PROCEEDINGS — OF — **THE ROYAL SOCIETY** **B** | **BIOLOGICAL SCIENCES**

Polygyny among the Tsimane of Bolivia: an improved method for testing the polygyny –fertility hypothesis

Jeffrey Winking, Jonathan Stieglitz, Jenna Kurten, Hillard Kaplan and Michael Gurven

Supplementary data	"Data Supplement" http://rspb.royalsocietypublishing.org/content/suppl/2013/02/11/rspb.2012.3078.DC1.html
References	**This article cites 38 articles, 1 of which can be accessed free** http://rspb.royalsocietypublishing.org/content/280/1756/20123078.full.html#ref-list-1
Subject collections	Articles on similar topics can be found in the following collections behaviour (919 articles) evolution (1396 articles)
Email alerting service	Receive free email alerts when new articles cite this article - sign up in the box at the top right-hand corner of the article or click **here**

Polygyny among the Tsimane of Bolivia: an improved method for testing the polygyny–fertility hypothesis

Jeffrey Winking[1], Jonathan Stieglitz[2], Jenna Kurten[1], Hillard Kaplan[2] and Michael Gurven[3]

[1]Department of Anthropology, Texas A&M University, College Station, TX 77843-4352, USA
[2]University of New Mexico, Albuquerque, NM 87131, USA
[3]Department of Anthropology, University of California-Santa Barbara, Santa Barbara, CA 93106-3210, USA

The polygyny–fertility hypothesis states that polygyny is associated with reduced fertility for women and is supported by a large body of literature. This finding is important, because theoretical models of polygyny often differentiate systems based on the degree to which women are forced or willingly choose to enter polygynous marriages. The fact that polygyny tends to be associated with reduced fertility has been presented as evidence that polygyny is often less favourable for women, and that women must, therefore, be pressured into accepting such arrangements. Previous studies, however, have been hampered by the non-random assignment of women into monogamous and polygynous unions (i.e. self-selection), as differences between these groups of women might explain some of the effects. Furthermore, the vast majority of such studies focus on sub-Saharan populations. We address these problems in our analysis of women's fertility in polygynous marriages among the Tsimane of Bolivia. We offer a more robust method for assessing the impact of polygynous marriage on reproductive outcomes by testing for intra-individual fertility effects among first wives as they transition from monogamous to polygynous marriage. We report a significant link between polygyny and reduced fertility when including all cases of polygyny; however, this association disappears when testing only for intra-individual effects.

1. Introduction

Though the practice of polygyny is rare in Western societies, more than 80 per cent of populations listed in the standard cross-cultural sample (SCCS) permit polygynous marriage [1]. A large body of research going back nearly a century has developed around the testing of the polygyny–fertility hypothesis, which states that polygyny is associated with lower fertility in women (for citations, see [2]). The majority of these studies support the hypothesis. Reduced fertility is often presented as evidence that polygyny is associated with less favourable conditions for women—not only is higher fertility often a preferred end unto itself in natural-fertility populations, but it is an indicator of health and resource availability [3]. Researchers have thus argued that women are probably being pressured into polygyny, as women would not freely choose to enter into such unions if they are associated with negative outcomes [1,4]. Such a conclusion is important, as the degree of freedom that women have in choosing their marital partners is an important element that distinguishes different models of polygyny.

Here, we try to improve on this research paradigm in our exploration of polygyny among the Tsimane of Bolivia. While our sample of polygynous marriages is limited owing to the low frequency of polygyny, this study addresses a deficiency in the extensive polygyny–fertility literature, which is dominated by studies of African populations and largely devoid of studies among South American populations (see [5]). We examine the impacts of polygyny on

women's fertility and offer a novel analytical approach that focuses on the testing of intra-individual effects. Previous studies have been hampered by self-selection problems, as women are not randomly assigned to monogamous and polygynous marriages. It is thus impossible to determine the degree to which fertility differences are due to differences between polygynously and monogamously married women, or to polygyny itself. Here, we test for intra-individual fertility reductions as first wives move from a monogamous arrangement to a polygynous one, thus controlling for self-selection. We also test for self-selection by exploring differences between monogamous women, and polygynous first and second wives.

(a) Explaining polygyny

Polygyny can take many different forms and attempts to characterize the practice cross-culturally have grown in complexity as researchers have come to realize the numerous ways by which it varies across the globe [6]. An important factor that distinguishes many theoretical models of polygyny is the degree to which women freely choose to enter into polygynous unions [1,7,8]. Under *female choice* systems, women have freedom to choose marital partners and do so according to their best interests [9]. Males vary in the value they offer females, and if there exists enough variance, females might prefer to partner with a high-quality already-paired male rather than with a single male with comparably lower offerings [10,11].

In contrast to systems driven by female choice are those dominated by *male coercion* [1,12–14]. This can take the form of direct physical coercion, such as in harem-defence polygyny seen in many polygynous primate species. In humans, some marriage markets are dominated by similarly forceful strategies, although male coercion can also take less aggressive forms, something that might be termed hegemonic coercion. Marital customs, such as gender norms, often lead women to accept a subordinate status and to relinquish their reproductive autonomy. Even if they are not physically coerced into unwanted marriages, they might be socially pressured without any culturally appropriate avenues to exert their will.

(b) Comparisons of outcomes

The impact of polygynous marriage on women's wellbeing is important in differentiating explanatory models as well as informing public health and legal policy (e.g. [15,16]). A large body of literature has thus developed around evaluating these impacts, using numerous proxies of wellbeing [2,17–19]. The majority of such studies have focused on testing the polygyny–fertility hypothesis: that women in polygynous marriages exhibit reduced fertility compared with those in monogamous marriages [17]. Fertility is a useful proxy, as it is a good indicator of overall health and resource availability in natural-fertility populations [3]. Josephson [2] compiled a list of 86 studies spanning nearly a century that tested the polygyny–fertility hypothesis. Including six studies that have appeared since his original publication [1,14,20–23], a full 74 per cent (68 of 92) of the studies found that polygynous women have lower fertility than their monogamous counterparts (although some effects are not so straightforward; see [14]). It is important to note that some populations are covered in multiple studies, and

more importantly, 87 per cent (80 of 92) of these studies focus on sub-Saharan African populations.

There is reason to doubt whether the observed fertility trend can be generalized to South American populations. Polygyny is reported to exist in some degree in all African populations in the SCCS ($n = 28$), with a median 34 per cent of married men being married to more than one wife [6]. In comparison, 90 per cent of populations in South America ($n = 29$) allow for polygyny, with a median of 20 per cent of married men being married to multiple wives [6]. Across Africa, co-wives are mostly nonsororal (24 of 28), meaning that co-wives are not sisters, and they tend to reside in separate houses (27 of 28). In South America, however, half of populations that practise polygyny prefer sororal polygyny (13 of 26) and co-residence among co-wives (13 of 26) [6]. Many factors have been proposed to account for the fertility effects commonly found in African populations, some of which may be attenuated in South American populations. These include direct effects, such as reduced frequency of marital coitus [24,25], dilution of family resources [26] and co-wife conflict [27], as well as factors that are associated with polygyny, such as first-wife infertility and greater age disparities between spouses [17,28]. Furthermore, differences in overall subsistence patterns (e.g. the lack of pastoralism in Amazonia) likely translate to different patterns of labour roles for husbands and wives.

Negative outcomes associated with polygyny are often taken as evidence that the institution is maladaptive for women, that women must, therefore, be coerced into such arrangements, and that male-coercion models better explain the phenomenon. The flaws of this logic have been outlined before, as it is possible for such an effect to exist, *even if women enjoy total reproductive autonomy* [1,22,27,29]. This possibility arises from the fact that women are not randomly assigned to monogamous or polygynous marriage [1]. If marriage to an unmarried man is preferable to women (all else equal), then single men might be more likely to marry women who are more competitive on the marriage market, relegating less competitive women to polygynous marriage. If such competitiveness is associated with later fertility, this selection might account for some or all of the observed fertility reduction. Even if polygyny does result in less favourable outcomes, it might be the best option available to less competitive women. To more accurately test for the impact of polygyny, it is, therefore, necessary to examine intra-individual effects as women move from one condition to another, something which, to our knowledge, has not yet been done and which we attempt here. Whether women are being pressured into polygynous marriage, on the other hand, can only be determined through ethnographic explorations of marital practices, gender norms and women's opinions of polygynous marriage.

(c) Hypotheses

A number of scenarios might characterize polygyny in a population. It is important to determine whether women are pressured into or freely choose polygyny (H1), whether polygyny is associated with lower outcomes (H2) and whether women are self-selected into polygynous unions (H3). Assuming that the Tsimane practice polygyny as outlined in male-coercion models, we derive from H1 the following predictions: women do not have a high degree of

marital autonomy (P1.a), and women do not favour polygyny (P1.b). To test H1 predictions, we use semi-structured ethnographic interviews concerning perceptions of polygyny and women's marital autonomy.

From H2, we derive the predictions that women living polygynously should exhibit lower fertility than those living monogamously (P2.a), but more specifically, that first wives should experience a reduction in fertility upon the addition of a second wife (P2.b). In order to evaluate H3, we test the predictions that second wives are less competitive on the marriage market, as indicated by higher ages at marriage (P3.a). The retrospective nature of the data precludes more direct measures of competiveness that would have allowed for more powerful tests of self-selection, but there is reason to believe that age at marriage is associated with competitiveness. Attractiveness is associated with earlier marriage in Western populations [30–32], while in natural-fertility populations, younger age at marriage/first birth has been found to be associated with better nutrition and growth [33,34], higher subsequent fertility [35–37] and higher bride-prices [37,38]. Polygynous husbands and first wives should also be self-selected, as they may exhibit greater competitiveness on the marriage market. Thus, we predict that the first wives of men who go on to marry polygynously should be younger than the first wives of men who remain monogamous (P3.b). Similarly, first wives should have higher fertility during their pre-polygynous monogamous phase compared with wives of men who remained monogamous (P3.c), and first wives should have higher fertility than second wives during their polygynous years (P3.d).

2. Methods

(a) Population and ethnographic interview

The Tsimane are a population of 11 000 forager–horticulturalists who reside mainly along the Maniqui River system in lowland Beni, Bolivia. Their diet is based largely on the cultivation of rice, plantains, sweet manioc and corn, as well as on hunting, fishing and varying levels of market goods depending on their proximity to town. Households typically consist of a single nuclear family with related families living close to one another, creating extended-family household clusters. While nuclear families maintain individual gardens, food is often communally shared at the cluster level.

Marriages tend to be stable, with divorce increasingly uncommon after the birth of children. The period of courtship tends to last no more than a couple of weeks. If successful, the couple customarily resides near the wife's family for two or three years, after which time they can move to wherever they desire. Cross-cousin marriage is preferred, as is sororal polygyny, if it occurs.

In order to examine views concerning marriage, semi-structured interviews were conducted in the Tsimane language by J.W. and a Tsimane assistant with 23 married men (two of whom were polygynously married) and 24 married women (all of whom were monogamously married), as well as a focus group consisting of three married men who were fluent in Spanish. The interviews were not exclusively designed to explore polygyny, but contained questions concerning this topic.

(b) Demographic data collection

Demographic interviews were conducted on all available adults in 21 villages from 2002 to 2006, in which the reproductive histories of the interviewee and of his or her parents and siblings were recorded. These interviews were conducted in Tsimane with the aid of translators. Birth years were estimated using a number of methods, including the use of well-known dated events, relative age lists, formal records, etc. These methods resulted in redundancy that allowed for estimates to be corroborated and refined. Methods are described at length in Gurven et al. [39]. These methods resulted in the identification of 6795 individuals for whom birth years and, if necessary, death years were estimated. Subsequent data collection allowed for the collection of reproductive data for some individuals until 2009.

(c) Definition of marriage and sample characteristics

Marriage was determined by reproductive patterns, as data concerning the timing of marriages were less complete and relied more on informant reports. This unfortunately eliminates data covering the early nulliparous years of marriage as well as childless couples. Analysis of intra-individual fertility effects, however, minimizes any bias introduced by such limitations. Monogamous first marriages were defined as marriages involving individuals who each only had one lifetime spouse. Polygyny occurs if a man reproduced with the first wife (W1), then another woman (W2), then with W1 again, and then again with W2 (W1, W2, W1, W2). This eliminates the possibility that a man divorced his first wife and then remarried (W1, W2), or had a child through an extramarital affair (W1, W2, W1). Only the most recent marriage of each individual was included. Thus, to indicate a second (or later) marriage, the couple had to have at least two children together, no children with previous reproductive partners since their first birth together, and to have been together at least five years since the first birth of a child. Marriages with a reproductive infidelity were also included. These were defined as cases in which the spouse had only one child with another individual, this occurred more than five years in the past, and the original couple had at least two subsequent children. Cases that did not fit into any of these scenarios were excluded.

Marriage is defined to have taken place the year prior to the first birth of the couple. This is based on a sample of 595 estimated years of marriage (using informant reports), which showed one to be the modal number of years until first birth. The dataset was expanded to include a record for each year of marriage. The beginning year is set to the year after the first birth, as reproductive outcomes for the first two years are set by the definition of marriage. Polygyny is defined to begin the year before the second wife's first birth. The terminal year is defined as the first year in which one spouse dies, the final year of data collection for the individual, age 50 for women, age 60 for men, or, for one man, the year in which a third wife is added (only polygynous marriages consisting of two wives are examined). For each year, the data include the individual's age, polygyny status and whether the individual reproduced. The resulting dataset consists of 528 men and 477 women for whom there are 11 124 and 9453 risk years, respectively (table 1). Finally, while no direct measures of individual competitiveness were recorded, we use the age of marriage for women as an indicator of their competitiveness on the marriage market.

(d) Data analysis

In order to isolate the effects of polygyny on fertility and to control for repeated risk years for each individual, mixed effects logistic regression is used to predict the probability of giving birth in a given year. The model includes age, age^2, and polygyny status with the inclusion of personal ID number as a random effect. The age of the husband at marriage and the year of the woman's birth (to account for cohort effects) were initially included in the models but were omitted as they were not significant predictors of fertility. For analyses of ages

Table 1. Sample characteristics.

	n (individuals)	risk years (mono)	risk years (poly)	median age of marriage	median age at polygyny
men					
monogamous	499	10 546	—	22	—
polygynous	29	79	499	22	27
women					
monogamous	425	8579	—	17	—
polygnous first wife	31	98	448	17	22
polygnous second wife	21	—	328	17	17

at first birth, Mann–Whitney U tests are used owing to the right-tailed distribution of this measure. Survival analysis was not feasible (i.e. examining survival to first birth), because individuals could be censored in both the dependent (age at first birth) and independent variable (polygyny status). Samples are thus limited to only those who were born more than 25 (for women) or 30 (for men) years prior to the year of data collection. This reduces the effect of censoring (i.e. only including individuals who have already reproduced), which artificially lowers medians. Well over 90 per cent of men and women have reproduced by these ages [40]. All analyses were conducted using SPSS v. 19.

3. Results

(a) Female autonomy and perceptions of polygyny (H1)

Earlier research revealed that over a third of Tsimane women report being pressured against their will to be the major reason for having chosen their spouse (compared with 11% of men reporting this reason) [41]. A larger percentage, however, reported positive reasons for having chosen their spouse. Furthermore, although uncommon, there is no severe cultural sanction against divorce and when it does occur, it is often initiated by women who 'escape' (*cajoij*) back to their parents' home or to another suitor. Thus, the prediction that women have a low level of marital autonomy (P1.a) is equivocal. Women also exhibit a fair degree of marital autonomy concerning polygynous marriage, as discussed below.

Polygynous marriages are nearly universally sororal (15 of 16 marriage from the sample described below), with co-wives living either in a common house or houses that are adjacent. The addition of a second wife seems more difficult to arrange than a monogamous marriage as it must be desired by the husband, the wife's parents and *both* sisters. Any party can initiate a polygynous marriage, but men claim that first wives are often most reluctant to agree to such arrangements. All monogamously married men ($n = 21$) who were interviewed stated that their wives would be angry if they were to marry a sister-in-law, and indeed, all monogamous women voiced similar opinions ($n = 24$). Similarly, women universally ($n = 23$) reported that they did not want to marry as a second wife when they were younger and first on the marriage market. Only two ($n = 19$) suggested they would have considered this option if their sister's husband had been very wealthy or always able to procure food. Interestingly, except for the two polygynously married men, none of the interviewed

men wanted to become polygynously married. When asked what difficulties arise in polygynous marriages, a lack of resources was most commonly cited, distantly followed by co-wife conflict. Few were able to list any benefits of polygyny, although some reported it can be helpful to have an extra caretaker to allow the other wife to work in the garden.

Thus, monogamy appears largely preferred over polygyny by both men and women, supporting prediction P1.b. And yet polygyny still occurs. Anecdotes provided by interviewees shed light on the motivations underlying polygynous marriage. For instance, one man reported that his mother-in-law and his wife initially pressured him to also marry his younger sister-in-law (as a co-wife), so as to ensure the continuation of his presence and labour at the homestead. He was reluctant, and eventually, the younger sister decided to marry her own husband. Another man reported that it was the sister-in-law who showed interest in him, and while the first wife seemed accepting at first, she ultimately put a stop to it. Other men reported having desired to marry a younger sister-in-law, but being unable to convince their wives to accept the arrangement. Thus, while polygyny might be generally less preferable, there appear to be situations in which any party might wish it and often channels for any party to stop it. Surprisingly, no one suggested that a first wife's sub-fecundity might lead to polygyny. Indeed, of five possible causes of divorce, infertility was reported to be the least likely to result in divorce.

(b) Prevalence of polygny

To assess the current frequency of polygyny among the Tsimane, we used a 2009 census of 70 villages consisting of 8853 individuals. Based on the demographic sample (see below), the median age of first birth for Tsimane men is 22, and 27 is the median age of polygynous men at the first birth of their second wife. We thus limited the census to men ages 25 to 54, in which just over 90 per cent are monogamously married (327 of 363). Only 4.4 per cent of men (16 of 363) were married polygynously, along with 5 per cent that were single (18 of 363) and two brothers who were married polyandrously. Limiting the sample further to age 35 and older increases the percentage of polygynous men to 6.1 per cent (12 of 198). Of the 16 men that were married polygynously, 15 of them, or 94 per cent, were married to women who were sisters.

All other analyses rely on the retrospective demographic dataset, which is further altered by the inclusion/exclusion
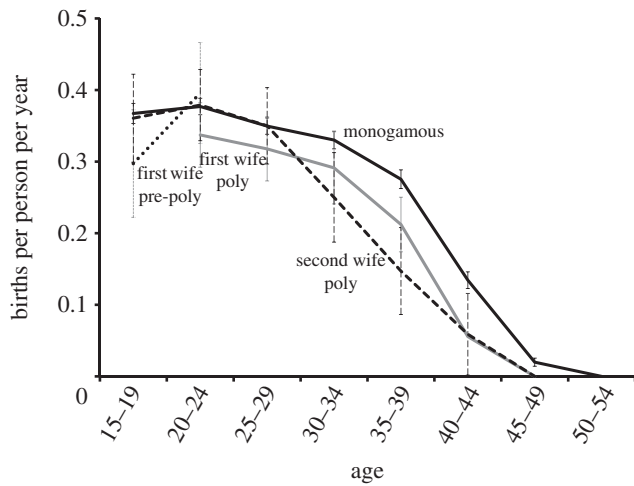
Figure 1. Age-specific fertility rates for monogamous and polygynous women. (Error bars = s.e.)

5

Table 2. Mixed effects logistic regression of women's fertility on polygyny status.

	OR	OR 95% CI	significance
(a) all women[a] (n = 9453/477)[b]			
polygynous	0.822	0.694 – 0.973	0.022
age	1.290	1.234 – 1.350	<0.001
age^2	0.995	0.995 – 0.995	<0.001
(b) first wives (n = 382/19)[a]			
polygynous	0.935	0.471 – 1.857	0.848
age	1.366	1.010 – 1.848	0.043
age^2	0.993	0.987 – 0.999	0.011

[a]This analysis includes all women and 'polygynous' denotes risk years of second wives or of first wives after the addition of a second wife.
[b]The first number represents the number of risk years, and the second number represents the number of individuals.

criteria described above. Within this final dataset, 5.1 per cent of men are polygynously married, 6.5 per cent of women are first wives and 4.4 per cent are second wives (table 1). Median ages of marriage are the same across categories (note that these might not be individuals' first marriage in this sample).

(c) Female fertility and polygyny status (H2)

Figure 1 displays the age-specific fertility rates of women by their polygyny status. Including all women, with first and second wives pooled under a single category, polygynous marriage is associated with lower probability of giving birth in any given year (OR = 0.822, p = 0.022, n = 9453; table 2a), supporting P2.a. However, P2.b was not supported: there was no significant effect of moving from a monogamous to polygynous state on first-wife fertility (OR = 0.935, p = 0.848, n = 382) (table 2b). It is important to note that this analysis of first wives includes only 19 women. Twelve women were excluded as they did not experience any years married monogamously—this was due to the conservative manner in which years-of-marriage had to be defined. A *post hoc* analysis revealed no significant effect of polygyny when only comparing second wives with monogamous wives, although the effect was in the predicted direction of lower fertility among second wives (OR = 0.838, p = 0.174, n = 465; see the electronic supplementary material).

(d) Tests of self-selection (H3)

Median age of first marriage of women who married into a polygynous marriage as second wives ($\tilde{x}$ = 16.5, n = 18) was not significantly different from those who married men who remained monogamous ($\tilde{x}$ = 17, n = 388, U = 2989, p = 0.297), failing to support P3.a. The reduced sample size is a result of limiting the sample to women age 25 years or over to avoid censoring.

Median age of marriage for the first wives of men who ultimately married polygynously ($\tilde{x}$ = 17, n = 25) was not significantly lower than that of wives of men that remained monogamous ($\tilde{x}$ = 17, n = 456, U = 4976, p = 0.530). Note here, that this tests for self-selection in men, and thus includes men's first wives, whether or not they themselves had been

married previously. The sample was limited to men age 30 or over to avoid censoring. Additionally, women who went on to become first wives did not experience higher fertility during their monogamous years than wives of men who remained monogamous (OR = 1.075, p = 0.734, n = 8677), nor did first wives experience higher fertility than second wives during polygynous years (OR = 1.007, p = 0.967, n = 776; see the electronic supplementary material, table S3). Thus, P3.c and P3.d are also not supported by the data.

4. Discussion

We report mixed support for H1: while some women are pressured into marital arrangements they do not want, and polygyny is considered less preferable to monogamy, it is clear from the ethnographic accounts that women often have avenues to exert their will. In accordance with the general aversion to polygyny reported by Tsimane individuals, women in polygynous marriages did exhibit lower fertility than their monogamous counterparts, in support of H2. This analysis is very similar to the approach traditionally used in tests of the polygyny–fertility hypothesis. Despite this result, however, we find no evidence that the addition of a second wife negatively impacts the fertility of first wives. The fact that the intra-individual result is at odds with the pooled test might indicate that polygyny is not itself driving the fertility reduction, although the limited sample size inhibits any firm conclusions. Thus, we can only conclude that polygynous marriage trends towards lower fertility for women, but we are unable to determine if this reduction is due to the polygynous state itself. The mixed results reported for women stand in stark contrast to men's experience with polygyny, which nearly doubles their total fertility rate (see the electronic supplementary material)—a result which mirrors similar studies on human and animal polygyny [42,43].

In contrast to the equivocal assessments of H1 and H2, H3 received no support: there was no evidence that first wives, second wives or monogamous wives were self-selected. Our finding of no differences in ages among these groups runs

counter to the major trend in polygyny literature, in which second and later wives tend to be older at age of marriage than those who marry into monogamous unions [1,2,17,27]. Similarly, women who go on to become polygynous first wives are sometimes found to marry younger than those whose husbands remain monogamous [1,17], or even experience higher fertility during their pre-polygynous years [1,2]. This suggests that women can be selected into all marriage classes differently, highlighting the importance of distinguishing co-wife order and the difficulty of interpreting fertility effects.

The strongest method of testing for the direct impact of polygyny on fertility patterns is thus to compare a woman's fertility before and after she marries polygynously, something that is only possible with first wives. While this is the first study that we are aware of to formally test for intra-individual effects, others have noted a similar pattern. For instance, among nineteenth century Mormons, women who went on to become polygynous first wives experienced significantly higher fertility during their monogamous years than those who remained monogamous, but lost this advantage after the addition of a second wife [2]. The testing of intra-individual fertility effects may not be suitable for all populations or datasets, as it requires detailed retrospective reproductive data and limits the sample to first wives. Despite the constraints imposed by this method and by sample characteristics of the present study, we feel that through this exercise, we have illustrated a solution to the self-selection problem that has plagued this voluminous body of literature.

Finally, it is important to distinguish between different types of polygyny. The profile of polygynous marriage in most South American populations differs greatly from that commonly found in sub-Saharan African populations on which much of the evidence for the polygyny–fertility hypothesis is based [6]. Pastoralism, and heritable wealth associated with it, was traditionally absent in Amazonian populations; horticulture in South America often requires extensive male labour in the form of clearing large forest plots. Men in such populations might thus be limited in their ability to control enough resources to attract multiple wives or attain enough social and economic power to coerce women (and their kin) to accept such arrangements. These realities would undoubtedly impact the historical developments of the cultural institutions, preferences and beliefs that define women's marital and reproductive options. The results of the present study suggest that polygyny among the Tsimane might be more equally negotiated between men and women than is often found in sub-Saharan African populations and that polygyny might thus prove less detrimental to women. However, the low frequency of polygyny combined with the more robust study design (limiting the sample to first wives) resulted in limited sample sizes. We hope future studies will continue the focus on polygyny and its effects on women in South American populations to allow for more robust comparisons with the large body of research based on African populations.

References

1. Gibson MA, Mace R. 2007 Polygyny, reproductive success and child health in rural Ethiopia: why marry a married man? *J. Biosoc. Sci.* **39**, 287–300. (doi:10.1017/s0021932006001441)

2. Josephson S. 2000 Polygyny, fertility, and human reproductive strategies. Utah, PhD dissertation, Department of Anthropology, University of Utah, Salt Lake City.

3. Ellison PT. 1994 Advances in human reproductive ecology. *Annu. Rev. Anthropol.* **23**, 255–275. (doi:10.1146/annurev.anthro.23.1.255)

4. Strassman B. 1997 Polygyny as a risk factor for child mortality among the Dogon. *Curr. Anthropol.* **38**, 688–695. (doi:10.1086/204657)

5. Hern WM. 1992 Polygyny and fertility among the Shipibo of the Peruvian Amazon. *Popul. Stud. J. Demogr.* **46**, 53–64. (doi:10.1080/0032472031000146006)

6. White DR. 1988 Rethinking polygyny: co-wives, codes and cultural systems. *Curr. Anthropol.* **29**, 529–558. (doi:10.1086/203674)

7. Chisolm JS, Burbank VK. 1991 Monogamy and polygyny in southeast Arnhem Land: male cercion and female choice. *Ethol. Sociobiol.* **12**, 291–313. (doi:10.1016/0162-3095(91)90022-l)

8. Mulder MB. 1990 Kipsigis women's preferences for weatlhy men: evidence for female choice in mammals. *Behav. Ecol. Sociobiol.* **27**, 255–264. (doi:10.1007/BF00164897)

9. Mulder MB. 1985 Polygyny threshold: a Kipsigis case study. *Natl. Geogr.* **21**, 33–39.

10. Orians GH. 1969 On the evolution of mating systems in birds and mammals. *Am. Nat.* **103**, 589–603. (doi:10.1086/282628)

11. Verner J, Willson MF. 1966 The influence of habitats on mating systems of North American birds. *Ecology* **47**, 143–147. (doi:10.2307/1935753)

12. Sellen DW, Hruschka DJ. 2004 Extracted-food resource-defense polygyny in native western North American societies at contact. *Curr. Anthropol.* **45**, 707–714. (doi:10.1086/425637)

13. White DR, Burton ML. 1988 Causes of polygyny: ecology, economy, kinship, and warfare. *Am. Anthropol.* **90**, 871–887. (doi:10.1525/aa.1988.90.4.02a00060)

14. Sellen DW, Mulder MB, Sieff DF. 2000 Fertility, offspring quality, and wealth in Datoga pastoralists: testing evolutionary models of intersexual selection. In *Adaptation and human behavior: an anthropological perspective* (eds L Cronk, N Chagnon, W Irons), pp. 91–114. New York, NY: Aldien de Gruyter.

15. Reniers G, Tfaily R. 2008 Polygyny and HIV in Malawi. *Demogr. Res.* **10**, 1811–1830. (doi:10.4054/DemRes.2008.19.53)

16. Canadian Press. 2010 Abuse not unique to polygamy. See http://www.cbc.ca/news/canada/british-columbia/story/2010/12/15/bc-polygamy-hearing.html.

17. Bean LL, Mineau GP. 1986 The polygyny fertility hypothesis: a reevaluation. *Popul. Stud.* **40**, 67–81. (doi:10.1080/0032472031000141846)

18. Hadley C. 2005 Is polygyny a risk factor for poor growth performance among Tanzanian agropastoralists? *Am. J. Phys. Anthropol.* **126**, 471–480. (doi:10.1002/ajpa.20068)

19. Amey FK. 2002 Polygyny and child survival in sub-Saharan Africa. *Soc. Biol.* **49**, 74–89.

20. Lardoux S, Van de Walle E. 2003 Polygyny and fertility in rural Senegal. *Population* **58**, 807–835. (doi:10.2307/3271283)

21. Sueyoshi S, Ohtsuka R. 2003 Effects of polygyny and consanguinity on high fertility in the rural Arab population in South Jordan. *J. Biosoc. Sci.* **35**, 513–526. (doi:10.1017/s0021932003005911)

22. Effah KB. 1999 A reformulation of the polygyny–fertility hypothesis. *J. Comp. Fam. Stud.* **30**, 381.

23. Sear R, Mace R, McGregor IA. 2003 The effects of kin on female fertility in rural Gambia. *Evol. Hum. Behav.* **24**, 99–112. (doi:10.1016/S1090-5138(02) 00122-8)

24. Musham HV. 1956 The fertility of polygynous marriages. *Popul. Stud.* **10**, 3–16.

25. Bongaarts J, Frank O, Lesthaeghe R. 1984 The proximate determinants of fertility in sub-Saharan Africa. *Popul. Dev. Rev.* **10**, 511–537. (doi:10.2307/1973518)

26. Brabin L. 1984 Polygyny: an indicator of nutritional stress in African agricultural societies. *Africa* **54**, 31–45. (doi:10.2307/1160142)

27. Mulder MB. 1989 Marital-status and reproductive-performance in Kipsigis women: re-evaluating the polygyny fertility hypothesis. *Popul. Stud.* **43**, 285–304. (doi:10.1080/0032472031000144126)

28. Josephson S. 2002 Does polygyny reduce fertility? *Am. J. Hum. Biol.* **14**, 222–232. (doi:10.1002/ajhb.10045)

29. Olusanya PO. 1971 Problem of multiple causation in population analysis, with particular reference to the polygamy–fertility hypothesis. *Sociol. Rev.* **19**, 165–178. (doi:10.1111/j.1467-954X.1971.tb00625.x)

30. Kalick SM, Zebrowitz LA, Langlois JH, Johnson RM. 1998 Does human facial attractiveness honestly advertise health? Longitudinal data on an evolutionary question. *Psychol. Sci.* **9**, 8–13. (doi:10.1111/1467-9280.00002)

31. Udry JR, Eckland BK. 1984 Benefits of being attractive: differential payoffs for men and women. *Psychol. Rep.* **54**, 47–56. (doi:10.2466/pr0.1984.54.1.47)

32. Jaeger MM. 2011 'A thing of beauty is a joy forever'? Returns to physical attractiveness over the life course. *Soc. Forces* **89**, 983–1003.

33. Riley AP. 1994 Determinants of adolescent fertility and its consequences for maternal health, with special reference to rural Bangladesh. *Ann. NY. Acad. Sci.* **709**, 86–100.

34. Komlos J. 1989 The age of menarche and age at first birth in an undernourished population. *Ann. Hum. Biol.* **16**, 463–466. (doi:10.1080/030144689 00000592)

35. Hill K, Hurtado AM. 1996 *Ache life history: the ecology and demography of a foraging people.* New York, NY: Aldine.

36. Sear R, Mace R, McGregor IA. 2003 A life-history analysis of fertility rates in rural Gambia: evidence for trade-offs or phenotypic correlations? In *The biodemography of human reproduction and fertility* (eds J Rodgers, HP Kohler), pp. 135–160. Boston, MA: Kluwer Press.

37. Mulder MB. 1989 Early maturing Kipsigis women have higher reproductive success than late maturing women and cost more to marry. *Behav. Ecol. Sociobiol.* **24**, 145–153. (doi:10.1007/BF00292097)

38. Hoogeveen J, van der Klaauw B, van Lomwel G. 2011 On the timing of marriage, cattle, and shocks. *Econ. Dev. Cult Change* **60**, 121–154. (doi:10.1086/661215)

39. Gurven M, Kaplan H, Supa AZ. 2007 Mortality experience of Tsimane Amerindians: regional variation and temporal trends. *Am. J. Hum. Biol.* **19**, 376–398. (doi:10.1002/ajhb.20600)

40. Winking J, Gurven M, Kaplan H. 2011 Father death and adult success among the Tsimane: implications for marriage and divorce. *Evol. Hum. Behav.* **32**, 79–89. (doi:10.1016/j.evolhumbehav.2010.08.002)

41. Gurven M, Winking J, Kaplan H, von Rueden C, McAllister L. 2009 A bioeconomic approach to marriage and the sexual division of labor. *Hum. Nat.* **20**, 151–183. (doi:10.1007/s12110-009-9062-8)

42. Bateman AJ. 1948 Intra-sexual selection in *Drosophila. Heredity* **2**, 349–368. (doi:10.1038/hdy.1948.21)

43. Moorad JA, Promislow DEL, Smith KR, Wade MJ. 2011 Mating system change reduces the strength of sexual selection in an American frontier population of the 19th century. *Evol. Hum. Behav.* **32**, 147–155. (doi:10.1016/j.evolhumbehav.2010.10.004)