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Summary. Specific ecological constraints create specific reproduction strategies. This paper examines data on birth spacing in a scheduled caste, Bengali speaking, non-contracepting population of Karimganj district of southern Assam, India, in view of an evolutionary ecological perspective. It is found that on average a birth interval closed by boy-boy is the longest and that by girl-girl is the shortest. Birth spacing is likely to be longer among upper-income, and Craftsman mothers. The presence of a "grandmother" in the household shortens early birth spacing of a childbearing mother. Our findings are compatible with an evolutionary based reproductive decision-making process.

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Introduction

The natural patterns of human reproduction have been explored through consideration of ecological factors affecting the reproductive patterns of our hunter-gather ancestors. For example, energy constraints underlie the fact that nomadic hunters and gatherers can only carry one child at a time, which necessitated long birth intervals. Births needed to be spaced approximately 4 years apart, so that the older child would be able to walk relatively long distances on its own by the time its younger sibling was born (Short, 1994, Blurton-Jones, 1986). Thus, approaching the study of human fertility through evolutionary ecology will contribute to understanding the evolved mechanisms of energy investment that underlie differences in fertility (Blurton-Jones, 1989).

The closed birth interval (CBI), which is the interval of time between two successive births, is a useful measure of fertility. Henry (1956) showed that the fertility of a woman inversely related to her mean closed birth interval. Rodriguez and Hobcraft (1980) demonstrated the greater sensitivity of birth interval analysis compared with more conventional methods for studying fertility. The marriage to first birth interval for Indian mothers is usually longer and erratic because of early marriage and other social customs and taboos acting through several socio-demographic factors (Nath et al., 1993, 1998; Singh et al., 1993). Therefore, intervals between first and second, and second and third are considered in order to explore how ecological factors affect natural fertility in a traditional Indian caste dominated society.

Investment of costly energy in producing offspring is the ecological basis for reproductive or evolutionary success. Variation in resources and their allocation to reproduction is basic to understanding differentials in measures of fertility. Many studies (Greenberg and White, 1967;

Westoff et al., 1961; Wyhak, 1969; Blanchard and Bogaert, 1997) report that birth intervals are longer following a male than a female child. The greater the cost of each child to the mother, and the longer the period over which that cost is extracted, the longer the birth interval should be. A few empirical studies (Hrdy, 1987, Sieff, 1990) demonstrate within society differences in the attention, care and resource allocation to sons and daughters. It has been hypothesised that parents provide better care for males than females when males have a reproductive advantage over females with respect to resource access (Trivers and Willard, 1973). Birth intervals may vary among different castes and sub-castes that occupy different ecological niches in India (Nath et al, 1993, 1994; Singh et al, 1993). A grandmother or other older woman genetically related to childbearing woman's children may increase a childbearing woman's fertility through her energy contributions of labour and food production, thus enhancing her own evolutionary success (Hawkes et al., 1998). Thus, the birth intervals will be predicted to be shorter in the presence of a "grandmother" in a family. This hypothesis directs attention to likely ecological presence for variation.

Most of the relevant research in birth spacing patterns among married females in India has been carried out from a socio-demographic perspective (Nath et al., 1993; Nath and Land, 1994; Nath et al 1994; Nath et al., 1998; Singh et al., 1993). No study analysing birth interval dynamics of an Indian population from an evolutionary ecological perspective has been reported.

In this paper, the structure of second and third closed birth intervals are examined with respect to the effects of four ecological correlates, viz., sexes of the consecutive sibs, per capita monthly household income, sub-caste and type of household (presence of "grandmother" helper) on the spacing of length of the first to second and second to third birth intervals in a traditional Indian society. Life table techniques are employed to estimate median birth intervals for several categories of these characteristics in the study population. Hazards regression techniques are used to estimate the net effect of each explanatory variable.

Materials and Methods

Data

Data for the research presented here come from the retrospective survey, ‘A Study on Effects Socio-Economic Factors on Fertility among Scheduled Caste Population in the Rural Areas of Karimganj District, Assam’ conducted during 1988-89 (the reference date for survey questions was June 15, 1988) under the auspices of University Grants Commission (UGC), New Delhi. The survey was confined to only the scheduled caste population -- the socially and economically deprived class of the Indian population. They are in the lowest class of Hindu society -- a caste system of social organisation found in old India and continuing to the present day. Membership in a caste is hereditary and is fixed for life. A couple was defined as *eligible* for the present study if both the partners were alive on the reference day of the survey and the age of the female spouse was less than 50 years.

The Karimganj district of Southern Assam is predominantly a Bengali speaking area, where a large number of villages are identified as scheduled caste villages. If at least 10 per cent of the village population belongs to the scheduled castes, the village is considered to be a scheduled caste village by the Directorate of Economics and Statistics, Assam. From a list of scheduled castes of the district, a sample of 37 villages was selected by simple random sampling. Then, all scheduled caste households were enumerated. The survey comprises 1,805 scheduled caste households from the selected villages. There were 2,052 eligible couples in the sample.

It is observed that only 1.5 per cent of the couples practised some sort of modern contraception at some time during their married life. Only those couples who did not practice any method of family planning to space and limit births were considered. Educational attainment among these groups of people is very low, and most of them are still engaged in traditional occupations like agriculture, fishing, cloth washing, hair cutting, cane weaving, and pot-making. Only a small number of persons were employed in government or non-traditional private sector jobs.

Explanatory Variables and corresponding Hypotheses

In the present analysis, the impacts of four independent ecological variables on the duration of second and third birth intervals of mothers are examined. These covariates are: (i) sex of the consecutive sibs, (ii) per capita monthly household income, (iii) sub-caste, and (iv) type of household.

In a country like India, parents desire more surviving children, especially sons for their old age security as well as for after death religious rituals. In this rural Hindu society there is a preference for sons over daughters because of the Hindu belief that only a son can perform some the religious rites upon the deaths of his parents, and sons are considered heirs of the fathers' property. Thus, sons receive better treatment than daughters. Humans like most mammals also have a polygynous evolutionary history reflected in physical dimorphism – males are larger than females, carried slightly larger and longer in utero, nurse more and more frequently, and over all, are more expensive energetically to produce. The sex of offspring might thus be expected to influence women's reproductive capacity.

Recent research (Low, 1991; Mace and Sear, 1997) indicates that the length of birth intervals is influenced by the sexes of the children born at the beginning and end of the birth interval. We consider four sequences of sexes of the consecutive sibs of a birth interval as: (i) boy-boy, (ii) boy-girl, (iii) girl-boy, and (iv) girl-girl. We hypothesise that: (a) the longest closed birth interval should be boy-boy, and (b) the shortest closed birth interval should be girl-girl.

Daly and Wilson (1983) found that fertility correlates with income in pre-demographic transition societies. Vining (1986), however, argues that in contemporary societies there has developed a negative correlation between wealth and fertility. On the basis of monthly per capita income (PCI), four economic groups were formulated for households: (1) PCI $\leq$ Rs.50.00 (2) Rs.51.00 $\leq$ PCI $\leq$Rs. 75.00 , (3) Rs 76.00$\leq$ PCI $\leq$ Rs 100.00, and (3) PCI$\geq$ Rs 101.00. These four income groups represent very low, low, middle and upper income households within this community. Monthly per capita income of the family may be considered as an indicator of social status of mother and children. Despite their low social status, upward social striving through education is common now throughout the Indian population. It is hypothesised, therefore, that for the study population PCI is positively associated with the length of the closed birth interval i.e., negatively associated with levels of fertility.

Individuals within a population may experience different ecological positions within the environment; therefore reproductive strategies can vary within subgroups of a population (Low, 1993). As the survey was restricted to the scheduled caste population, subcastes were identified for the present analysis, each having its own distinct social organisation and culture. Sub-castes were (a) Namasudra: primarily engaged in cultivation and bamboo basket making, (b) Kaibarta: traditionally were fishermen, but in addition cultivated land, and (3) Craftsman: barbers, washer-men, cobblers, earthen pot-makers and cultivators of small plots of land. In each of these subcastes a small percentage of people were employed in non-traditional jobs. Subcaste groups reflecting their different cultural and ecological settings are expected to show distinct variation in closed birth interval distributions.

The influence of older generation women, "grandmothers", on the reproductive success of younger generation women, "daughters" who are either closely related to them or are wives of their sons has been hypothesised to be critical in the evolution of the human family as a food-sharing unit in which reproductive success or biologic fitness is enhanced. So critical is this relationship that it is hypothesised to explain the evolved post-menopausal extension of life span seen in our species, dubbed the "grandmother hypothesis". Through contributions to the energy needs of a younger woman producing offspring related to the older woman, the latter can indirectly increase her own reproductive success at ages past the years of her own reproductive capacity (Hawkes et al., 1998). Grandmothering may affect infants in at least two ways: (a) by feeding nursing mothers and infants, thus accelerating the growth of infants, and (b) by providing food to weanlings, thus allowing infants to be weaned earlier. In the present study, we classified households: (i) with no grandmother or any grandmother like person who could play the role of a grandmother, (ii) with grandmother or grandmother like person. We can hypothesise that females living with a "grandmother" helper are likely to experience shorter birth intervals and thus greater reproductive success.

Response Variables and Analytical Methods

We have restricted our analysis only to ever-married women who had at least two live births. Because of our study design – as we need to know the sex of the baby at the end of each birth interval, this analysis did not consider right censored observations. Only birth intervals where the child that opened the birth interval survived for at least 12 months are included in this analysis. Life tables of these two closed birth intervals for groups defined by each variable were constructed first. Two summary measures, median closed birth intervals and the proportions of mothers not having a closed birth interval by specified months were calculated by standard life table techniques

(Namboodiri and Suchindran, 1987). Univariate proportional hazards model analysis is used to measure the effect of each variable on the duration-specific probabilities of the length of the closed birth interval (hazards function) in the absence of controls for other variables. Because of the dependence of the length of the closed birth interval on many of the covariates studied, the use of conventional single-decrement life tables, while revealing, is not sufficient for the analysis. To investigate the partial effects of multiple factors on the timing of second or third birth, multivariate regression analysis was used to determine the effects of each variable (Cox, 1972). The hazard function or instantaneous risk function at time t is given by

$$h(t;z) = h(t)\exp(\beta Z)$$

where, h(t;z) represents the instantaneous rate of having a second (third) birth at time t given that there is a first (second) birth for a married female with a vector of covariates Z; h(t) is an arbitrary non-negative unspecified baseline hazard function not dependent on the covariate; β is a vector of unknown regression coefficients to be estimated. The hazard function allows estimation of the relative risks of the other groups in relation to specific baseline groups by the exponent of the regression coefficient $\exp(\beta_i)$. Each exponentiated coefficient, $\exp(\beta_i)$, represents the effect of the ith covariate on the hazard function for a certain group. When there is no covariate present, the $\exp(\beta)$ term reduces to unity. Values greater than unity indicate that relative risk of having a second (third) birth is greater (i.e., the birth interval is shorter) for this group compared with the reference group, whereas values less than unity indicate a decrease in the risk (i.e., the birth interval is longer).

Results

Table 1 presents a summary of the life table median second and third birth intervals and the proportion of mothers who failed to attain the next birth within 5 years following the first and second births. The overall median of the second birth interval for scheduled caste mothers is 29.2 months and that of the third birth interval is longer by 4.2 months. The results show that the groups differ widely in their birth intervals. The maximum median length for the second birth interval (35.7 months) is found in the Craftsman subcaste. Mothers belonging to very poor households have the minimum median length for the second birth interval (27.1 months). The maximum and minimum median lengths of the third birth interval correspond to the birth intervals closed by boy-boy (36.4 months) and girl-girl (31.9 months) sequences respectively.

--- Table 1 about here---

For consecutive sexes of a sib pair, the longest median closed birth intervals were boy-boy and the shortest were girl-girl. For the second birth interval if the previous child was a boy, the median interval to the subsequent child was 33.0 months (boy) or 31.5 months (girl); if the previous child was a girl, the median interval to the subsequent child was 29.5 months (boy) or 28.8 months (girl). We observe a similar pattern of variation in the durations of median third birth intervals.

As the level of income goes up, the lengths of the second and third birth intervals also increase. Within subcastes, a Kaibarta mother has the shortest closed birth intervals. A mother who reproduced with “grandmother” present in the household has a 3.0 (2.3) months shorter second (third) birth interval compared to mothers living with no “grandmother” present.

A nonparametric statistical procedure (the generalised Wilcoxson test) is used for group comparisons of these differences because some variables are not normally distributed. It tests for significant differences between the survival functions for various groups. All four covariates under study are found to show statistically significant difference between groups (Table 2).

--- Table 2 about here ---

The proportions of mothers who failed to attain a subsequent birth within 60 months of the birth of the first child and or the birth of second child also reveal differential timing of second and third birth intervals among the subgroups considered. In this sample, only 2.1 to 6.5 per cent of the mothers of first parity in the various subgroups failed to have their second birth within 60 months of their first birth. These corresponding percentages of mothers of second parity range from 4.0 to 10.5 per cent. Of all mothers sampled 96 (93.5) per cent have their second (third) birth within 5 years of their first (second) birth.

Univariate proportional hazards model analysis is used to measure the effects of each variable on the duration-specific probabilities of the length of the birth interval (hazards function) in the absence of other variables (Table 3). It can be seen from this table that all of the covariates have significant univariate relationships to the second- and third- birth interval dependent variable. Ordered by reductions in chi-square relative to the null model (with only a constant term) accounted for by each explanatory variable from the largest to the smallest, the covariates can be arrayed as follows for the second birth interval: sub-caste, sex of the consecutive births, per capita monthly household income, and type of household. For the third birth interval this order becomes: sex of the consecutive births, per capita monthly household income, sub-caste, and the type of household.

-- Table 3 about here ---

A comparison of second and third birth intervals classified by specified covariates while controlling for other covariates is then performed through multivariate hazards regression analysis and is presented in Table 4. This table provides the relative risk of the timing of the occurrence of the second and third birth, the effects of the covariates on the hazards function, and the standard error of the hazards function for the four selected ecological factors. The results show that groups classified by consecutive sibs, per capita monthly household income, sub-caste, and type of household groupings differ widely in their second and third birth intervals.

--- Table 4 is about here---

A second birth interval closed respectively by boy-boy, boy-girl, and girl-boy is 24.0, 20.8 and 14.7 per cent less likely to be shorter than that closed by girl-girl. While, a third birth-interval closed by boy-boy, boy-girl, and girl-boy is 18.9, 15.9 and 10.5 per cent less likely to be shorter than closed by girl-girl. The estimated relative risk of a shorter second birth interval is increased by 7.8, 11.6 and 18.9 per cent for a mother belonging to middle, poor, very poor income groups, respectively, compared to upper income group mothers in this society. Corresponding increases in the relative risks for having a shorter third birth interval are 4.0, 15.0 and 20.1 per cent. A Kaibarta mother in first parity is 18.8 per cent more likely and a Craftsman mother is 23 per cent less likely to have a shorter second birth interval as compared to a Namasudra mother. We observe a similar trend of risk for a mother in second parity to have a shorter third birth interval. A mother with a "grandmother" present has an 11.7 (8.7) per cent greater risk of having a shorter second (third) birth interval as compared with one with no "grandmother" present in the household.

Discussion

The fertility of this scheduled caste rural population is close to natural. It appears that parents prefer to invest in those children who, under the family's particular living conditions, are likely to be successful, thus increasing their chances to maximise future gene replication (Voland, 1989; Trivers and Willard, 1973). High levels of fertility exist in spite of low levels of fecundability associated with longer birth intervals. Variations in fertility rates within populations correlate with resource availability and this is very well supported by data from various traditional societies (see Betzig, 1996 for a review). Parental investment of time, energy, or resources in the production or nurturing of one offspring can diminish a mother's ability to invest in older offspring or her ability to produce additional offspring in the future (Trivers, 1972).

Mace (1996) predicted that the cost of marrying a child has an important influence on the reproduction rates of parents. In this Indian society, the cost of marrying girls greatly exceeds the cost of marrying boys. Longer intervals following a male child may reflect Indian parent's preference for sons: parents who have just had a boy are more contented than parents who have just had a girl, and they are therefore less eager to proceed to the next pregnancy. Further, it may be that boys are more difficult to raise than girls are, so parents of boys require more time before they are ready to have another. The greater physiological costs of carrying and rearing boys are probably also reflected in boy-boy closed birth intervals. Thus, a male child delayed the timing of next the birth while a female child hastened the time of next birth.

The distribution of wealth has an impact on fertility, Rogers (1990) argued that the rich reproducing more slowly than the poor is not inconsistent with the hypothesis that reproductive strategies have been shaped by evolution. It seems that an upper income group family invests more in bearing, rearing and educating their children, thus ensuring survivability and success of their offspring. As the levels of income decrease, the lengths of birth intervals decrease for mothers in this society. This society has a patrilineal inheritance system. Heritable resources provide an additional reason why parents may not like to maximise their reproduction rates. Wealthier parents might have decided to produce a few relatively rich offspring whose resources would increase their probability of reproducing.

In a life table and multivariate analysis, Nath et al. (1993) and Singh et al. (1993) reported substantial variations in the duration of birth intervals among different castes and religions. Even today, especially among uneducated lower castes, their occupational patterns are determined by virtue of their birth in a particular caste or sub-caste. For example, in this study population, the son of a Kaibarta father is supposed to follow fishing and fish selling. Slower transition to the next birth occurred among Craftsman females. This reflects that Craftsman invest more in the lives of their offspring. As most members of this Craftsman subcaste were either landless or small cultivators, their economic stability depends upon their sons who in due course are trained in the fathers' skills.

Several evolutionary biologists (Gaulin, 1980; Hawkes et al. 1989, 1997) have suggested that older females can use their energy to increase the reproductive success of their close relatives. Among Hazda mothers of Tanzania higher fertility has been associated with compensating effects of older women's' help (Hawkes et al., 1997). Our findings support the hypothesis that the contributions of "grandmothers", i.e., senior females, would increase the reproductive success of childbearing in the household. This hypothesis of course counters the hypothesis that a family with no "grandmother" present has greater privacy and thus has a wider scope for coital activity resulting in high fertility in a non-contracepting population. Thus the long post-menopausal life span in humans and the joint family system which made it likely to have at least one "grandmother" in the household may have contributed to rapid population growth in India.

More research would be needed to establish the causes of the longest interval between males and the shortest interval between females. The growth of population in India appears to be slowing; though it remains very sensitive to localised conditions. It will be very interesting to find out how these variables affect human reproduction in different societal and ecological contexts in different traditional societies of India. Direct information on parental and grandparental investment in offspring could contribute to a clearer understanding of the birth interval mechanisms. However, the profound significance of the impact of these four selected ecological correlates has been established for a non-contracepting traditional population.

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Table 1. Life table estimates of median birth intervals and proportions of mothers having no birth within 60 months by selected characteristics

Covariates	Median birth interval (months) between		Percentage not attaining next birth	
	1st and 2nd	2 nd and 3 rd	After 1 st birth	Aftrer 2nd birth
Overall	29.2	33.4	4.0	6.5
Sex of the consecutive sibs				
Boy-Boy	33.0	36.4	5.6	6.0
Boy-Girl	31.5	33.4	6.5	7.3
Girl-Boy	29.5	32.4	2.9	6.8
Girl-Girl	28.8	31.9	2.5	5.5
Per capita monthly household income				
≤Rs. 50.00	27.1	32.9	3.4	4.5
Rs.51.00-Rs. 75.00	28.1	32.3	2.8	5.0
Rs.76.00-Rs.100.00	29.5	34.8	4.2	6.2
≥ Rs. 101.00	30.3	34.1	5.9	10.5
Sub-caste				
Namasudra	29.1	34.0	4.5	6.9
Kaibarta	28.3	32.4	2.1	4.0
Craftsman	35.7	36.0	5.2	9.8
Type of Household				
No Grandmother	32.4	35.4	5.6	6.7
With Grandmother	29.4	33.1	3.6	6.4

Table 2. Values of χ^2 based on the Wilcoxon log-rank test for comparison of groups

	Second birth interval		Third birth interval	
Groups	df	χ^2	df	χ^2
Sex of the consecutive births	3	14.1^{**}	3	9.6^{*}
Per capita monthly household income	3	9.6^{**}	3	8.7^{*}
Sub-caste	2	29.3^{**}	2	6.5^{*}
Type of Household	1	7.2^{*}	1	4.1^{*}

* Significant at 5% level
** Significant at 1% level

Table 3. Univariate hazards regression of the selected ecological covariates on the length of birth interval

Model	Birth interval between 1 st and 2 nd birth: -2logL with Covariates	Model χ^2	df	Birth interval between 2 nd and 3 rd birth.: 2logL with Covariates	Model χ^2	df
Null	16264.9	---	---	13284.5	---	---
Sex of the consecutive sibs	16252.5	12.4**	3	13275.1	9.4*	3
Per capita monthly household income	16256.9	9.1*	3	13276.5	8.0*	3
Sub-caste	16244.7	20.2**	2	13277.6	6.9*	2
Type of Household	16259.7	4.2*	1	13279.7	3.9*	1

* Significant at 5%
* Significant at 1%

Table 4. Hazards regression estimates of the effects of ecological covariates on the length of birth interval

Covariates	Birth interval between: 1 st and 2 nd births			2 nd and 3 rd births		
	Regression coefficient(β)	Exp (β)	SE	Regression coefficient (β)	Exp (β)	SE
Sex of the consecutive sibs						
Boy-Boy	-0.274^{***}	0.760	0.080	-0.210^{***}	0.811	0.090
Boy-Girl	-0.233^{***}	0.792	0.077	-0.169^{*}	0.844	0.085
Girl-Boy	-0.159^{***}	0.853	0.086	-0.111^{*}	0.895	0.084
Girl-Girl	a	a	a	a	a	a
Per capita monthly household income						
$\leq$Rs. 50.00	0.171^{*}	1.186	0.083	0.187^{***}	1.201	0.089
Rs.51.00-Rs. 75.00	0.110^{**}	1.116	0.077	0.140^{**}	1.150	0.087
Rs.76.00-Rs.100.00	0.075	1.078	0.082	0.039	1.040	0.088
$\geq$ Rs. 101.00	a	a	a	a	a	a
Sub-caste						
Namasudra	a	a	a	a	a	a
Kaibarta	0.172^{**}	1.188	0.066	0.110^{**}	1.116	0.073
Craftsman	-0.261^{***}	0.770	0.089	-0.081^{*}	0.922	0.099
Type of Household						
No Grandmother	a	a	a	a	a	a
With Grandmother	0.111^{**}	1.117	0.072	0.084^{*}	1.087	0.086

* p<0.1, ** p<0.05, *** p<0.01, a= reference category