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Estimating Polygyny Rates Among Hunter-Gatherers: A Statistical Model for Historical Source Criticism With a Yamana Case Study

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The purpose of this study is to incorporate an evolutionary perspective into the field of ethnohistory. Specifically, I developed a statistical model to estimate the polygyny rate among hunter-gatherers and applied it as a supplementary method of historical source criticism. The records of Reverend Thomas Bridges, who began his research in the late 1850s, are considered the most reliable accounts of the Yamana (Yahgan) people of Tierra del Fuego, South America. However, his records on the practice of polygyny are inconsistent, stating that polygyny was "very general" at times and denying its existence at others. While historical source criticism necessitates efforts to discover new sources, in cases such as that of the Yamana where reliance on inaccurate records by missionaries and travelers of the time is unavoidable, the evaluation and selection of conflicting sources become crucial. Therefore, I attempted to estimate the polygyny rate among the Yamana using a generalized linear mixed model with hunter-gatherer societies as the population. The results suggest that Bridges's records, particularly those from the early stages of his research, are likely to be unreliable, even when considering Bayesian credible intervals.

Keywords
polygyny, hunter-gatherer, Yamana, Tierra del Fuego, ethnohistory, source criticism

Introduction

In the field of comparative cultural studies, a growing body of research aims to examine evolutionary adaptive behaviors through observational records of hunter-gatherer societies. Nevertheless, when coding the variables crucial for comparative research, there are instances where ethnographic or historical sources exhibit contradictions, necessitating a critical examination of the textual evidence. For example, in the case of the Yamana (Yahgan) people in the Tierra del Fuego archipelago, Reverend Thomas Bridges's records from the late 1850s and early 1860s are widely considered the most reliable, as noted by Cooper (1917). However, these records contain conflicting information about the practice of polygyny, which is the focus of this paper. Bridges stated, "Owing to the almost general practice of polygamy, many men are without wives" (Bridges, 1866, p. 203), "Polygamy is very general … in fact, the marriage of two or three sisters by the same man is not the exception but the rule" (Bridges, 1869, p. 117), "Twenty-three men and youths assembled to tea at six P.M. Four of these were unmarried, seven have one wife each, five have two apiece, three have three, and one have four; the nineteen who are married having thirty-two wives" (Bridges, 1871, p. 138), and "they were neither cannibals nor polygamists" (Bridges, 1893, p. 234)[1].

The Austrian ethnologist Martin Gusinde collected testimony from elderly Yamana informants who had direct knowledge of that era in three fieldwork expeditions conducted between 1919 and 1924. He critically examined historical records by Europeans, including Bridges, and his analysis led him to conclude, "Monogamous single marriage is, after all, the general rule among Yamana. It has often been proven that the rare cases of polygamy are necessarily tolerated only as exceptions" (Gusinde, 1937/1961, pp. 439–440)[2]. However, to critically analyze Bridges's records, it is also necessary to critically examine Gusinde's ethnography itself. Gusinde's research was conducted half a century after the imposition of Christian values that prohibited polygyny as a "bad habit" (Chapman, 2010, p. 411), and Gusinde himself was a priest. In this paper, I employ a statistical model to estimate the degree of polygyny as a supplementary method of historical source criticism. In other words, I utilize "species-typical reaction norms, or 'context-dependent human universals'" (Ringen et al., 2019, p. 377) to conduct historical source criticism from a fresh perspective by incorporating evolutionary insight into the field of ethnohistory.

Previous studies

In previous studies, the contribution of women (or men) to subsistence has been identified as a variable predicting the degree of polygyny (e.g., Murdock, 1949; Schlegel & Barry, 1986). For instance, Marlowe (2003) conducted a comparative cross-cultural study using hunting and gathering societies from the Standard Cross-Cultural Sample (SCCS), pointing out two variables correlated with polygyny: male subsistence contribution and pathogen

1 This is a collection of Bridges's reports that were published in the *South American Missionary Magazine* since 1888 and later compiled and published by the Argentine Geographic Institute.

2 Cooper (1917), in his 1917 publication, discussed the marriage practices of the Yamana people, describing it as "dominant monogamy with, however, considerable polygamy" (p.166). However, in 1946, possibly influenced by Gusinde's research findings, he noted, "Monogamy was by far the most prevalent form of marriage. Polyandry did not occur. Polygyny was permitted, but was uncommon" (Cooper, 1946, p. 92).

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stress. In a multiple regression analysis using these factors as independent variables, Marlowe reported that subsistence contribution is the only statistically significant factor.

Polygyny is considered to influence the operational sex ratio (Emlen & Oring, 1977), and several studies have reported an association between skewed sex ratios and violence. However, within this discussion, there are reports that when the sex ratio skews toward males, competition between men intensifies over a limited number of females, leading to an increase in violence (Hudson & den Boer, 2002, 2004). Conversely, when the sex ratio skews toward females, competition between men intensifies over an expanded pool of potential partners (Schacht et al., 2014), resulting in an increase in violence (Barber, 2000, 2009).

Carter and Kushnick (2018) reported on the relationship between polygyny and male aggression, using polygyny to reflect the intensity of mate competition. In this comparative cross-cultural study involving 76 societies from the SCCS, variables predicting male aggression, including polygyny, sex ratio, and male subsistence contribution, were examined, and it was concluded that polygyny is the best predictor of aggression. While the results revealed that polygyny intensifies competition between men and leads to an increase in aggression, Stone (2017) focused on intersexual violence, pointing out that in societies where women who could become partners are scarce, men's violence toward women increases as a means to prevent betrayal and retain partners.

Based on these studies, I create a statistical model to predict the practice of polygyny and discuss its potential as a supplementary means for the critical analysis of historical sources.

Methods

Sample & variables

To build statistical models that predict polygyny, I utilized the SCCS, which has been widely used in the field of comparative cultural research. The SCCS is a dataset created by clustering 200 regions based on geographic proximity and cultural similarity and then extracting 186 societies that are assumed to be independent of each other, accounting for data scarcity and the problem of nonindependent data (Galton's Problem) (Murdock & White, 1969).

In this study, I extracted 35 hunting and gathering societies following Marlowe's selection criteria (Marlowe, 2003), given that the Yamana people are hunter-gatherers[3]. Specifically, societies were extracted from four categories of the nine classifications in the subsistence type – ecological classification (v858): 1. gathering, 2. hunting and/or marine animals, 3. fishing, and 4. anadromous fishing (spawning fish such as salmon). These societies were also selected because the percentage of their diet from agriculture (v3 < 4) or animal husbandry (v5 < 4) was less than 10% or because they used intercommunity trade for food sources (v1 < 6) less than 50%[4].

The dependent variable used in this study was the percentage of married women who are polygynously married (share husband with one or more co-wives) (v872). Theoretically, since all women of reproductive age are expected to be in demand, the higher the rate of female polygyny, the greater the proportion of unmarried men, thus intensifying the pressure for sexual selection against men, which may potentially increase male violence[5]. On the other hand, however, violent men may also be able to secure multiple wives. Although a cross-sectional study cannot reveal causal relationships, the purpose of this study was to construct a statistical model to predict the degree of polygyny as a means of historical source criticism. Therefore, polygyny was employed as the dependent variable.

In the SCCS, to avoid discrepancies and confusion in coding due to historical cultural changes and differences between subgroups within the society, temporal and spatial information was provided for each society through the "Pinpointing Sheets". The Yamana people, specifically the eastern and central subgroups, located approximately between latitudes 54°30' S and 56°30' S and longitudes 67°W and 70°W, were selected as the target group. The pinpoint time was 1865, when "approximately the beginning of the scientific contributions of Bridges" (White, 2009, p. 223)[6] occurred. Additionally, the "Focused Ethnographic Bibliography" (White, 1989)[7] specifies a list of ethnographic sources to serve as the basis for coding[8]. The dependent variable, v872, used in this study was evaluated by White (1988), and the polygyny rate among the Yamana people was coded at 10%[9], primarily referring to Cooper (1946), which states:

> Monogamy was by far the most prevalent form of marriage. Polyandry did not occur. Polygyny was permitted, but was uncommon. A few men had two

3 Following Marlowe's criteria, 36 societies were extracted. However, since the purpose of this study is to estimate the polygyny rate of the Yamana people, this ethnic group was excluded from the sample.

4 These three variables were coded by Murdock and Morrow (1970) as follows. Agriculture – contribution to local food supply (v3): 1. none, 2. non-food crops, 3. less than 10%, 4. less than 50%, and less than any other single source, including trade, 5. less than 50%, and more than any other single source, including trade, and 6. primarily agricultural. Animal husbandry – contribution to food supply (v5): 1. none, 2. present, not food source, 3. less than 10% food supply, 4. less than 50% – chiefly meat, 5. less than 50% – chiefly dairy, and 7. greater than 50%. Intercommunity trade as food source (v1): 1. no trade, 2. food imports absent although trade present, 3. salt or minerals only, 4. less than 10% of food (90% from local extractive sources), 5. less than 50% of food, and less than any single local source, and 7. greater than 50% of food.

5 The variable percentage of married men with more than one wife (v871) represents the polygynous marriage rate among men. However, as Marlowe (2003, p. 287) has noted, because the number of wives held by polygynous men varies, the proportion of polygynous men does not fully reflect the sex ratio bias and the intensity of sexual selection on men as effectively as the proportion of polygynous women does.

6 The original pinpointing sheets was prepared by Murdock and White (1969) and the complete edition was published by White (2009).

7 Murdock and White (1969) designated authorities for each target society, Murdock and Morrow (1970) prepared bibliography by those authorities, and White (1989) later published an updated edition.

8 Regarding the Yamana, Cooper (1917, 1946) and Gusinde (1937/1961) are designated as reference sources.

9 The reliability of the coding was indicated on a 5-point scale in v873, and the reliability of the code for the Yamana is 5, which is based on "estimates from 0 to 5% male polygyny inferred from statements about limited polygyny; these are doubled for female percentages (a minimal estimate)".

wives, more commonly sisters; cases of three wives, if they occurred, must have been very rare. (p. 92)

The predictor variables were individual aggression – assault (v1666), female contribution to subsistence (v885), and pathogen stress (v1269). Assault was coded from 1 = low to 9 = high, reflecting men's assault toward both men and women (Ember & Ember, 1992). Previous research, as mentioned above, suggests that in societies where females are scarce, men's violence toward both men and women increases. While this variable is convenient, it does not explicitly exclude women's violence toward both men and women. Therefore, in this study, this variable was used as a proxy for men's violence toward both men and women. Female contribution to subsistence is a variable constructed by White (1986) from Murdock's "Ethnographic Atlas" (1962–1971), coded from 0 to 100%. Pathogen stress is the sum of seven pathogen stresses (1 = absent, 2 = present, 3 = present and serious) for leishmaniasis, trypanosomes, malaria, schistosomes, filariae, spirochetes, and leprosy (Low, 1988, 1994).

Finally, despite the SCCS accounting for autocorrelation due to geographical proximity, concerns have been raised about the independence of the societies in the sample (Eff, 2004). Therefore, region (v200) was employed as a random

Table 1. Description of study variables.

Variable	SCCS Variable (v#)	SCCS Coding	Source
Polygyny	Percentage of married women polygynously married (v872)	From 0 to 100 %	White (1988)
Assault	Individual aggression − Assault (v1666)	From low = 1 to high = 9	Ember & Ember (1992)
Female contribution to subsistence	Female contribution to subsistence: Ethnographic atlas (v885)	From 0 to 100 %	White (1986) constructed the variable from Murdock's "Ethnographic Atlas" (1962–1971)
Pathogen stress	Pathogen stress: Total pathogen stress (v1260)	From 7 to 21 Sum of variables 1253−1259 v1253. Pathogen stress: Leishmanias v1254. Pathogen stress: Trypanosomes v1255. Pathogen stress: Malaria v1256. Pathogen stress: Schistosomes v1257. Pathogen stress: Filariae v1258. Pathogen stress: Spirochetes v1259. Pathogen stress: Leprosy	Low (1988)
Region	Region (v200)	1. Africa (exclusive of Madagascar and the Sahara) 2. Circum-Mediterranean (North Africa, Europe, Turkey, Caucasus, Semitic Near East) 3. East Eurasia (including Madagascar and Islands in the Indian Ocean) 4. Insular Pacific (including Australia, Indonesia, Formosa, Philippines) 5. North America (indigenous societies to the Isthmus of Tehuantepec) 6. South America (including Antilles, Yucatan, Central America)	Murdock's "Ethnographic Atlas" (1962–1971) Installments in *Ethnology 1–10*
Pinpointing time	Pinpointing date by year (v838)	From 1750 to 1965[a]	Murdock & White (1969)
Subsistence	Subsistence type − Ecological classification (v858)	1. Gathering 2. Hunting and/or marine animals 3. Fishing 4. Anadromous fishing (spawning fish such as Salmon) 5. Mounted hunting 6. Pastoralism 7. Shifting cultivation, with digging sticks or wooden hoes 8. Shifting cultivation, with metal hoes 9. Horticultural gardens or tree fruits 11. Intensive agriculture, with no plow 12. Intensive agriculture, with plow	White et al. (1986)

[a] In this study, the period was divided primarily into 20-year intervals and categorized as follows: 1. 1750–1859, 2. 1860–1879, 3. 1880–1899, 4. 1900–1919, 5. 1920–1939, 6. 1940–1965.

effect[10]. Additionally, considering the possibility that the motivation and focus of ethnographers change over time, which may introduce biases in ethnographic records at certain intervals, pinpointing time (v838) was utilized as a random effect[11]. Furthermore, I extracted societies from four categories of subsistence type – ecological classification (v858) and restricted the sample to hunter-gatherer societies. However, considering the possibility that these societies may be nested within each subgroup, this variable was also used as a random effect[12].

Statistical analysis

In this study, a model for predicting the polygyny rate was created using a generalized linear mixed model (GLMM), where the random slopes and intercepts were assumed to be independent. For parameter estimation, considering the small sample size, the results were reported by estimating posterior distributions within the framework of Bayesian statistics rather than providing point estimates and *p* values. As the model was intended for historical source criticism, it was designed to be as simple as possible to facilitate interpretation, and the random effects were not included simultaneously in the model but were incorporated separately.

The model assumed a zero-inflated beta distribution for the dependent variable, the polygyny rate, which comprised percentage data, including zero values[13]. For estimation using hierarchical Bayesian methods, noninformative priors and weakly informative priors were employed, following the defaults of brms in R (version 4.2.2; R Core Team, 2022), as there were no specific prior assumptions regarding the prior distribution and hyperprior distribution[14]. The posterior distribution of the parameters was estimated using the Markov chain Monte Carlo (MCMC) method, and for all models, the number of iterations was set to 2000, the warmup period was set to 1000, and the number of chains was set to 4. The R-hat values for all estimated parameters were less than 1.01.

Results

As a preliminary step before analyzing the above models, zero-inflated beta regression analyses were conducted using generalized linear models with three variables: assault (v1666), female contribution to subsistence (v885) and pathogen stress (v1260), which have been found to be predictors of polygyny rates in previous studies. The results showed that the coefficients and their Bayesian credible intervals were as follows: assault, 0.31 [0.14, 0.48]; female contribution to subsistence, 3.13 [0.21, 6.05]; and pathogen stress, 0.10 [0.00, 0.19]. The credible intervals of all coefficients did not include zero, indicating positive effects on the polygyny rate.

Table 2 shows the results of the zero-inflated beta regression analysis using a random intercepts and slopes model, with assault, female contribution to subsistence, and pathogen stress as the predictor variables. Region, pinpointing time, and subsistence type were included as random effects. In the models where the predictor variable was pathogen stress and the random effects were region (Model 3a), pinpointing time (Model 3b), and subsistence (Model 3c), the 95% credible intervals of the coefficient for pathogen stress included zero in all subgroups. For models with assault or female contribution to subsistence as predictor variables and region as the random effect (Models 1a and 2a), the 95% credible intervals of the coefficients for assault and female contribution to subsistence included zero within all subgroups. Additionally, in the models incorporating pinpointing time as the random effect, the 95% credible interval of the coefficient included zero for all subgroups of assault, except for 5 and 6 (Model 1b), and for all subgroups of female contribution to subsistence, except for 5 (Model 2b). Furthermore, in the model with subsistence as the random effect and female contribution to subsistence as the predictor, the 95% credible interval of the coefficient included zero in subgroups 1 and 2, while not in 3 and 4 (Model 2c). On the other hand, the model with subsistence as the random effect and assault as the predictor variable was the only model in which the 95% credible interval of the coefficient did not include zero for any subgroups (Model 1c). Figure 1 shows the scatterplot of Model 1c, including the 95% credible interval.

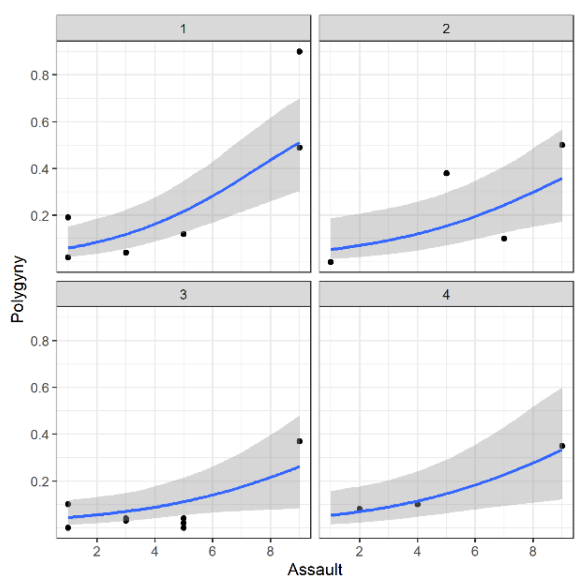

Figure 1. Relationship between polygyny and assault by subsistence type (Model 1c).
Note. 1. gathering, 2. hunting and/or marine animals, 3. fishing, and 4. anadromous fishing.

10 The data used in this study did not include societies from 2 (Circum-Mediterranean).

11 For issues regarding the nonindependence of ethnographic data collected over time, refer to Ringen et al. (2019).

12 The variable codes corresponding to Table 1 for the Yamana people are as follows: polygyny (v872) is 10%, assault (v1666) is 9, female contribution to subsistence (v885) is 45%, pathogen stress (v1260) is 7, region (v200) is 6 for South America, pinpointing time (v838) is 2 for the period 1860–1879, and subsistence (v858) is 3 for fishing.

13 The zero-inflated beta model includes two steps: First, a logistic regression is used to determine whether the probability of polygyny is zero; and second, a beta regression is used to model the probability of polygyny for nonzero values. The link function for the parameter μ of the beta distribution is the logit function.

14 Specifically, the prior distribution of the zero inflation probability (zi) was set to beta (1, 1), the prior distribution of the beta distribution parameter φ was set to gamma (0.01, 0.01), the prior distribution of the fixed effect coefficient was set to uniform (−∞, ∞), the prior distribution of the fixed effect intercept was set to Student's t (3, 0, 2.5), the prior distribution of the random effect coefficient and intercept was set to Normal (0, σ^2), and the hyperprior distribution of the hyperparameter σ^2 was set to Student's t (3, 0, 2.5).

Table 2. Estimated intercepts and coefficients for subgroups for Models 1, 2, and 3.

		Estimate	95% CI	Estimate	95% CI
(*n* = 21)		Intercept		Assault	
Model 1a (Region)	1	−1.95	[−3.40, −0.69]	0.04	[−0.31, 0.36]
	3	−3.32	[−4.81, −1.98]	0.03	[−0.38, 0.37]
	4	−0.98	[−4.01, 2.49]	0.34	[−0.02, 0.72]
	5	−3.03	[−4.06, −1.99]	0.19	[−0.00, 0.36]
	6	−1.51	[−3.22, 0.17]	0.15	[−0.06, 0.36]
Model 1b (Pinpointing time)	1	−2.80	[−4.14, −1.48]	0.24	[−0.19, 0.53]
	2	−2.85	[−4.55, −1.09]	0.26	[−0.00, 0.47]
	3	−2.93	[−4.24, −1.56]	0.19	[−0.18, 0.46]
	4	−3.07	[−4.85, −1.54]	0.20	[−0.11, 0.46]
	5	−2.86	[−4.11, −1.68]	0.35	[0.17, 0.52]
	6	−2.59	[−3.91, −1.20]	0.28	[0.07, 0.48]
Model 1c (Subsistence)	1	−2.92	[−4.13, −1.74]	0.38	[0.18, 0.57]
	2	−2.95	[−4.52, −1.37]	0.30	[0.08, 0.50]
	3	−3.16	[−4.55, −1.92]	0.26	[0.02, 0.47]
	4	−2.97	[−4.42, −1.60]	0.28	[0.06, 0.50]
(*n* = 27)		Intercept		Female contribution to subsistence	
Model 2a (Region)	1	−2.86	[−5.00, −0.68]	2.05	[−1.87, 5.68]
	3	−3.59	[−5.36, −1.88]	1.43	[−3.68, 5.25]
	4	−0.66	[−3.58, 1.98]	3.77	[−0.37, 8.72]
	5	−2.91	[−4.06, −1.82]	2.66	[−0.63, 5.82]
	6	−1.15	[−2.43, 0.01]	2.89	[−0.38, 6.52]
Model 2b (Pinpointing time)	1	−2.39	[−3.93, −0.91]	2.74	[−0.91, 6.19]
	2	−2.22	[−3.70, −0.66]	3.13	[−0.38, 6.44]
	3	−2.26	[−3.62, −0.93]	3.20	[−0.14, 6.38]
	4	−2.32	[−3.81, −0.92]	2.87	[−0.84, 6.37]
	5	−2.19	[−3.54, −0.84]	3.32	[0.18, 6.63]
	6	−2.22	[−3.65, −0.82]	2.95	[−0.29, 6.13]
Model 2c (Subsistence)	1	−2.45	[−4.15, −0.94]	3.63	[0.38, 7.03]
	2	−2.10	[−3.48, −0.72]	4.06	[0.06, 8.51]
	3	−2.47	[−4.10, −0.96]	2.59	[−1.86, 6.63]
	4	−2.38	[−3.98, −0.84]	3.22	[−1.02, 7.29]
(*n* = 29)		Intercept		Pathogen stress	
Model 3a (Region)	1	−1.87	[−4.38, 0.53]	0.00	[−0.16, 0.17]
	2	−2.75	[−5.02, −0.46]	−0.04	[−0.31, 0.17]
	4	−0.90	[−3.82, 2.23]	0.24	[−0.05, 0.55]
	5	−2.56	[−5.26, −0.33]	0.07	[−0.24, 0.44]
	6	−1.62	[−4.03, 0.81]	0.09	[−0.06, 0.24]
Model 3b (Pinpointing time)	1	−2.37	[−3.80, −0.94]	0.10	[−0.06, 0.26]
	2	−2.12	[−3.56, −0.52]	0.13	[−0.03, 0.32]
	3	−2.26	[−3.64, −0.88]	0.12	[−0.01, 0.26]
	4	−2.32	[−3.83, −0.85]	0.11	[−0.06, 0.27]
	5	−2.28	[−3.84, −0.74]	0.11	[−0.02, 0.22]
	6	−2.34	[−3.97, −0.84]	0.10	[−0.01, 0.22]
Model 3c (Subsistence)	1	−1.86	[−3.35, −0.19]	0.08	[−0.05, 0.19]
	2	−2.14	[−3.99, −0.55]	0.11	[−0.02, 0.26]
	3	−2.29	[−3.91, −0.83]	0.09	[−0.09, 0.27]
	4	−2.06	[−3.69, −0.46]	0.10	[−0.10, 0.31]

Note. Estimated values are the posterior distribution means.

Table 3. Estimated intercepts and coefficients for subgroups for Model 4.

		Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
(*n* = 20)		Intercept		Assault		Female contribution to subsistence		Pathogen stress	
Model 4a (Region)	1	−2.69	[−5.98, 0.80]	0.03	[−0.59, 0.47]	1.66	[−2.84, 6.71]	−0.01	[−0.27, 0.25]
	3	−3.46	[−6.53, −0.36]	0.05	[−0.50, 0.47]	0.33	[−5.17, 5.31]	−0.02	[−0.31, 0.20]
	4	−2.33	[−6.05, 2.16]	0.28	[−0.21, 0.83]	1.77	[−3.90, 8.60]	0.08	[−0.26, 0.50]
	5	−3.73	[−6.58, −1.11]	0.24	[0.02, 0.44]	1.00	[−2.68, 4.75]	0.00	[−0.39, 0.40]
	6	−2.34	[−5.05, 0.43]	0.11	[−0.13, 0.35]	0.77	[−5.06, 6.03]	0.06	[−0.11, 0.22]
Model 4b (Pinpointing time)	1	−3.44	[−6.57, 0.31]	0.30	[−0.27, 0.84]	1.00	[−6.19, 6.64]	−0.09	[−0.62, 0.28]
	2	−3.28	[−6.69, 1.03]	0.31	[−0.09, 0.72]	1.15	[−5.96, 7.09]	−0.08	[−0.64, 0.31]
	3	−2.94	[−5.88, 0.85]	0.25	[−0.28, 0.66]	−0.09	[−6.87, 4.80]	−0.08	[−0.62, 0.27]
	4	−3.59	[−6.57, 0.12]	0.29	[−0.13, 0.70]	0.76	[−5.95, 5.77]	−0.10	[−0.66, 0.27]
	5	−4.04	[−7.00, −1.22]	0.39	[0.13, 0.74]	3.80	[−0.67, 8.99]	−0.04	[−0.34, 0.18]
	6	−2.32	[−5.78, 2.73]	0.33	[−0.04, 0.72]	0.79	[−3.87, 5.15]	−0.05	[−0.40, 0.22]
Model 4c (Subsistence)	1	−4.97	[−7.44, −2.45]	0.45	[0.22, 0.68]	4.82	[−0.05, 9.20]	−0.05	[−0.16, 0.08]
	2	−4.85	[−7.42, −2.33]	0.21	[−0.11, 0.50]	1.43	[−8.21, 9.91]	0.17	[−0.02, 0.36]
	3	−4.89	[−7.52, −2.46]	0.31	[−0.11, 0.71]	−0.60	[−6.27, 4.98]	0.11	[−0.17, 0.44]
	4	−4.58	[−7.10, −1.83]	0.23	[−0.09, 0.55]	1.60	[−6.52, 8.99]	0.16	[−0.23, 0.60]

Note. Estimated values are the posterior distribution means.

Table 3 shows the results for models that included all three predictors and any of the three random effects variables. In the model that incorporated region as the random effect, the 95% credible intervals for all coefficients in all subgroups included zero, except for subgroup 5 of assault (Model 4a). Similarly, in the model with pinpointing time as the random effect, the 95% credible intervals for all coefficients in all subgroups included zero, except for subgroup 5 of assault (Model 4b). Furthermore, in the model with subsistence as the random effect, the 95% credible intervals for all coefficients in all subgroups, excluding subgroup 1 of assault, included zero (Model 4c).

Table 4 presents the estimated values of the predicted rates of polygyny among the Yamana people with Bayesian 95% credible intervals for each model. The predicted values of Models 1 to 3, each containing one predictor variable, ranged from 0.14 to 0.46. The values for Models 1a, 1b, and 2a exceeded 0.3, whereas those for the remaining six models fell within the range of 0.14 to 0.27. Among the three models that displayed relatively high predicted values, Models 1a and 2a, along with Model 3a, incorporated region as the random effect. The upper bounds of the 95% credible intervals for these models ranged from 0.50 to 0.61, all exceeding 0.5. Model 1b also showed an upper 95% credible interval value of 0.57, above 0.5. However, as shown in Table 2, the 95% credible intervals for every coefficient of subgroup 6 with region as the random effect, and the coefficient for assault in subgroup 2 with pinpointing time as the random effect, all included zero within their intervals. The predicted values for Model 4a, 4b, and 4c, which included all three predictor variables, ranged from 0.18 to 0.31. The upper bounds of the 95% credible interval for these models ranged from 0.51 to 0.66. However, as shown in Table 3, every coefficient for subgroups 6 of region, 2 of pinpointing time, and 3 of subsistence, included zero. The upper bounds of the predicted values for the remaining five models were below 0.49. Among these models, only subgroup 3 of Model 1c did not include zero within the 95% credible interval for its coefficient, with a lower prediction of 0.08 and an upper prediction of 0.48.

Table 4. Estimated polygyny rates among the Yamana with different models.

		Estimate	95%CI
Model 1	a	0.38	[0.27, 0.50]
	b	0.31	[0.09, 0.57]
	c	0.27	[0.08, 0.48]
Model 2	a	0.46	[0.33, 0.61]
	b	0.27	[0.12, 0.48]
	c	0.19	[0.07, 0.35]
Model 3	a	0.25	[0.07, 0.53]
	b	0.21	[0.09, 0.43]
	c	0.14	[0.07, 0.24]
Model 4	a	0.31	[0.05, 0.66]
	b	0.31	[0.10, 0.58]
	c	0.18	[0.01, 0.51]

Note. Estimated values are the posterior distribution means.

Discussion

The objective of this study was to construct a statistical model to estimate the degree of polygyny as a supplementary method for evaluating the reliability of historical sources. In this study, the predicted values of polygyny rates among the Yamana people for the candidate models ranged from 14% to 46%. As mentioned, Bridges left conflicting accounts of the practice of polygyny among the Yamana people. However, the results of this study suggest that the early accounts describing Yamana practices of polygyny, such as “Polygamy is very general” (Bridges, 1869, p. 117) or “seven have one wife each, five have two apiece, three have three, and one have four” (Bridges, 1871, p. 138) (simple calculations from this instance estimate a polygyny rate of approximately 77%), are extreme descriptions. In fact, when calculating the probability that the observed polygyny rate was 77% or higher from the posterior probability distribution estimated by each model, the probability was less than 0.006 for all models.

In historical source criticism, discovering new sources is essential. However, in cases such as that of the Yamana people, where historical claims rely on inaccurate records by travelers and missionaries of the time and discovery of more credible new sources is difficult, the selection of conflicting sources is crucial. In these cases, while reexamining records related to the unique marriage practices of the Yamana people and their background is important, I attempted to estimate the polygyny rate of this ethnic group by setting hunting-gathering societies as the population and utilizing a generalized linear mixed model. In this way, the validity of the sources is based not only on the diversity among ethnic groups but also on “species-typical reaction norms, or ‘context-dependent human universals’” (Ringen et al., 2019, p. 377), which provides an important perspective for conducting multifaced historical source criticism.

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Data accessibility & program code

Data and the analysis code have been deposited in the Open Science Framework (https://osf.io/6r2hx/).

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