainy season, spanning late November to early April. It is this coincidence that underlies the analyses we report below: adult male labor directed toward mining draws work effort away from the peak season for agricultural work in the economy of Cuyo Cuyo.

Although gold mining is the primary source of income for households in these two communities, other moneymaking opportunities include the sale of crops, occasional wage labor, and small-scale trading or marketing.

Methods

Although undertaken independently, the studies in Nicaragua and Peru both used the “spot check” technique to document the time allocation of residents (Johnson 1975; Borgerhoff Mulder and Caro 1985). This method entails

recording individuals’ behaviors at the moment that they are encountered. The researcher arrives unannounced at randomly selected times to document the subjects’ activities and whereabouts. The observations are analogous to a series of photographs; random observation times ensure that activity counts over repeated visits provide unbiased estimates of the relative amounts of time spent performing the observed activities during the period of observation (Johnson and Sackett 1998). In both studies, the coding schemes were based on Johnson and Johnson’s (1987) standard cross-cultural codes, as modified to reflect locally relevant activities.

The sampling methodology in the two studies was generally similar. In both cases, households were the sampling unit and no individuals were sampled more than once per day. In Nicaragua, the lead author (JK) conducted observations with the help of local research assistants for 1 week per month during a calendar year. Observations occurred at randomly chosen households every 30 min between 5:30 AM and 6:00 PM. In Peru, university-trained, bilingual local assistants collected most of the observational data under the day-to-day guidance of the ethnographers. Puna Ayllu and Ura Ayllu were sampled on sequential days, with each community visited by the assistants every 6 days over the 2-year study period. Households were visited for spot checks at random times (set on half-hour intervals) during daylight hours between 6:30 AM and 5:30 PM. The time of each visit was assigned using a random number generator. If the same time was designated for two or more households on the same day, visits were made one right after the other, typically within 10 min of the assigned time. Although the sampling strategies were somewhat different in the two research projects, we have no reason to think these details bias the data in ways that would affect comparison.

Analysis

Comparative Models of Economic Work by Co-residents

We restrict our initial analyses to observations of individuals who are not male household heads, who are at least 13 years old, and who are present in the community at the time of the observation. The latter criterion means that we do not include activities performed when individuals are absent from the local community, whether or not they are accompanying or traveling with the male household heads. Using these criteria, there are 4343 observations in the Nicaraguan dataset, with an average of 63 (\pm 18.3) per individual. In the Peruvian dataset, there are 2865 observations, with an average of 73 (\pm 23.2) observations per individual.

To create a single, binary outcome variable, we have merged activity codes from the original schemes of categorization. Given the hypothesis that other household members

must conduct more of what is customarily treated as men's work when male household heads are away, we create an aggregate variable that encompasses the variety of customary men's economic labor at each field site. Whenever an individual was observed performing one of these activities, the observation was re-coded as conventional men's economic labor. For example, in Arang Dak, males and females of virtually all ages periodically help to collect firewood, but this work is done primarily by adult men. In Cuyo Cuyo, by contrast, adult men sometimes help in the collection of firewood, but children are primarily responsible for this chore. Accordingly, collecting firewood was coded as men's economic labor in the Nicaraguan but not the Peruvian dataset. Despite some differences in the types of socio-economic activities associated with gender, there is considerable overlap between the two datasets in the activity codes that comprise the outcome variable (Table 1). This coding scheme does not imply that men's work is limited to these activities, nor does it mean that women never perform these tasks. In both settings, for example, men sometimes help to care for livestock or other chores, but these tasks are generally performed by other household members. For brevity, we subsequently refer to the variable simply as MEL, or "men's economic labor."

Table 1 Codes for activities related to household or economic production in Nicaragua and Peru. Codes that are included as MEL in the respective study sites are marked with an "X." For the Peruvian data, note that gold prospecting is not included as MEL because it requires temporary migration away from the household

Economic activities	Nicaragua	Peru
Categories common to both studies		
Agricultural field preparation	X	X
Planting crops	X	X
Weeding	X	X
Harvesting crops	X	X
Miscellaneous agricultural labor	X	X
Local wage labor	X	X
Business transactions	X	X
Gold prospecting	X	
Collecting firewood	X	
Processing food and cooking		
Categories specific to Arang Dak, Nicaragua		
Hunting	X	
Fishing	X	
Livestock care		
Categories specific to Cuyo Cuyo, Peru		
Herding		
Home-related production (e.g., weaving)		

We analyze the data using logistic regression, appropriate when the predicted outcome is constrained to lie between 0 and 1.¹ In our case, the observed outcome is a binary code for MEL, and the predicted outcome is the estimated probability that a spot-check observation would reveal a co-resident performing MEL, given the values of demographic and contextual variables at the time of observation. In order to satisfy the assumptions of a generalized linear model, the log odds of the outcome are modeled as a linear combination of those explanatory variables.

We incorporate individual-level *random effects* into all statistical models in order to capture inter-individual heterogeneity in the performance of MEL. Inclusion of random effects allows for the possibility that individuals differ in their baseline propensities for MEL, regardless of tendencies that might be explained by covariates such as gender, age and other *fixed effects*. The nested observations in time allocation datasets enable—and could be understood to require—either the mixed-effects models used here or suitable alternatives for hierarchically structured datasets. The clustering of individuals within households further enables the inclusion of household-level random effects.² These would be needed if, for example, levels of MEL were positively correlated among co-residents, or if overall frequencies of MEL varied considerably by household. However, preliminary analyses of the Nicaraguan and Peruvian datasets showed little evidence of inter-household heterogeneity, and the inclusion of a household-level random effect was not supported by comparisons of Deviance Information Criteria.³ In the analyses to follow, we therefore restrict attention to models that include only an individual-level random effect (varying intercept).

The fixed effects in the models (Table 2) include variables that frequently have been considered important predictors of economic and subsistence labor, namely sex, age, household

¹ Some authors recommend aggregations of spot-check time allocation data, resulting in a proportional value for each individual that can be analyzed via conventional OLS regression (Martin and Bateson 2007). McCabe's (2009) work on the Peruvian data, however, shows that such analyses may lead to erroneous conclusions, even after transforming the data with the arcsine-square root transformation to account for the problem of nonconstant variance in proportional data.

² A practical impediment to the inclusion of household-level random effects is that, in the Peruvian communities, half of the households have only one co-resident (a female head of household) meeting the age requirement for inclusion in the MEL dataset. For these households, the identification of both an individual-level and a household-level random effect is problematic. Such "singleton" clusters present few problems for Markov Chain Monte Carlo methods, but they are handled ungracefully by the more familiar maximum-likelihood method we use here.

³ "Empty" models with both individual-level and household-level random effects were fit in MLwiN 2.19 (Rasbash *et al.* 2009) using Markov Chain Monte Carlo estimation methods.

Table 2 Description of main-effects predictor variables

Variable	Description
Age, Age-squared	Age of individual, centered at 30 years old, and the square of this variable
Sex	Binary variable, coded as 1 for males and 0 for females
Married female	Binary variable, coded as 1 for married women and 0 otherwise
Household size	Number of people in individual's household, centered at five persons
Male head age, Male head age-squared	Age of male head in individual's household, centered at 45 years old, and the square of this variable
Season	Binary variable for the peak agricultural season. Coded as 1 for October–April in Peru; and coded as 1 for December–February and April–May in Nicaragua
Male head absence	Binary variable, coded as 1 when male household head is away from the community
Community	Binary variable for the Peruvian data only, coded as 0 for Ura Ayllu and 1 for Puna Ayllu

size, and seasonality (Hames 1992). By definition, we predict that the binary variable for *Sex*, coded as 1 for males and 0 for females, will be positively associated with MEL. Our predictions about the effects of *Age* are less clear. Gurven and Kaplan (2006) note that time allocated to labor may remain fairly constant across the lifespan as individuals rebalance the composition of their economic efforts to specific activities that are better-suited to their varying physical and cognitive abilities. In some cases, however, time allocated to labor exhibits a convex pattern, with a peak for middle-aged adults and lower values for older and younger individuals (Nag *et al.* 1978; Kaplan 1994).⁴ Therefore, after centering the variable at 30 years old (a value close to the mean age in both the Nicaraguan and Peruvian samples), we include both linear (*Age*) and quadratic terms (*Age-squared*) for age.⁵

The work of other household members may also reflect the age of the male head of household. Because a middle-aged man may work more than his older or younger peers, there might be less need for other household members to contribute additional MEL. Alternatively, the presence of a middle-aged head of household might facilitate the economic and subsistence labor of other household members. To

⁴ In some cases, it might be appropriate to consider the interaction of age and sex. However, our attempts to include these terms produced numerically unstable estimates. We understand this to be a consequence of small numbers of individuals in some age-by-sex combinations.

⁵ In fitting models, we use orthogonal polynomials (Kennedy and Gentle 1980:342–347) derived from the linear and quadratic age variables, to ensure that all fixed effects are similarly scaled. We then convert the coefficients of the orthogonal variables back to natural (year and year-squared) units, using output of the orthogonalization routine.

distinguish these potential effects, we add a term for the male head's age (*Male head age*), centered at 45 years old, and a quadratic term (*Male head age-squared*).⁶

For women, we predict that being married reduces the allocation of time to MEL. The presence of a husband may allow married women, who are frequently responsible for juvenile children, to contribute relatively less male-oriented economic labor whereas unmarried women might be inclined to work more in these tasks, either as a contribution to their current household's well-being or their own personal gain. A binary variable (*Married female*), coded as 1 for married women, allows us to measure this effect.

Following Chayanov (1966), the Russian economist whose work partly focused on the degree to which producers will work more to support unproductive (dependent) juveniles, we predict that household size will have a positive effect on participation in MEL. For ease of interpretability and comparability across models, the variable *Household size* has been centered at five persons, which is the median in the Peruvian sample and reasonably close to the median of eight persons in the Nicaraguan sample.

Because both societies rely primarily on cultivated crops, we anticipate that MEL will be highest during seasons of agricultural labor (Panter-Brick 1993). The Mayangna and Miskito conform to the general Neotropical pattern, in which agricultural labor is most common during the dry season as farmers clear their fields in anticipation of burning and planting prior to the onset of the rainy season (Beckerman 1987). In Cuyo Cuyo, by contrast, agricultural labor typically peaks during the rainy season (Goland 1993a). For both datasets, we include a binary variable for the peak agricultural season (*Season*), defined in the Nicaraguan sample as December through February and then also April through May (see House 1997), and in Peru as coincident with the wet season (October through April).

The binary variable, *Male head absence*, indicates observations that occurred when the male household head was away from the community (with “absent” coded as 1). Underlying our hypothesis is the premise that such absences might especially increase the need for other household members to provide substitute labor during periods of peak agricultural work. We therefore include the interaction of *Male head absence* and *Season*, along with the main effects.

In the model for the Peruvian sample, we include a binary variable for *Community* coded as 1 for Puna Ayllu and 0 for Ura Ayllu. We understand this variable to control (however roughly) for altitude-related differences in ecology and subsistence strategy between the two communities. Finally, in

⁶ This age was selected for centering because it is close to the mean age for male household heads in both datasets. The centering value is used (here and elsewhere) to facilitate computation; the particular choice is a matter of convenience—any value within the sample range would produce a functionally equivalent model.

the Peruvian sample we include variables for two- and three-way interactions between *Community*, *Season*, and *Male head absence*.

We call models containing individual-level random effects, along with the fixed effects mentioned above, “full models” for MEL. In parallel, we present models including only individual-level random effects (along with an intercept), known as “empty models”. We compare empty and full models in order to investigate the extent to which inter-individual differences in time allocated to MEL can be explained by the fixed effects under consideration. Our aim is not to select the “best” predictive models of MEL for each community, but to facilitate cross-cultural comparisons by fitting analogous models to the two datasets. Thus, we do not eliminate weak predictors of MEL or otherwise emphasize the significance of individual variables. We use the models, which are admittedly large, as devices for describing structure in the data captured by covariates, and for revealing inter- and intra-community variation in MEL.

Seasonal Effects Mediated by Male Household Heads

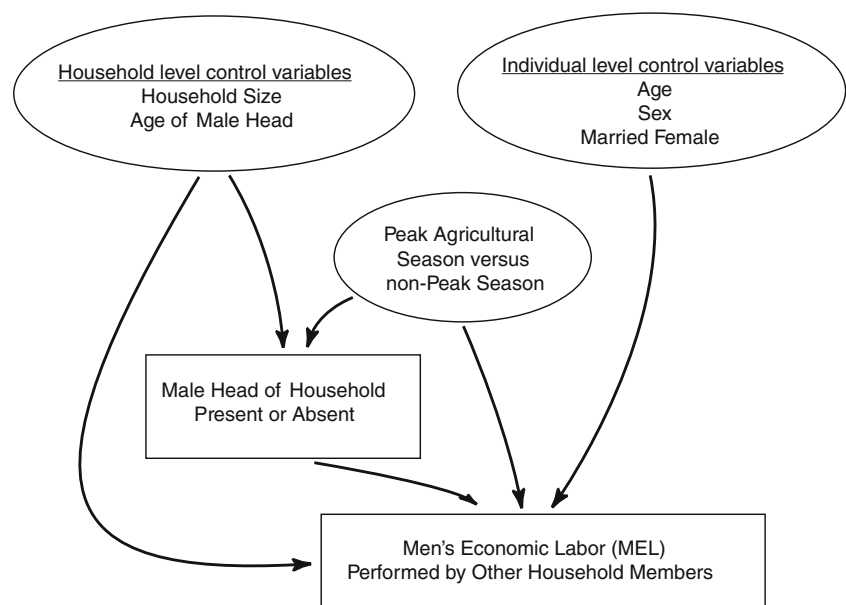
We hypothesized that participation in MEL by wives and other household members varies with *Season*, but it is possible that male household heads mediate this relationship by choosing the times of year during which they will be away. For example, men might be less inclined to leave the community when there is considerable agricultural work to be done, and this tendency could lessen demands for substitute labor by co-residents during the peak agricultural season. The potential mediating role of male household heads suggests a second, indirect form of association between MEL and *Season*. Figure 1 gives

a schematic representation of these relationships, showing a direct path from *Season* to MEL as well as an indirect path passing through the variable *Male head absence*. Similar graphical models are used in the theory of causal inference in fields such as psychology and epidemiology (see Petersen *et al.* 2006; MacKinnon *et al.* 2007).

As a necessary first step to investigate a mediating role for male household heads, we fit models that treat *Male head absence* as an outcome in the Nicaraguan and Peruvian samples (we will call these “auxiliary” models as a reminder of their subsidiary role in Fig. 1). Explanatory variables in these models include *Household size*, *Season*, *Community* (in the Peruvian sample), linear and quadratic terms for the male’s age, and individual-level random effects (varying intercepts) for the male heads. The samples consist of 1,972 observations in the Nicaraguan dataset, with an average of 79 (± 9.1) observations per individual, and 2,267 observations of male household heads in the Peruvian dataset, with an average of 113 (± 4.2) observations per individual.

Finally, to quantify the two forms of association between MEL and *Season*, we combine the models of MEL and *Male head absence* in accordance with Fig. 1. The *direct effect* of *Season* on MEL (shown as an arrow between these variables) is estimated by straightforward calculation, using coefficients of the model for MEL (called the “main” model). Quantification of the indirect path (shown by the sequence of arrows from *Season* to *Male head absence* to MEL) requires integration of the main and auxiliary models. For this purpose, we calculate the *total effect* of *Season* on MEL—which combines the direct and indirect paths into a single, integrated coefficient—using methods described

Fig. 1 A graphical model of the predictors of men’s economic labor by household members other than the male household head who are at least 13 years old. Arrows indicate dependent relationships



by Rao *et al.* (2008).⁷ We gain insight into the mediating role of *Male head absence* by comparing the direct and total effects.⁸

We use the package *lme4* (Bates *et al.* 2011) of the statistical computing language R, version 2.13.0 (R Development Core Team 2011) to fit all of the following models, employing numerical integration with 10 quadrature points for the random effects.

Results

Men's Economic Labor among All Residents

Figure 2 displays observed frequencies of MEL as a function of age using aggregated data for each resident older than 12 years old, *including* male household heads. In Arang Dak, a sexual division of labor begins in the teenage years and is unambiguous by the time individuals reach their twenties. In Cuyo Cuyo by contrast, gender roles with respect to MEL activities (Table 1) are not readily distinguishable across the lifespan, with all residents older than 12 appearing to share relatively equitably in MEL. In order to provide additional context, the frequencies shown in Fig. 2 are grouped by household in Supplemental Figure 1.

Adequacy of the Models

Table 3 gives estimated coefficients and other numerical summaries for the models of MEL. Comparing the full model to the empty model for Arang Dak, we see substantial

⁷ The calculation proceeds as follows. Let *MEL*, *AG* and *MA* indicate the events “men’s economic labor”, “peak agricultural season” and “male head absent”, respectively, and let *AG'* and *MA'* indicate the complement events “non-peak season” and “male head present”. Conditional probabilities of the form $p(MEL | AG, MA)$ or $q(MA | AG)$ are calculated from the main or auxiliary models, respectively, applying the inverse-logit transform to appropriate linear combinations of model coefficients. All other explanatory covariates are held at fixed values. The probabilities $r_{AG} = p(MEL | AG, MA) q(MA | AG) + p(MEL | AG, MA') q(MA' | AG)$ and $r_{AG'} = p(MEL | AG', MA) q(MA | AG') + p(MEL | AG', MA') q(MA' | AG')$ integrate predicted MEL frequencies over the “absent” and “present” conditions; thus r_{AG} and $r_{AG'}$ are said to be “marginal to” the variable *Male head absence*. The total effect of *Season* on MEL is defined as the difference $\text{logit}(r_{AG}) - \text{logit}(r_{AG'})$ (Rao *et al.* 2008). Standard errors are obtained by a delta-method calculation similar to that in Rao *et al.* (2008), though we warn that logistic models can produce very cumbersome expressions.

⁸ Rao *et al.* (2008) define the *indirect effect* as the difference between the total and direct effects. Thus there are two freely-varying quantities among the direct, indirect, and total effects. We find interpretation of the direct and total effects most useful in the present case. Debate about how to estimate and interpret coefficients in graphical models like Fig. 1 is ongoing (see Petersen *et al.* 2006; MacKinnon *et al.* 2007; Imai *et al.* 2010; Pearl 2012), and effects which are nominally the same may be defined differently by different authors. We urge readers to avoid confusion.

decreases in both the AIC and the random-effect variance, which suggest that the covariates (taken together) explain considerable variation in MEL.⁹ In Cuyo Cuyo, the change in AIC also supports the full model, although inclusion of the covariates does not substantially reduce the random-effect variance. Binned residual plots for the full models (not shown; see Gelman and Hill 2007) indicate no systematic lack of fit.

Table 4 gives analogous results for the auxiliary models of male head absence. In Arang Dak, the full model is well-supported by the change in AIC, and most covariates exceed conventional thresholds of statistical significance. In Cuyo Cuyo, the change in AIC and the presence of several significant covariates also support the full model; but as with the corresponding main model above, the covariates do not capture much of the inter-individual heterogeneity.¹⁰ Goodness-of-fit diagnostics indicate no lack of fit in the full models for male head absence.

Synthetic Graph for Model Interpretation

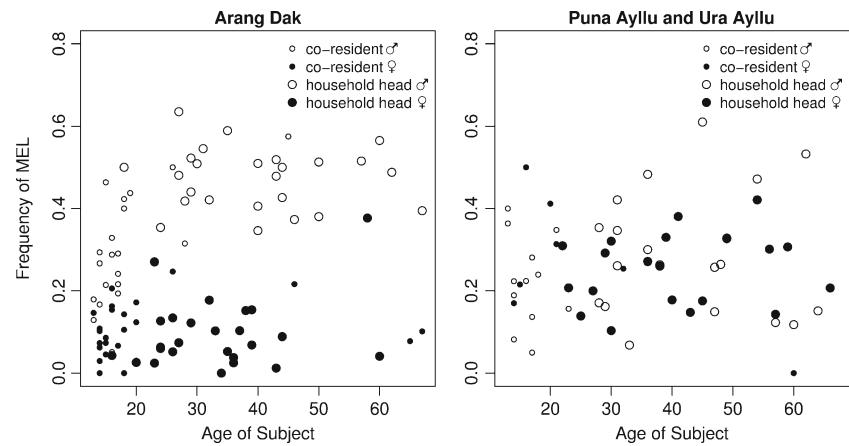
Regression models including many covariates and interactions are difficult to interpret based on estimated coefficients and standard errors alone. Following Gelman and Hill (2007), we use a graph that shows model predictions and confidence intervals (Fig. 3) as our primary interpretive device. We focus attention on three hypothetical groups of individuals in each of the three communities: 16-year-old boys and girls, respectively, and 45-year-old married female heads of household. We suggest that these groups are relevant to our specific questions, as well as useful for revealing the structure of the models.¹¹ Figure 3 displays predictions of the log odds of MEL under varying conditions of *Season* and *Male head absence* for these groups. Other explanatory variables included in the main and auxiliary models are held fixed (see the Fig. 3 legend for details). Figure 3 facilitates comparisons of model predictions at several nested levels:

⁹ Multiple approaches have been proposed for characterizing the extent of the variance associated with random effects. A straightforward approach is presented by Snijders and Bosker (1999), who note that the lowest-level variance in a multilevel logistic regression can be assumed to be fixed at $\pi^2/3 = 3.29$. Accordingly, the “variance partition coefficient” of a higher-level random effect (τ^2) can be calculated as: $\tau^2/(\tau^2 + 3.29)$. In the empty model for the Nicaraguan dataset, the calculation is: $0.94/(0.94 + 3.29) = 0.22$. The corresponding calculation for the full model is: $0.25/(0.25 + 3.29) = 0.07$. Thus, the inclusion of relevant predictor variables accounts for considerable individual-level variance.

¹⁰ The large random-effect variance for Cuyo Cuyo suggests that some men are frequently away from home, whereas others seldom leave. In fact, three men in the sample were never documented as being away for mining, and two others were away on mining trips less than 5 % of the time. Such divergences from the typical pattern may explain why the random-effect variance *increases* after inclusion of *Season* and other covariates (see Gelman and Hill 2007:480).

¹¹ Displays for other groups could readily be made, albeit with provisos about the risk of predicting outside sample ranges.

Fig. 2 Observed frequencies of men's economic labor by age and sex among residents of Arang Dak, Nicaragua and Puna Ayllu and Ura Ayllu, Peru



within age and gender groups, among age and gender groups of the same community, and between communities. We return to these comparisons at appropriate points below.

Co-resident MEL in the Broad Sense

The empirical gender-related and age-related patterns in MEL frequency seen in Fig. 2 are echoed in the model predictions of Fig. 3. Following the column for Arang Dak from top to bottom, 16-year-old males are predicted to perform MEL more often under all conditions

of *Season* and *Male head absence* than females of the same age. Married female heads of household have the lowest predicted values in Arang Dak. For the Peruvian communities, Puna Ayllu and Ura Ayllu, age and gender differences are not pronounced in the predictions, although modestly lower MEL frequencies are suggested overall for 16-year-old males. Comparisons among the three communities reveal stark differences in MEL activities of females, with MEL relatively common among girls and married women in the Peruvian communities, but rare in Arang Dak.

Table 3 Comparative main models of men's economic labor (MEL) by household members older than 12 who are not the male household head. Coefficients are on the log-odds scale

Model	Arang Dak, Nicaragua		Cuyo Cuyo, Peru	
AIC (empty model)	3386		3209	
AIC (full model)	3344		3194	
Random effects (variance)				
Individual-level (empty model)	0.94		0.25	
Individual-level (full model)	0.25		0.22	
Fixed effects (full model only)	Coefficient	Std. error	Coefficient	Std. error
Intercept	-2.09***	0.37	-1.44***	0.40
Community (Puna Allyu)			-0.23	0.24
Season (Peak ag. season)	-0.10	0.10	0.29*	0.13
Household size	0.03	0.04	0.03	0.07
Male head age	0.02*	0.01	0.02	0.02
Male head age-squared	0.002**	0.001	-0.001	0.001
Sex (Male)	1.40***	0.20	-0.51	0.33
Married female	-0.58*	0.29	0.55	0.48
Age	0.02*	0.01	-0.02	0.02
Age-squared	-0.001	0.001	0.0003	0.0006
Male head absent	-0.27	0.20	-0.32	0.33
Season* Male head absent	0.41	0.27	0.29	0.36
Season* Community			0.23	0.21
Male head absent* Community			1.75***	0.45
Community* Season* Male head absent			-1.65**	0.53

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 4 Comparative auxiliary models predicting the absence of male household heads. Coefficients are on the log-odds scale

Model	Arang Dak, Nicaragua		Cuyo Cuyo, Peru	
AIC (empty model)	1596		2284	
AIC (full model)	1571		1977	
Random effects (variance)				
Individual-level (empty model)	1.21		3.17	
Individual-level (full model)	0.59		3.63	
Fixed effects (full model only)				
	Coefficient	Std. error	Coefficient	Std. error
Intercept	−1.31***	0.36	−2.71***	1.02
Household size	0.01	0.07	−0.10	0.31
Male head age	−0.07***	0.02	−0.01	0.04
Male head age-squared	−0.005***	0.001	−0.002	0.005
Season (Peak ag. season)	−0.47***	0.14	1.54***	0.17
Community (Puna Allyu)			0.13	1.00
Community* Season			1.01***	0.26

* $p < .05$; ** $p < .01$; *** $p < .001$

Season

The effects of *Season* can be seen in Fig. 3 by comparing the filled and open circles of closely-spaced intervals. Consider, for example, 16-year-old boys in Arang Dak: they perform MEL slightly more often on average during the peak agricultural season than during the non-peak season, when their fathers are absent. Yet, the ample overlap between intervals reflects the lack of a statistically significant result for *Season* (as seen in Table 3).

The direct effects of *Season* are very modest in most cases. An exception occurs in Puna Ayllu when male household heads are absent. Contrary to expectations, when male heads are absent, co-residents perform MEL more often on average in the non-peak season than in the peak season, with predicted MEL frequencies among females exceeding 50 % in the non-peak season. In Ura Ayllu, the largest direct effects of *Season* are also found when the male head is absent, though they are in the hypothesized direction and of smaller magnitude than in Puna Ayllu. The contrasting directions and magnitudes of these effects are shown by black arrows in Fig. 3. Leftward arrows for Puna Ayllu indicate less frequent MEL in the peak season than in the non-peak season, and rightward arrows for Ura Ayllu indicate the converse.

Male Head Absence

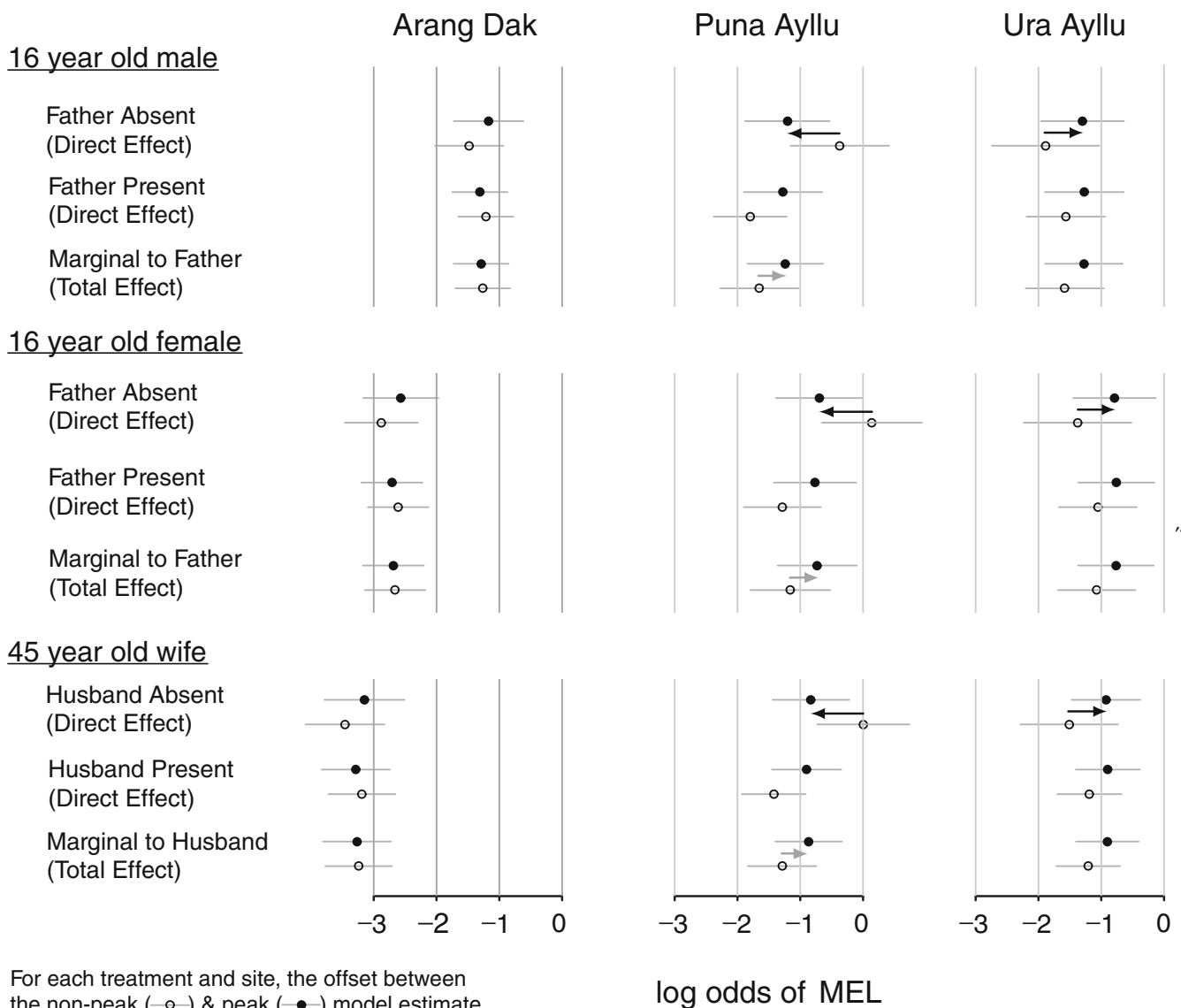
The effects of *Male head absence* can be seen in Fig. 3 by comparing filled circles in the “absent” condition to filled circles in the “present” condition, and by analogous comparisons of open circles. For example, during the peak agricultural season, 16-year-old boys in Arang Dak perform MEL slightly more often on average when their fathers are absent than when their fathers are present. Direct effects of *Male head absence* are not shown, but could be obtained as the difference between

the log odds of MEL in the “absent” and “present” conditions, for given values of *Season* and the other covariates.

In Arang Dak, the effects of *Male head absence* on MEL are modest in all cases. In contrast, MEL frequencies in Puna Ayllu increase significantly when male heads are absent, compared to when they are present, during the non-peak season. During the peak agricultural season, however, MEL frequencies in Puna Ayllu do not appear to vary with *Male head absence*. In Ura Ayllu, the effects of *Male head absence* appear to be slight overall, but contrary to expectations, on average co-residents perform MEL less often when male heads are absent than when they are present.

Mediating Role of Male Head Absence

Pairs of intervals grouped by the labels “marginal to father”, or “marginal to husband” inform us about the mediating role of male household heads. Recalling Fig. 1, there are two potential paths connecting *Season* to MEL: a direct path (quantified by the direct effects shown in Fig. 3) and an indirect path, which passes through the intermediate variable, *Male head absence*. The total effects shown in Fig. 3 reflect the integration of these two paths. Broadly speaking, the total effect of *Season* is a weighted function of direct effects, in which infrequent conditions for *Male head absence* receive small weight. For example, the auxiliary model of *Male head absence* predicts that in Arang Dak, male heads of household are infrequently absent during the peak agricultural season (calculating from Table 4, the probability is 0.14, for 45-year-old male heads of households of size 5). Thus the direct effect of *Season* in the “absent” condition contributes relatively little to the total effect in Arang Dak. We understand the total effect of *Season* to describe how co-resident MEL differs in the aggregate—over many periods of male head presence or absence—between peak and non-peak seasons.



For each treatment and site, the offset between the non-peak (—○—) & peak (—●—) model estimate measures the strength and direction of the effect of season on MEL

Fig. 3 Model estimates for three study communities, showing direct and total effects of *Season* on MEL for 16-year-old boys and girls, and 45-year-old married female heads of household. MEL frequency is depicted on the log-odds scale, with a log-odds of zero indicating a 1:1 ratio of MEL compared to all other activities. Negative values for the log-odds imply less frequent MEL. A log-odds value x can be converted to a frequency f using the formula $f = \exp\{x\}/(1 + \exp\{x\})$. Thus a log-odds of zero corresponds to $f = 1/(1 + 1) = 0.5$, and a log-odds of -1 corresponds approximately to $f = 0.37/(1 + 0.37) = 0.27$. Filled and

open circles indicate estimates for the peak agricultural and non-peak seasons, respectively. Error bars depict 95 % confidence limits for population averages. Variation in MEL with respect to *Male head absence* is shown within age and gender groups. Intervals grouped with the text “marginal to father” (or “husband”) are derived from the integrated probabilities rAG and rAG' (see “Methods”), and indicate the possible mediating role of male heads of household (see “Results”). All estimates assume a 45-year-old male head of household and a household size of 5

A mediating role for male heads is suggested where the total effect of *Season* differs in direction or magnitude from one of the direct effects (shown in Fig. 3 for Puna Ayllu by contrasting directions of the black and light gray arrows). Recall that in Puna Ayllu, co-residents may perform MEL as much as 50 % of the time in the non-peak season, during periods of male head absence. Yet, the total effect of *Season* is small in Puna Ayllu (resembling the direct effect in the “present”, rather than the

“absent”, condition). In Puna Ayllu, male heads are absent much more often during the peak agricultural season—when co-resident MEL frequencies appear to be moderate and stable—than during the non-peak season.¹² Thus, in Puna Ayllu, potentially sharp increases in co-resident MEL are “smoothed” in the

¹² The estimated probabilities for male head absence are 0.50 and 0.07 during the peak and non-peak seasons, respectively, for 45-year-old male heads of households of size 5.

aggregate by the fact that absences are rare during the non-peak season. In Ura Ayllu, by contrast, direct and total effects are similar in magnitude and direction, although the direct effect in the “absent” condition appears to be slightly dampened in the aggregate. Finally, in Arang Dak, co-resident MEL varies little with either *Season* or *Male head absence*, although the total effect suggests that in the aggregate, MEL frequencies are almost entirely buffered from seasonal effects.

Other Covariates for MEL and Male Head Absence

We turn briefly to explanatory variables not discussed above. In Arang Dak, relationships between MEL frequencies and household ages can be discerned. The coefficient of *Age* in Table 3 suggests that co-residents perform more MEL on average as they gain in years, but a (weakly-supported) negative coefficient for *Age-squared* produces a downward concavity notable in older individuals (Supplemental Figure 2). The coefficients of *Male head age* and *Male head age-squared* suggest a concave-upward relationship, consisting of a general increase in co-resident MEL as male heads of household age, along with specific increases in MEL for co-residents of the oldest and youngest males (Supplemental Figure 3). In contrast, age-related effects on MEL in Cuyo Cuyo appear weak (see Table 3).

Regarding the auxiliary models that predict the absence of male household heads, the age of the male head of household again seems relevant in Arang Dak. Negative coefficients of *Male head age* and *Male head age-squared* imply a concave-downward relationship, consisting of a general decline in absences as men age, with especially infrequent absences among the oldest and youngest male heads (Supplemental Figure 4). In Cuyo Cuyo, the same trends are suggested but their statistical support is weak (see Table 4). The variable, *Household size*, is apparently an uninformative predictor of both MEL and the absence of male heads in our study communities.

Discussion

Do other household members do more “men’s work” when male household heads are temporarily away from home? Our results reveal substantial variation across the three study communities. In the Nicaraguan community, Arang Dak, the absence of male heads does not consistently result in increased MEL for co-residents, in part because the men are less frequently away during the peak agricultural season. In the Peruvian communities, by contrast, the gold mining activities of men frequently lead to their absence during the peak agricultural season. In Ura Ayllu, however, variation in MEL among co-residents primarily seems to reflect seasonal changes, not the absence of male household heads. In Puna Ayllu, on the other hand, other household members

do in fact conduct more MEL when male heads are away, but this effect is largely restricted to the non-peak season, when the men are infrequently absent.

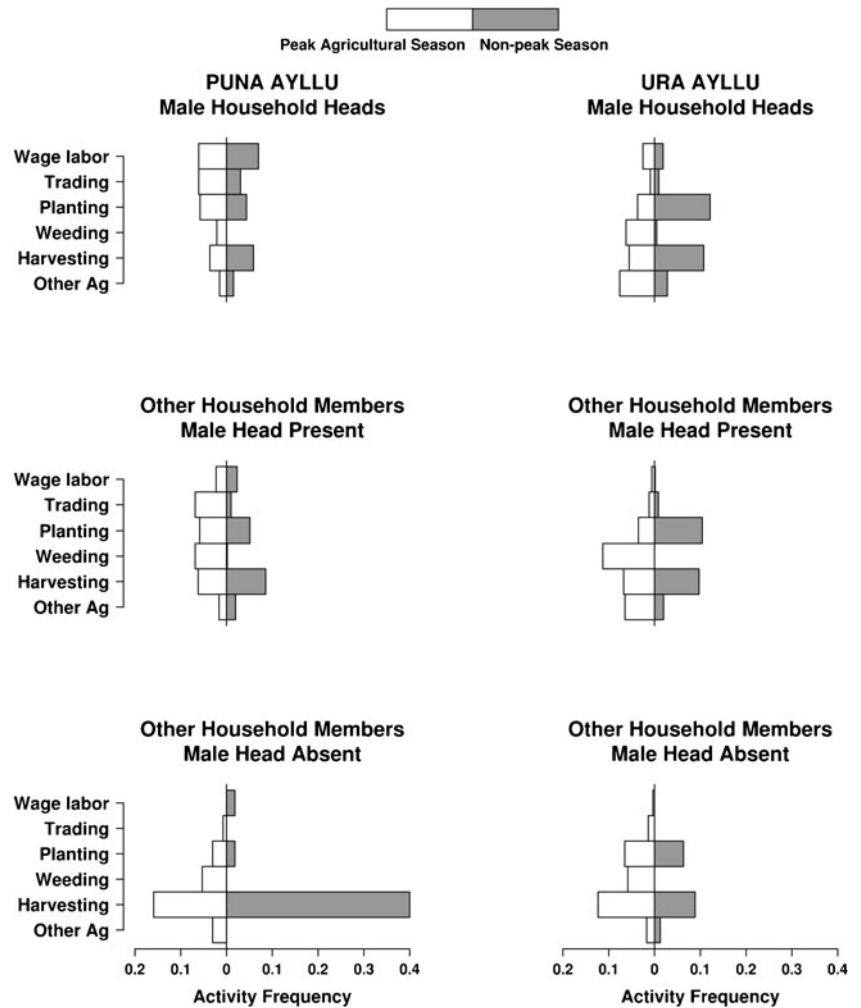
Given these results, our discussion focuses on three themes: (1) a qualitative exploration of the data to contextualize the unexpected increase in MEL during the non-agricultural season in Puna Ayllu, (2) the broader implications of this study for research on intra-household time allocation, and (3) the use of mixed-effects modeling and mediation analysis for the statistical analysis of time allocation data.

Contextual Variation in Puna Ayllu

A disaggregation of the outcome variable suggests that the increase in MEL during the dry season in Puna Ayllu when male heads are absent is largely attributable to time spent harvesting, as co-residents were observed to be harvesting in more than 40 % of the observations under these conditions (Fig. 4). For both male heads and co-residents, we therefore plotted the monthly variation in the harvesting and mining-related activities in the two Peruvian communities (Fig. 5). Whereas it is relatively uncommon for household co-residents in Ura Ayllu to accompany male heads to the gold fields in the lowlands, entire households in Puna Ayllu often relocate to their mining settlement in the uplands, where adult males focus on mining while co-residents engage in complementary domestic and productive activities. For much of the rainy season, therefore, male heads and co-residents spend roughly equivalent amounts of time at the mining settlement. In April, however, perhaps influenced by the beginning of the school year, household co-residents are more likely to return to Puna Ayllu while male heads continue mining. Reduced time at the mining settlement coincides with a sharp increase in harvesting effort that peaks in May. Similar covariation between mining and harvesting is evident to a lesser extent among male household heads in Ura Ayllu, but the harvesting behavior of household co-residents is more evenly dispersed across the first six months of the calendar year, which seems to reflect their reduced migration and participation in mining-related activities throughout the rainy season.

These data lend themselves to multiple interpretations, primarily because it is not clear why household co-residents from Puna Ayllu spend so much time at the mining settlement from January to April. Conceivably, their presence provides logistical support for the male heads, freeing the men to devote as much effort as possible to the primary source of household income. We cannot eliminate alternative explanations, however, including a desire by either the men or the women to monitor the activities of their spouses (e.g., Flinn 1988). Furthermore, given the altitudinal variation and the different repertoire of crops in the two

Fig. 4 Activities comprising observed men’s economic labor in Peru, by community, season, and the presence or absence of male household heads. As a further comparison, the figure also includes the activities comprising men’s economic labor by male household heads when they are present in the community



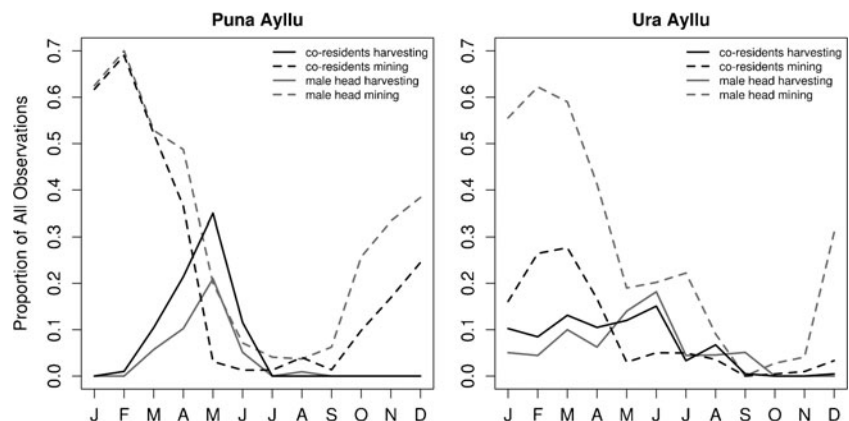
communities, it is not clear to what extent the residents of Puna Ayllu could devote more time to harvesting from January to April, as practiced by their lower-altitude counterparts in Ura Ayllu. Nevertheless, the data suggest that the focused period of harvesting in April and May among household co-residents in Puna Ayllu cannot be regarded simply as a by-product of the men’s lingering presence at the mining settlement. Instead, this period of intense harvesting also seems to reflect the co-residents’

relocation to the mining settlement in the preceding months and the need to harvest crops before the onset of the dry season.

Intra-household Time Allocation

Among cultivators, variation in intra-household time allocation, particularly the sexual division of labor, has conventionally been attributed to numerous factors, including

Fig. 5 Month-to-month allocation of time to mining-related activities, including temporary relocation to the mining settlement by residents of Puna Ayllu, and harvesting by male heads and (non-child) co-residents in two communities in Cuyo Cuyo, Peru



variation in the harvesting and processing demands of cereal versus root crops (Baumann 1928; Ember 1983), seasonal time pressure associated with short growing seasons (White *et al.* 1981), reliance on plowing (Boserup 1970), the care provided to important domestic animals (Burton and White 1984), and variation in fertility (Ember 1983). Implicitly, these explanations tend to invoke the familiar distinctions between the required mobility and physical demands of tasks and their compatibility with childcare. Notably, the distinction between male and female tasks is often blurred when agricultural systems require high overall inputs (Stone *et al.* 1995) or when temporary migration by men increases the need for agricultural labor by women (Doss 1999; Lastarria-Cornhiel 2006; Radel *et al.* 2012).

The results in this study initially seem to provide contradictory evidence for the importance of male migration as an influence on women's agricultural labor. That is, whereas men are frequently away from home in both settings, women and juveniles in Arang Dak contribute minimally to most agricultural activities while their counterparts in the Peruvian communities are integrally involved with all aspects of farming. The seasonality of migration and the agricultural calendar seem to account for this difference. Men in Nicaragua can pursue wage labor opportunities throughout the year, and they are absent primarily during the non-peak agricultural season. By contrast, placer mining in Puna Ayllu and Ura Ayllu necessarily coincides with the growing season, and women and juveniles therefore assume responsibility for many farming tasks. The difference between the study sites consequently supports Ember and Ember's (1973) observation on the potential importance of seasonality:

For instance, if the men have to be away often on long trading trips (as in parts of Micronesia and Melanesia in the recent past) or to earn money in mines or cities (as in parts of Africa now), *and work has to be done while they are away*, the women might end up doing at least as much as the men in subsistence activities, even though warfare is no longer present. This second explanation is testable, and we trust that future research will provide us with the evidence needed to evaluate it. (1973:581; emphasis added)

Although few cross-cultural studies have followed up on the Embers' hypothesis, our comparative research suggests that the timing of men's competing obligations and activities indeed affects the activity budgets of household co-residents, and such considerations of seasonality should be incorporated into future ethnological studies whenever possible. In short, when men are often absent during the peak season for farming activities, our results lead us to predict more flexibility in the intra-household division of subsistence labor.

Despite the apparent importance of men's typical migratory patterns on the customary activity budgets of household co-residents, this study reveals little evidence that the temporary absence of male household heads necessitates substitute labor. In other words, except for the circumstances of the aforementioned harvesting in Puna Ayllu, household co-residents seemingly conduct little additional MEL when male heads are absent in either Arang Dak or the Peruvian communities. Although these results are subject to interpretation, one likely explanation is that men do not depart if their absence would impose burdensome workloads on family members. As evidence, we note that our auxiliary models of observed absences among male heads reveal considerable inter-individual heterogeneity. For instance, although it is common for men in Puna Ayllu and Ura Ayllu to be away in search of gold, several of the men rarely embark on such excursions, and the aggregated data suggest that the seasonal work-related activities of non-traveling men resemble those of women and teenagers of both sexes (Fig. 4). Thus, our attempt to generalize about community-level trends potentially overlooks the extent to which men modify their migratory behavior to ensure that household co-residents will not endure abnormally high workloads. Because all three study communities partly rely on storable food and the limited use of national monetary currency, it would also be worthwhile in future research to determine how the short-term availability of those resources impacts the migratory decisions of male heads.

In addition, this study suggests that male household heads are not simply providers of MEL that requires substitution when they are away from the community. Instead, men often facilitate and cooperate in labor by other household members. During observations when male household heads were present in the community, household co-residents in the Nicaraguan sample who were observed to be conducting MEL on short excursions away from the community ($n=440$) were accompanied by male household heads 39 % of the time. In other words, much of the observable MEL by household co-residents is conducted alongside male household heads. Sons often clear fields or hunt with their fathers, for example, and household members of both sexes sometimes assist with planting and harvesting, especially of grain crops. Partly because much of this work requires travel by boat, it is not surprising that the presence of men seems to facilitate such labor. At many water levels, it is difficult to pole a boat upstream without the assistance of an adult man. Conversely, adult men benefit from having assistance rather than having to navigate their boats independently. Accordingly, household members frequently seem to coordinate their activities around the shared use of the boat. By extension, because households typically have only one boat, when male household heads use it for long trips away from the community, other

household members may be effectively confined to the community, which helps to explain why the absence of male household heads does not result in substantial increases in MEL in Arang Dak.

Mixed-effects Modeling

Mixed-effects modeling represents an important advance in the analysis of spot-check time allocation data. As seen in the empty models, there is considerable variance associated with the individual-level random effect (see Table 3). The inclusion of predictor variables, especially sex in the Nicaraguan sample, reduces this variance to some extent, but it remains substantial in both datasets. This result suggests that, even after accounting for standard demographic variables, there are noteworthy differences in individuals' propensities for specific types of economic work. Sampling variation likely accounts for some of these differences, but future research could also incorporate additional predictors that account for previously unrecognized sources of variation in workloads.

Whatever the source, failing to acknowledge and incorporate individual heterogeneity may lead to erroneous conclusions. For example, if we reexamine the Peruvian dataset with a conventional logistic regression model without a random effect for individuals, then the binary variable for sex exhibits a significant negative effect on MEL (Supplemental Table 1). In other words, if we were to treat all observations of non-household heads as independent rather than as repeated observations of individuals with varying propensities for men's economic labor, then we would conclude that males conduct significantly less MEL than females. By using an analysis that allows for individual heterogeneity, we avoid a spurious interpretation, in this example based in gender.

Similarly, if we were to reexamine the Nicaraguan dataset with a conventional logistic regression model, then variables for household size, status as a married female, age, and the absence of male household heads all would appear to exhibit significant effects on men's economic labor (Supplemental Table 2). Among other misinterpretations, if we were to ignore individual-level variance, we would conclude that the household members who remain behind when male heads are temporarily absent conduct significantly less MEL in the rainy season. Analyses that fail to account for nested sources of variance—in our experience, most statistical studies of time allocation data—should therefore be interpreted with caution. Conventional methods are not suited to data that violate assumptions of independence. They routinely underestimate the standard errors of covariates and may therefore falsely indicate statistical significance (Goldstein 2003).

To our knowledge, this study represents the first anthropological application of mediation analysis (or similar approaches such as structural equation modeling) to time allocation data. In Puna Ayllu, empirical observation and model-based inference suggest that *Male head absence* has a mediating role in the relationship between *Season* and MEL; and in all three communities, there is at least modest support for the claim that co-residents are buffered from seasonally-related changes in MEL by the timing of these absences. We urge caution in interpreting our results: we view these as statistical, rather than cause-and-effect (“structural”) relationships. Causal interpretations require additional assumptions that we are disinclined to make (Judd and Kenny 2010; Pearl 2012).

Although our use of mixed-effects modeling represents a promising alternative to prior approaches, there are nevertheless opportunities to develop increasingly appropriate models. Our analysis treats the behavior of male household heads as a predictor of co-residents' activities, which is largely consistent with our ethnographic observations, but there often will be no a priori reason to assume unidirectional dependence in the behavior of co-residents. Models that incorporate correlated behaviors are needed to fully address the tradeoffs and intra-group coordination that characterize human time allocation decisions.

In this study, we aggregated behavioral categories to create a dichotomous outcome variable. Fundamentally, however, spot check time allocation data are characterized by a multinomial set of categorical outcome variables. Models for multinomial outcomes are challenging to fit and interpret, especially in contexts of mixed-effects modeling, where decisions about random-effects structure are consequential and the computational burden is heavy. Time allocation data sets, which typically feature more than twenty behavioral codes, pose special combinatorial problems. More positively, software packages that can accommodate mixed-effects multinomial models are becoming increasingly common (e.g., MLwiN), and we are hopeful that recent computational advances (see Scott 2011) will make multinomial modeling of time allocation data feasible.

Conclusion

The use of systematic observational methods challenges the stereotypes that emerge from an inordinate emphasis on participant observation and key informants as sources of anthropological data. As noted by Johnson and Behrens (1989), the normative generalizations that tend to characterize ethnographic research are often incompatible with quantitative observational data. This discrepancy arises partly because of the researchers' psychological

biases, but also because societies are comprised of heterogeneous individuals whose behavioral patterns defy simplistic categorizations and summaries. Our Peruvian sample, for example, reveals behavioral variation both between and within communities, and this variation cannot be easily reduced to a single normative pattern. Such variation and the limitations of conventional ethnographic methods accentuate the risks and disadvantages of relying on cross-cultural compilations like the Ethnographic Atlas (Murdock 1967) as a basis for comparisons.

The fine-grained quality of quantitative time allocation data has long exceeded the sophistication of statistical analyses by anthropologists. Mixed-effects modeling and related advances have the potential to unlock the rich inferential possibilities afforded by such detailed, high-quality data. That potential applies not only to isolated case studies but also to broader cross-cultural comparisons. Whereas anthropologists have pooled data for compelling analyses of economic norms (Henrich *et al.* 2005) and wealth transmission across generations (Borgerhoff Mulder *et al.* 2009), few recent studies have addressed cross-cultural variation in time allocation despite the existence of standardized datasets that are ideally suited for such comparisons, specifically the Human Relations Area Files (HRAF) series on time allocation (e.g., Johnson and Johnson 1987; see Gray and Anderson 2010 for a recent analysis based on these data), as well as the existence of comparable datasets that follow the same methods, including ours. Instead of summary statistics or descriptive generalizations, the data files in this series provide the original observation-level data, which permits researchers to aggregate all observations into a single dataset while using mixed-effects modeling to partition the higher-level variance that stems from repeated observations of the same individuals, nested in households and further nested in communities and societies.¹³ Explanatory variables at all levels can then be tested as predictors of behavioral variation. Such undertakings are considerably more ambitious than the analyses in this paper, especially if they tackle multinomial response variables, but the statistical methods in this cross-cultural comparison of men's work aptly elucidate the benefits and long-term potential of mixed-effects modeling for the study of time allocation in small-scale societies.

¹³ In this paper, we have not focused on temporal autocorrelation, but if observations of the same individuals occur in quick succession (e.g., within the same hour), then these observations might exhibit additional non-independence (Borgerhoff Mulder and Caro 1985). Temporal autocorrelation can be incorporated in mixed-effects models by appropriate modification of the random-effects structure.

Acknowledgements Fieldwork in Nicaragua was funded by a Fulbright student grant, the National Science Foundation (Dissertation Improvement Award #0413037), the Hill Foundation, and a William Sanders dissertation grant. Fieldwork in Peru was funded by the National Science Foundation (BNS-8313190). A grant from the National Science Foundation (BCS-0963752) facilitated this collaborative analysis. We thank Maria Fox for formatting the supplemental file.

References

- Bates, D., Maechler, M., and Bolker, B. (2011). *lme4: Linear Mixed-Effects Models Using Eigen and S4*. Classes.
- Baumann, H. (1928). The Division of Work According to sex in African hoe Culture. *Africa* 1: 289–319.
- Becker, G. S. (1991). *A Treatise on the Family*. Harvard University Press, Cambridge.
- Beckerman, S. (1987). Swidden in Amazonia and the Amazon Rim. In Turner, B. L. I., and Brush, S. B. (eds.), *Comparative Farming Systems*. Guilford Press, New York, pp. 55–94.
- Bock, J. (2002). Evolutionary Demography and Intrahousehold Time Allocation: Schooling and children's Labor Among the Okavango Delta Peoples of Botswana. *American Journal of Human Biology* 14: 206–221.
- Booth, A., & Tamura, Y. (2009). Impact of Paternal Temporary Absence on Children Left Behind. Unpublished manuscript.
- Borgerhoff Mulder, M., and Caro, T. M. (1985). The use of Quantitative Observational Techniques in Anthropology. *Current Anthropology* 26: 323–335.
- Borgerhoff Mulder, M., Bowles, S., Hertz, T., Bell, A., Beise, J., Clark, G., et al. (2009). Intergenerational Wealth Transmission and the Dynamics of Inequality in Small-Scale Societies. *Science* 326: 682–688.
- Boserup, E. (1970). *Woman's Role in Economic Development*. St. Martin's, New York.
- Brown, J. K. (1970). A Note on the Division of Labor by Sex. *American Anthropologist* 72: 1073–1078.
- Burton, M. L., and White, D. R. (1984). Sexual Division of Labor in Agriculture. *American Anthropologist* 86: 568–583.
- Chayanov, A. (1966). *The Theory of Peasant Economy*. American Economic Association, New York.
- Doss, C. R. (1999). *Twenty-Five Years of Research on Women Farmers in Africa: Lessons and Implications for Agricultural Research Institutions; with an Annotated Bibliography*. CIMMYT.
- Ember, C. R. (1983). The Relative Decline in Women's Contributions to Agriculture with Intensification. *American Anthropologist* 85: 285–304.
- Ember, M., and Ember, C. R. (1973). The Conditions Favoring Matrilocal Versus Patrilocal Residence. *American Anthropologist* 73: 571–594.
- Flinn, M. V. (1988). Mate guarding in a Caribbean village. *Ethology and Sociobiology* 9: 1–28.
- Fratkin, E., and Smith, K. (1995). Women's Changing Economic Roles with Pastoral Sedentarization: Varying Strategies in Alternate Rendille Communities. *Human Ecology* 23: 433–454.
- Gelman, A., and Hill, J. (2007). *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge University Press, Cambridge.
- Gibson, M. A. (2008). Does Investment in the Sexes Differ When Fathers are Absent? Sex-Biased Infant Survival and Child Growth in Rural Ethiopia. *Human Nature* 19: 263–276.
- Goland, C. (1993a). Field Scattering as Agricultural Risk Management: A Case Study from Cuyo Cuyo, Department of Puno, Peru. *Mountain Research and Development* 13(4): 317–338.

- Goland, C. (1993b). Cultivating Diversity: Field Scattering as Agricultural Risk Management in Cuyo Cuyo (Department of Puno, Perú). from <http://www.anthro.ucdavis.edu/winterweb/html/research/andean/golandCD/index.htm>
- Goldstein, H. (2003). *Multilevel Statistical Models*, 3rd ed. Arnold, London.
- Graham, M. (1999). Child Nutrition and Seasonal Hunger in an Andean Community (Department of Puno, Perú). from <http://www.anthro.ucdavis.edu/winterweb/html/research/andean/grahamCNSH/index.htm>
- Gray, P. B., and Anderson, K. G. (2010). *Fatherhood: Evolution and Human Paternal Behavior*. Harvard University Press, Cambridge.
- Gross, D. R. (1984). Time Allocation: A Tool for the Study of Cultural Behavior. *Annual Review of Anthropology* 13: 519–558.
- Gurven, M., and Kaplan, H. (2006). Determinants of Time Allocation Across the Lifespan: A Theoretical Model and an Application to the Machiguenga and Piro of Peru. *Human Nature* 17: 1–49.
- Gurven, M., Winking, J., Kaplan, H., von Rueden, C., and McAllister, L. (2009). A Bioeconomic Approach to Marriage and the Sexual Division of Labor. *Human Nature* 20: 151–183.
- Hames, R. (1992). Time Allocation. In Smith, E. A., and Winterhalder, B. (eds.), *Evolutionary Ecology and Human Behavior*. Aldine De Gruyter, New York, pp. 203–235.
- Hawkes, K., O’Connell, J. F., and Blurton Jones, N. G. (1997). Hadza women’s Time Allocation, Offspring Provisioning, and the Evolution of Long Postmenopausal Life Spans. *Current Anthropology* 38: 551–577.
- Henrich, J., Boyd, R., Bowles, S., Gintis, H., Fehr, E., Camerer, C., et al. (2005). “Economic man” in Cross-Cultural Perspective: Behavioral Experiments in 15 Small-Scale Societies. *Behavioral and Brain Sciences* 28: 795–855.
- Hill, K., Kaplan, H., Hawkes, K., and Hurtado, A. M. (1985). Men’s Time Allocation to Subsistence Work Among the Aché of Eastern Paraguay. *Human Ecology* 13: 29–47.
- Hooper, P. L. (2011). *The Structure of Energy Production and Redistribution Among Tsimane’ Forager-Horticulturalists*. Unpublished Ph.D. dissertation, University of New Mexico.
- House, P.R. (1997). *Ethnobotany of the Tawahka: Agricultural Practice and Forest Management in Lowland Central America*. Unpublished Ph.D. Dissertation, The University of Reading.
- Hurtado, A. M., Hawkes, K., Hill, K., and Kaplan, H. (1985). Female Subsistence Strategies Among Ache Hutner-Gatherers of Eastern Paraguay. *Human Ecology* 13: 1–28.
- Hurtado, A. M., Hill, K., Kaplan, H., and Hurtado, I. (1992). Trade-Offs Between Female Food Acquisition and Child Care Among Hiwi and Ache Foragers. *Human Nature* 3: 185–216.
- Imai, K., Keele, L., and Tingley, D. (2010). A General Approach to Causal Mediation Analysis. *Psychological Methods* 15: 309–334.
- Johnson, A. (1975). Time Allocation in a Machiguenga Community. *Ethnology* 14: 301–310.
- Johnson, A., and Behrens, C. (1989). Time Allocation Research and Aspects of Method in Cross-Cultural Comparison. *Journal of Quantitative Anthropology* 1: 313–333.
- Johnson, O. R., and Johnson, A. (1975). Male/Female Relations and the Organization of Work in a Machiguenga Community. *American Ethnologist* 2: 634–648.
- Johnson, A., & Johnson, O. R. (1987). *Time Allocation Among the Machiguenga of Shimaá (Peru)*. Cross-Cultural Studies in Time Allocation. New Haven, CT: Human Relations Area Files.
- Johnson, A., and Sackett, R. (1998). Direct Systematic Observation of Behavior. In Bernard, H. R. (ed.), *Handbook of Methods in Cultural Anthropology*. AltaMira, Walnut Creek, CA, pp. 301–331.
- Judd, C. M., and Kenny, D. A. (2010). Data Analysis. In Gilbert, D., Fiske, S. T., and Lindzey, G. (eds.), *The Handbook of Social Psychology*, vol. 1, 5th ed. Wiley, New York, pp. 115–139.
- Kaplan, H. (1994). Evolutionary and Wealth Flows Theories of Fertility: Empirical Tests and New Models. *Population and Development Review* 20: 753–791.
- Kennedy, W. J., and Gentle, J. E. (1980). *Statistical Computing*. Dekker, New York.
- Koster, J. M. (2007). *Hunting and Subsistence Among the Mayangna and Miskito of Nicaragua’s Bosawas Biosphere Reserve*. Unpublished Ph.D. dissertation, Penn State University.
- Koster, J. M. (2008a). Hunting with Dogs in Nicaragua: An Optimal Foraging Approach. *Current Anthropology* 49: 935–944.
- Koster, J. M. (2008b). The Impact of Hunting with Dogs on Wildlife Harvests in the Bosawas Reserve, Nicaragua. *Environmental Conservation* 35: 211–220.
- Koster, J. M. (2011). Interhousehold Meat Sharing Among Mayangna and Miskito Horticulturalists in Nicaragua. *Human Nature* 22: 394–415.
- Kramer, K. L. (2009). Does it Take a Family to Raise a Child? Cooperative Breeding and the Contributions of Maya Siblings, Parents and Older Adults in Raising Children. In Bentley, G., and Mace, R. (eds.), *Substitute Parents: Biological and Social Perspectives on Alloparenting in Human Societies*. Berghahn Books, Oxford.
- Larme, A. (1993). *Work, Reproduction, and Health in Two Andean Communities (Department of Puno, Perú)*. from <http://www.anthro.ucdavis.edu/winterweb/html/research/andean/larmeWRH/index.htm>
- Lastarria-Cornhiel, S. (2006). *Feminization of Agriculture: Trends and Driving Forces (Background paper for the World Development Report, 2008)*. Unpublished manuscript.
- Lee, R. B. (1979). *The !Kung San: Men, Women, and Work in a Foraging Society*. Cambridge University Press, Cambridge.
- Lokshin, M., and Glinskaya, E. (2009). The Effect of Male Migration on Employment Patterns of Women in Nepal. *The World Bank Economic Review* 23(3): 481–507.
- MacKinnon, D. P., Fairchild, A. J., and Fritz, M. S. (2007). Mediation Analysis. *Annual Review of Psychology* 58: 593–614.
- Martin, P., and Bateson, P. (2007). *Measuring Behavior: An Introductory Guide*, 3rd ed. Cambridge University Press, Cambridge.
- McCabe, C. W. (2009). *Human Behavioral Ecology and the Individual in Society*. Unpublished Ph.D. dissertation, UC-Davis, Davis.
- Merlo, J., Chaix, B., Yang, M., Lynch, J., and Rastam, L. (2005). A Brief Conceptual Tutorial of Multilevel Analysis in Social Epidemiology: Linking the Statistical Concept of Clustering to the Idea of Contextual Phenomenon. *Journal of Epidemiology and Community Health* 59: 443–449.
- Murdock, G. P. (1967). *Ethnographic Atlas*. University of Pittsburgh Press, Pittsburgh, PA.
- Murdock, G. P., and Provost, C. (1973). Factors in the Division of Labor by Sex: A Cross-Cultural Analysis. *Ethnology* 12: 203–225.
- Nag, M., White, B., and Peet, R. (1978). An Anthropological Approach to the Study of the Economic Value of Children in Java and Nepal. *Current Anthropology* 19: 293–306.
- Panter-Brick, C. (1993). Seasonal Organisation of Work Patterns. In Ulijaszek, S. J., and Strickland, S. S. (eds.), *Seasonality and Human Ecology*. Cambridge University Press, Cambridge, pp. 220–234.
- Paolisso, M., and Hames, R. (2010). Time Diary Versus Instantaneous Sampling: A Comparison of two Behavioral Research Methods. *Field Methods* 22: 357–377.
- Pearl, J. (2012) *The Causal Mediation Formula: A Guide to the Assessment of Pathways and Mechanisms*. *Prevention Science* 13: 426–436.
- Petersen, M. L., Sinisi, S. E., and van der Laan, M. J. (2006). Estimation of Direct Causal Effects. *Epidemiology* 17: 276–284.
- R Development Core Team (2011). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

- Radel, C., Schmook, B., McEvoy, J., Méndez, C., and Petrzalka, P. (2012). Labour Migration and Gendered Agricultural Relations: The Feminization of Agriculture in the Ejidal Sector of Calakmul, Mexico. *Journal of Agrarian Change* 12: 98–119.
- Rao, P. V., Li, H., and Roth, J. (2008). Recursive Path Models When Both Predictor and Response Variables are Categorical. *Journal of Statistical Theory and Practice* 2: 663–676.
- Rasbash, J., Charlton, C., Browne, W. J., Healy, M., & Cameron, B. (2009). MLwiN 2.19: Centre for Multilevel Modeling, University of Bristol.
- Recharte, J. (1993). Value and Economic Culture Among the Peasant Gold Miners of the Cuyo Cuyo District (Northern Puno, Perú). from <http://www.anthro.ucdavis.edu/winterweb/html/research/andean/recharteVEC/index.htm>
- Rodriguez, E. R., and Tiongson, E. R. (2001). Temporary Migration Overseas and Household Labor Supply: Evidence from Urban Philippines. *International Migration Review* 35: 709–725.
- Scelza, B. (2010). Father's Presence Speeds the Social and Reproductive Careers of Sons. *Current Anthropology* 51: 295–303.
- Scott, S. L. (2011). Data Augmentation, Frequentist Estimation, and the Bayesian Analysis of Multinomial Logit Models. *Statistical Papers* 52: 87–109.
- Shenk, M. K., Starkweather, K., Kress, H. C., and Alam, M. N. (2013). Does Absence Matter? A Comparison of Three Types of Father Absence in Rural Bangladesh. *Human Nature*. doi:10.1007/s12110-013-9160-5.
- Snijders, T., and Bosker, R. (1999). *Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling*. Sage, London.
- Stone, M. P., Stone, G. D., and Netting, R. M. (1995). The Sexual Division of Labor in Kofyar Agriculture. *American Ethnologist* 22: 165–186.
- White, D. R., Burton, M. L., and Dow, M. M. (1981). Sexual Division of Labor in African Agriculture: A Network Autocorrelation Analysis. *American Anthropologist* 83: 824–849.
- Winking, J., Gurven, M., Kaplan, H., and Stieglitz, J. (2009). The Goals of Direct Paternal Care Among a South Amerindian Population. *American Journal of Physical Anthropology* 139: 295–304.
- Winking, J., Gurven, M., and Kaplan, H. (2011). Father Death and Adult Success Among the Tsimane: Implications for Marriage and Divorce. *Evolution and Human Behavior* 32: 79–89.