J. biosoc. Sci. (1998) **30**, 411–422

IMPACT OF RURAL–URBAN MIGRATION ON FERTILITY: A POPULATION ECOLOGY ANALYSIS IN THE KOMBIO, PAPUA NEW GUINEA

MASAHIRO UMEZAKI AND RYUTARO OHTSUKA

Department of Human Ecology, School of International Health, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan

Summary. The Anjangmui dialect group of the Kombio in Papua New Guinea has experienced a rapid increase in rural–urban migration since European contact commenced in the 1930s. Population ecology analyses of birth and migration histories for 240 Anjangmui women showed a higher total marital fertility rate in the cohort born in 1940–59 than that born in 1920–39. A decline in the age at menarche for nutritional reasons, and reduction in the birth interval for behavioural reasons, may explain the fertility difference between cohorts. Comparison of age-specific marital fertility rates between migrants in urban areas and non-migrants in rural areas revealed higher rates among migrants in the 15–19 and 20–24 year age groups, but lower rates in the 25–29 year or older age groups; the total marital fertility rate for migrants was lower than that for non-migrants. The differences may be attributable to the different influences of birth control practices on fertility reduction between the migrants in urban areas and non-migrants in rural areas. It is suggested that rural–urban migration in the Anjangmui during the post-contact period has had the effect of reducing fertility in the population as a whole.

Introduction

In developing countries, fertility rate and its age pattern have markedly changed since Western contact. During the initial stage of contact, fertility increased in many such populations owing to improvement of nutritional status, shortening of the lactational period, and relaxation of postpartum sex taboos. Demographically speaking, these modernization-related changes affected the proximate variables (cf. Bongaarts, 1978; Wood, 1990), such as the proportion married, the duration of lactational infecundability, and the duration of the fecund waiting time to conception, leading to an increase in fertility (Benefo, 1995; Johnson, 1990; Ohtsuka, 1990; Romaniuk, 1980, 1981; Werner, 1983). Later on, fertility declined in many such populations with socioeconomic development and spread of birth control practices, though the time at which fertility began to decline varied from country to country and from population

to population (Lightbourne, Singh & Green, 1982). It is obvious that the major proximate variables responsible for reduction in fertility are the levels of contraceptive use and the proportion married (Bongaarts & Potter, 1983), but the causes of such changes are still debated (Bongaarts, 1994; Easterlin & Crimmins, 1985; Gould & Brown, 1996; Jenkins, 1993; Knowles, Akin & Guilkey, 1994; Pritchett, 1994a,b; Woods, 1979).

On the other hand, rapid growth of urban areas in developing countries has progressed with increasing rural-to-urban migration. Attention has increasingly been paid to comparative study of fertility levels between rural–urban migrants and non-migrants. A number of such studies have shown lower fertility in the rural–urban migrants than in the non-migrants (Bogin, 1988; Brockerhoff & Yang, 1994; Goldstein & Goldstein, 1981; Hinday, 1978; Lee & Farber, 1984; Liberty, Hughey & Scaglion, 1976), though higher fertility in the rural–urban migrants than in the non-migrants has been shown in a few studies (Liberty, Scaglion & Hughey, 1976). It has also been reported that spousal separation, resulting from migration, has had a negative impact on fertility (Menken, 1979; Potter & Kobrin, 1982). An important corollary of such studies is that rural–urban migration is lowering the overall fertility of Third World populations (Bogin, 1988).

However, most demographic studies on fertility change in developing countries have treated the rural population and urban population separately and have compared the fertility levels between them despite the fact that (1) the urban population has expanded with the increase of migrants from rural areas and (2) most migrants have spent some portion of their life in urban areas and the earlier period of their life in a rural area. These features imply that the fertility of an individual woman reflects her and/or her spouse's life histories, especially their residential locations. It is also the case that an urban population is an aggregate of persons including a number of migrants from different places, so that determination of causal factors of fertility among the migrants is difficult. Therefore, one of the most effective ways of elucidating migration-induced effects on fertility is to consider all members of a single population (from a population ecology viewpoint), including migrants who stay in urban areas and non-migrants who remain in rural areas.

Bearing these ideas in mind, the present study is based on a population in Papua New Guinea, the Anjangmui, for whom demographic changes since the first contact with Europeans can be traced. The study aims to clarify: (1) the change in fertility of the whole Anjangmui population (migrants and non-migrants) throughout the post-European contact period; (2) the difference in fertility between the migrants and the non-migrants; and (3) the causal factors of such changes and inter-group differences. This study is thus expected to provide population ecology understanding of the fertility change with modernization in Papua New Guinea.

Subjects and methods

Subjects

The Kombio-speaking people, indigenous subsistence farmers, inhabit the southern slopes of the Torricelli Mountains in East Sepik Province, Papua New Guinea. The Anjangmui, the target population in this study, is one of five dialect groups of the

Kombio. The total size of the Anjangmui in 1992 was 662; in this study, the Anjangmui were defined as the males belonging to the patrilineal clans of the Anjangmui and their spouses and offspring; according to the traditional custom of the Anjangmui and the Kombio as a whole, any male or female person belongs to his/her father's clan when he/she is born, and his/her clan never changes throughout his/her life. Of the 662 persons, 527 inhabited the homeland (called rural sector hereafter) and 135 the destination areas (urban sector), mostly Wewak (the capital of East Sepik Province) and Rabaul (the capital of East New Britain Province). While most migrants of the Anjangmui stay together in their own settlement area in each major town, the three males who left the villages in the 1950s and 1960s did not live there in 1992. Despite numerous rumours, the Anjangmui people did not know whether they were alive or not, and whether they were married. In this study, they were assumed to live as unmarried migrants in 1992.

The modernization process in the Anjangmui villages and in the Kombio territory started in 1930, the time of first contact with Europeans. The history of modernization is categorized into three stages; in the first stage, that started with the initial European contact, the villagers, a few in number, were recruited as plantation labourers to the coastal/island areas. Most of them returned to the villages. The second stage, which started after World War II (1942–45), was characterized by an increase in out-migrated plantation labourers in accordance with the post-war labour demand for the reconstructed plantation industry (Riley & Lehmann, 1992). The migrants increased in number and, on their return, Western goods and foods were brought to the villages. At this stage, a missionary church and a primary school were established at Yassip in the Kombio territory in 1957 and 1961, respectively. The third stage started with the introduction of coffee as a cash crop in 1965, followed by the establishment of the road between the Kombio territory and Wewak in 1970. The events in the third stage enabled the villagers to expand their opportunity to earn income. Modern birth control practices have not become popular among the villagers, even in 1992, the time of which this study was conducted.

Methods

The field survey, on which this article is based, was conducted between 1991 and 1992 for 25 weeks in total. Demographic data, which were analysed principally, were collected as follows: genealogical charts over four generations were drawn up from reproductive-aged members of the whole Anjangmui; dates (in years) of births, deaths, marriages, divorces and migrations were estimated using the event calendar which was compiled from government patrol reports and other sources (listing at least one widely known datable event every 5 years since 1930). The following features contributed to the reliability of the genealogical charts obtained, and their accuracy over the years of vital events collection: (1) the occurrence of notable events, at least one in every 5 years, has been well remembered in their society; (2) the marriage custom of exchanging females between two clans compelled the villagers to memorize the marital relations of their ascendants; (3) they have lived in a population of small size; and (4) demographic information is shared among the Anjangmui as a whole. The Anjangmui people do not know the exact years of vital events (especially those in the past) but remember the

order of them. Thus, the order of all vital events (births, deaths, marriages, divorces and migrations) was clarified in each village through discussion with the villagers, particularly the aged. The order of events made it possible to estimate the dates of vital events, including those which were not memorized, in relation to the notable events.

Of 1724 persons listed in the genealogical charts, 240 were women who were born after 1920 and married to male members of the Anjangmui; few women remained unmarried after reaching reproductive age and few unmarried women gave birth. If an unmarried woman becomes pregnant, it is the custom of the Anjangmui people to find the man who is responsible for her pregnancy and ensure he marries her before she gives birth. In fact, there has been only one case of an unmarried Anjangmui woman giving birth during the post-contact period; the woman was excluded from this analysis. The major focus of this study was to reconstruct and analyse these 240 women's childbearing and migration histories in association with their marital histories and their spouses' migration histories. In this study, migration was defined as a movement of residence which led to a stay of at least 6 months at a new destination.

The ages between 15 and 49 years were defined as the reproductive period of women, following the general demographic definition (e.g. Pollard, Yusuf & Pollard, 1974). The whole reproductive period was categorized into pre-marital, marital and post-marital periods, or the period after divorce or death of the spouse. The marital period was then divided into four residential types: whether both of them stayed in the rural sector (R–R); the woman stayed in the rural sector and her spouse in the urban sector (R–U); both stayed in the urban sector (U–U); and finally the woman stayed in the urban sector and her spouse in the rural sector (U–R). Since the dates of events were estimated by year, they were assumed to have occurred at the midyear for analyses; for example, when a woman and her husband migrated together from the rural sector to the urban sector in 1965, this study considered that this woman spent 0·5 year in R–R and 0·5 year in U–U in 1965.

The age-specific marital fertility rate was used as the measure of fertility (this rate is free from the influence of the proportion of women analysed who were married, despite the fact that the 'proportion married' itself affects fertility rate); in order words, this study focused more on the biological aspects of fertility. The age-specific marital fertility rates were compared between R–R and U–U so as to examine the effect of residential type on fertility, and between R–R and R–U to examine the effect of spousal separation on fertility. The age-specific marital fertility rates in R–R and U–U were also compared among the three birth cohorts (women born in 1920–1939 ($n=64$), those born in 1940–1959 ($n=80$), and those born in 1960–1979 ($n=96$)). The age-specific fertility rates obtained from at least 35 woman-years over a given age group were judged to be statistically acceptable (Handwerker, 1988).

Methodological feasibilities

Recording childbearing histories of women who lived in a study population at the time of fieldwork has been a common approach for estimating the fertility level. Apart from the problem of the subjects' memory loss (e.g. Brass, 1975; Brittain, 1991), the fact that some of the subject women spent periods outside of the study area is also a possible source of error in this method. While such errors are judged not to have been

Table 1. Breakdown of reproductive period (person-years) for 240 women by marital status and age group

Age group (years)	Marital	Not marital		Censored
		Pre-marital	Post-marital	
15–19	379·5 (33·8)	741·0 (66·0)	2·5 (0·2)	77·0
20–24	843·5 (84·8)	137·0 (13·8)	14·5 (1·5)	205·0
25–29	765·0 (94·9)	16·5 (2·0)	24·5 (3·1)	394·0
30–34	553·0 (91·3)	0·5 (0·1)	52·0 (8·6)	594·5
35–39	386·5 (83·7)	0·0 (0·0)	75·5 (16·3)	738·0
40–44	246·0 (78·3)	0·0 (0·0)	68·0 (21·7)	886·0
45–49	150·5 (71·0)	0·0 (0·0)	61·5 (29·1)	988·0
Total	3324·0 (73·6)	895·0 (19·8)	298·5 (6·6)	3882·5

The percentage in each age group is shown in parentheses.

serious in the fertility estimations for relatively isolated populations, such as those in Papua New Guinea before European contact, it cannot be ignored in current Papua New Guinean populations whose members have experienced residential moves from rural villages to urban areas and vice versa (Ross, 1984).

The fertility rates in R–R and U–U estimated in this study reflect the fertilities in the rural and urban sectors more accurately than those estimated by the methods mentioned above. However, it should be noted that fertility rates were not based on the number of conceptions (which resulted in live births) but on the number of births. For instance, some women who became pregnant in the urban sector gave birth in the rural sector, while some births of women in U–U resulted from fertilization in the rural sector. However, in the Anjangmui society, pregnant women tend not to move from their residential locations; therefore, such cases may have been rare. A similar problem existed in cases when a husband moved his residential location during his wife's pregnancy. Marital fertility rates in R–U include these births.

Results

Table 1 show a breakdown of the reproductive period (in person-years) of 240 women by marital status in each age group. Of 8400 person-years (35 years × 240 females) in total, 3882·5 person-years were censored cases. For all the subjects, the percentage of married person-years increased with age up to the 25–29 year age group (94·9%), and then gradually decreased up to the 45–49 year age group (71·0%).

Table 2 shows the breakdown of the marital period (in person-years) in each age group by residential type. The women as a whole spent 85·2% of the marital period with their spouses in the rural sector, 11·4% with their spouses in the urban sector, 3·4% without their spouses in the rural sector, and only one person-year without their spouses in the urban sector (since the percentage of the last type (i.e. U–R) is so small, it will be ignored in subsequent analyses).

https://doi.org/10.1017/S0021932098004118 Published online by Cambridge University Press

Table 2. Breakdown of marital period (person-years) by residential type

Age group (years)	R–R	R–U	U–U	U–R
15–19	303·5 (80·0)	17·5 (4·6)	58·5 (15·4)	0 (0·0)
20–24	719·5 (85·3)	23·5 (2·8)	100·5 (11·9)	0 (0·0)
25–29	652·0 (85·2)	32·5 (4·2)	80·5 (10·5)	0 (0·0)
30–34	469·5 (84·9)	18·0 (3·3)	64·5 (11·7)	1 (0·2)
35–39	335·0 (86·7)	8·0 (2·1)	43·5 (11·3)	0 (0·0)
40–44	217·0 (88·2)	6·5 (2·6)	22·5 (9·1)	0 (0·0)
45–49	134·0 (89·0)	7·0 (4·7)	9·5 (6·3)	0 (0·0)
Total	2831·5 (85·2)	113·0 (3·4)	379·5 (11·4)	1 (0·0)

See the text for the definition of R–R, R–U, U–U and U–R. The percentages are shown in parentheses.

Table 3. Breakdown of marital period (person-years) in R–R and U–U by birth cohort

	R–R			U–U		
Age group (years)	Women born in 1920–39	Women born in 1940–59	Women born in 1960–79	Women born in 1920–39	Women born in 1940–59	Women born in 1960–79
15–19	97·0	96·5	110·0	10·5	19·0	29·0
20–24	244·5	234·5	240·5	2·5	50·5	47·5
25–29	259·5	261·5	131·0	1·5	47·5	31·5
30–34	214·5	232·5	23·5	4·0	52·0	8·5
35–39	180·5	154·5		6·0	37·5	
40–44	139·5	77·5		8·5	14·0	
45–49	96·5	37·5		6·5	3·0	
Total	1232·0	1094·5	505·0	39·5	223·5	116·5

Table 3 shows the breakdown of the marital period in R–R and U–U for the three birth cohorts. The ratio of the marital period in U–U to that in R–R increased from 0·032 for the cohort of women born in 1920–39 to 0·204 for the cohort of women born in 1940–59.

Table 4 shows the age-specific marital fertility rates for R–R, U–U and R–U. The age pattern of marital fertility rates in R–R had a peak in the 20–24 year age group, followed by an initially slow and accelerating decline to zero in the 45–49 year age group; this represents the typical age pattern of 'natural fertility' (Wood, 1990). In contrast, the age pattern in U–U was characterized by a rapid decline in fertility at relatively younger ages, reflecting the pattern of 'controlled fertility'. A comparison of the ratios of marital fertility rates between U–U and R–R indicated that

Table 4. Age-specific marital fetility rates for all subjects in R–R, U–U and R–U

Age group (years)	Age-specific marital fertility rates				Ratios	
	R–R	U–U	R–U	Total	U–U/R–R	R–U/R–R
15–19	0·221	0·256	0·171	0·224	1·16	0·78
20–24	0·260	0·328	0·085	0·263	1·26	0·33
25–29	0·244	0·186	0·185	0·235	0·76	0·76
30–34	0·215	0·078	0·056	0·193	0·36	0·26
35–39	0·164	0·092	0·125	0·155	0·56	0·76
40–44	0·106	0·000	0·000	0·093	0	0
45–49	0·022	0·000	0·000	0·020	0	0
TMFR*	6·161	4·703	3·109	5·923	0·76	0·50

*Total marital fertility rate.

they were higher in U–U in the 15–19 and 20–24 year age groups, and in R–R in the 25–29 year or older age groups. The age-specific marital fertility rates in R–U fluctuate due to the small sample size.

Table 5 shows the marital fertility rates in R–R and U–U for the three birth cohorts. The major observation is the shift of the peak age group in R–R: the first cohort had a peak marital fertility rate in the 25–29 year age group, the second cohort in the 20–24 year group and the third cohort in the 15–19 year group. The total marital fertility rate in R–R, which was calculated for only the first and second cohorts, increased from 4·782 to 6·619. Comparison of age-specific marital fertility rates and total marital fertility rates in U–U between birth cohorts is meaningless, because of the low person-years of the marital period in U–U for the cohort of women born in 1920–39.

Discussion

Increase in fertility in the rural sector

Among the Anjangmui, the total marital fertility rate of the second cohort of women born in 1940–59 was higher than that of the first cohort of women born in 1920–39 in the rural sector. From the fertility model of Bongaarts (1978), the level of fertility, which is recognized as natural fertility, is expected to increase during the early stage of modernization as a result of the disappearance of traditional customs or behaviours which inhibit fertility. In fact, an increase in fertility for these reasons has been observed among many human populations (e.g. Johnson, 1990; Ohtsuka, 1990; Romaniuk, 1980, 1981; Werner, 1983; Benefo, 1995). In the Anjangmui, the prevalence of sexually transmitted diseases has probably not declined (Jenkins, 1993; Lombange, 1984; Wood, 1992) and replacement of breast feeding by bottle feeding did not occur during the post-contact period (these two factors have been shown to increase fertility rates in some societies). Accordingly, the fertility increase from the first to second

https://doi.org/10.1017/S0021932098004118 Published online by Cambridge University Press

Table 5. Age-specific marital fertility rates in R–R and U–U in three birth cohorts

Age group (years)	R–R				U–U			
	Women born in 1920–39	Women born in 1940–59	Women born in 1960–79	Total	Women born in 1920–39	Women born in 1940–59	Women born in 1960–79	Total
15–19	0·134	0·197	0·318	0·224	0·286	0·158	0·310	0·256
20–24	0·176	0·311	0·295	0·263	0·400	0·317	0·337	0·328
25–29	0·185	0·283	0·282	0·235	0·000	0·232	0·127	0·186
30–34	0·168	0·254	0·267	0·193	0·000	0·096	0·000	0·078
35–39	0·144	0·188		0·155	0·000	0·107		0·092
40–44	0·129	0·065		0·093	0·000	0·000		0·000
45–49	0·021	0·027		0·020	0·000	0·000		0·000
TMFR*	4·782	6·619		5·923	3·430	4·550		4·703

*Total marital fertility rate.

cohort of Anjangmui women is attributable to socioeconomic and behavioural changes.

The role of social and/or behavioural factors in the increase in fertility in developing countries has been emphasized in several studies. For instance, Romaniuk (1980) pointed out that abandonment of the custom of prolonged postnatal abstinence, together with improvement in health status, were major factors which caused an increase in natural fertility in Zaire populations. It was suggested that the principal cause of increased fertility levels in West African populations was the decrease in the period of postnatal abstinence caused by modernization (Benefo, 1995). Similarly, the aged Kombio emphasized that postpartum sexual abstinence should be continued for two or three years (see Patrol Report: Dreikikir, 1970) and that sexual intercourse should be avoided on the nights before going to the gardens (informants explained that wild pigs will follow the smell of the man's sperm into the garden). In contrast, women of the younger generations who have been influenced by the teachings of missionary church have tended to ignore such traditional beliefs, which may have resulted in a reduction in their fecund waiting time to conception.

A unique feature observed among the Anjangmui women born in 1920–39 is that the age-specific marital fertility rate in the 25–29 year age group is higher than that in the 20–24 year age group. While this age pattern is not common in natural fertility populations, it has often been observed in Papua New Guinea (Wood, 1990); the slow growth, late maturation, and late menarche, which were well-known features of rural populations in this country, would tend to lower fertility during the early twenties (Wood, 1992). Estimates of the median age of menarche ranged from 15·5 (in the lowland population) to 18·6 (in the highland population) in eight Papua New Guinean populations (Malcolm, 1970). The Lumi on the Torricelli Mountains in West Sepik Province (the Lumi land is some 70 km to the west of the Anjangmui land) is the population most similar to the Anjangmui from both ecological and cultural aspects, and their median age at menarche was 18·4 years (Wark & Malcolm, 1969). Thus, it is reasonable to assume that the age at menarche among the Anjangmui women born in 1920–39 was similar to that of the Lumi women. Such a late age at menarche, together with subfecundity following menarche (Wood, 1994), probably contributes to the age pattern of marital fertility in the Angangmui women born in 1920–39.

Several lines of evidence suggest that a later age at menarche is associated with inadequate nutritional status (Bongaarts, 1980; Gage *et al*., 1989). As pointed out by Dennett & Connell (1988) in their review, the improvement of nutritional status in rural Papua New Guinea populations was triggered by the introduction of imported food. In the Anjangmui, modernization of dietary habit took place mostly in the 1960s, leading to a decrease in age at menarche for the cohort of women born in 1940–59. Consequently, the fertility of the 20–24 year age group increased in these women and their total marital fertility rate itself also increased, though detailed investigations of behavioural and/or biological determinant factors on fertility are required to confirm this hypothesis.

Influence of migration on fertility

The difference in marital fertility rates between R–R and U–U may be related to usage of modern birth control practices. The Anjangmui women in the rural sector did

not practise birth control, even in 1992; only four women in the rural sector were sterilized by means of an operation in the hospital before 1992, but their mean parity was 5·3. On the other hand, women in the urban sector have easy access to hospitals or health centres where they can be sterilized. In addition, the idea of family planning has become popular among migrants in the urban areas, who have to face the difficulty of feeding a large number of children, so many couples tend to use pills and condoms. In fact, Agyei (1984) reported that more women in urban areas than in rural areas used some form of modern birth control method in Papua New Guinea in 1979–80.

The analyses of Potter & Kobrin (1982) showed that a single residential separation of a couple has a disproportionate effect on fertility with the length of separation period; 6, 12 and 24 month separations prevent 0·070, 0·190 and 0·520 of births, respectively. In the Anjangmui, most R–U separations for the cohort of women born in 1920–39 were caused by their husbands' 2-year labour contracts in plantations in coastal areas, which prevailed before the 1960s. After the 1960s, the circular migrations (round-trips) of males were the main causes of R–U type (cf. Curtain, 1980). The durations of such migrations were so short that they had an insignificant effect on fertility.

Implications of the findings

Since migrants may not be a special group as regards demographics in the Anjangmui, whose women's educational level or socioeconomic status are homogeneous, the total marital fertility rate in R–R can be regarded as the fertility of the Anjangmui had they not experienced any rural–urban migration. Thus, the finding in this study that the total marital fertility rate in the whole Anjangmui was lower than that in R–R by 0·24 births implies that rural–urban migration is adaptive for the Anjangmui since it releases the excessive increase in population in the rural sector to the urban sector (Umezaki & Ohtsuka, 1996). It also makes it possible for the Anjangmui to utilize economic resources in urban areas.

On the other hand, the introduction of European foods and abandonment of traditional practices have raised fertility in the rural villages and, consequently, the fertility of the Anjangmui as a whole. These findings show that the prevailing demographic policies may have drawbacks, at least in the Anjangmui, in as far as they assume that socioeconomic development triggers a fertility decline (United Nations, 1987; World Bank, 1993). As has been pointed out by Johnson (1990), there are a number of factors which affect fertility change. In fact, rural–urban migration does not always seem to reduce fertility; in Papua New Guinea, six of the nineteen provinces showed a higher total fertility rate in urban sectors than in rural villages in 1980 (National Statistical Office, 1988). Further research is required to investigate in detail the relationship between modernization and fertility transition.

Acknowledgments

The authors sincerely thank the Kombio people, and the Anjangmui villagers in particular, for their generous support for this study.

References

Agyei, W. K. A. (1984) Fertility and family planning in Papua New Guinea. *J. biosoc. Sci.* **16**, 323–334.

Benefo, K. D. (1995) The determinants of the duration of postpartum sexual abstinence in West Africa: a multilevel analysis. *Demography* **32**, 139–157.

Bogin, B. (1988) Rural-to-urban migration. In: *Biological Aspects of Human Migration*, pp. 90–129. Edited by C. G. N. Mascie-Taylor & G. W. Lasker. Cambridge University Press, Cambridge.

Bongaarts, J. (1978) Framework for analyzing the proximate determinants of fertility. *Popul. Dev. Rev.* **4**, 105–132.

Bongaarts, J. (1980) Does malnutrition affect fecundity? A summary of evidence. *Science* **208**, 564–569.

Bongaarts, J. (1994) The impact of population policy: comment. *Popul. Dev. Rev.* **20**, 616–620.

Bongaarts, J. & Potter, R. G. (1983) *Fertility, Biology, and Behavior.* Academic Press, New York.

Brass, W. (1975) *Methods of Estimating Fertility and Mortality from Limited and Defective Data.* Laboratory for Population Statistics. California Population Center, University of North Carolina, Chapel Hill.

Brittain, A. W. (1991) Can women remember how many children they have borne? Data from the East Caribbean. *Social Biol.* **38**, 219–232.

Brockerhoff, M. & Yang, X. (1994) Impact of migration on fertility in Sub-Saharan Africa. *Social Biol.* **41**, 19–43.

Curtain, R. (1980) The structure of internal migration in Papua New Guinea. *Pacific Viewpoint* **21**, 42–61.

Dennett, G. & Connell, J. (1988) Acculturation and health in the Highlands of Papua New Guinea. *Curr. Anthropol.* **29**, 273–299.

Easterlin, R. A. & Crimmins, E. M. (1985) *The Fertility Revolution: A Supply–Demand Analysis.* The University of Chicago Press, Chicago.

Gage, T. B., McCullough, J. M., Weitz, C. A., Dutt, J. S. & Abelson, A. (1989) Demographic studies and human population biology. In: *Human Population Biology: A Transdisciplinary Science*, pp. 45–65. Edited by M. A. Little & J. D. Haas. Oxford University Press, Oxford.

Goldstein, S. & Goldstein, A. (1981) The impact of migration on fertility: An 'own children' analysis for Thailand. *Popul. Stud.* **35**, 265–284.

Gould, W. T. S. & Brown, M. S. (1996) Research Review 2: Fertility transition in Sub-Saharan Africa. *Int. J. Popul. Geogr.* **2**, 1–22.

Hasndwerker, W. P. (1988) Sampling variability in microdemographic estimation of fertility parameters. *Hum. Biol.* **60**, 305–318.

Hinday, V. A. (1978) Migration, urbanization and fertility in the Philippines. *Int. Migration Rev.* **12**, 370–385.

Jenkins, C. (1993) Fertility and infertility in Papua New Guinea. *Am. J. hum. Biol.* **5**, 75–83.

Johnson, P. L. (1990) Changing household composition, labour patterns, and fertility in a Highland New Guinea population. *Hum. Ecol.* **18**, 403–416.

Knowles, J. C., Akin, J. S. & Guilkey, D. K. (1994) The impact of population policy: Comment. *Popul. Dev. Rev.* **20**, 611–615.

Lee, B. S. & Farber, S. C. (1984) Fertility adaptation by rural–urban migrants in developing countries: The case of Korea. *Popul. Stud.* **38**, 141–155.

Liberty, M., Hughey, D. & Scaglion, R. (1976) Rural and urban Omaha fertility. *Hum. Biol.* **48**, 59–71.

Liberty, M., Scaglion, R. & Hughey, D. (1976) Rural and urban Seminole fertility. *Hum. Biol.* **48**, 741–755.

Lightbourne Jr, R., Singh, S. & Green, C. P. (1982) The world fertility survey: Charting global childbearing. *Popul. Bull.* **37**, 1–54.

Lombange, C. (1984) Trends in sexually transmitted disease incidence in Papua New Guinea. *Papua New Guinea Med. J.* **27**, 145–158.

Malcolm, L. A. (1970) Growth and development of the Bundi child of the New Guinea Highlands. *Hum. Biol.* **42**, 293–328.

Menken, J. (1979) Seasonal migration and seasonal variations in fecundability: Effects of birth rates and birth intervals. *Demography* **16**, 103–120.

National Statistical Office (1988) *Social Indicators of Papua New Guinea, 1980–1985.* National Statistical Office, Papua New Guinea, Port Moresby.

Ohtsuka, R. (1990) Fertility and mortality in transition. In: *Population Ecology of Human Survival: Bioecological Studies of the Gidra in Papua New Guinea*, pp. 211–218. Edited by R. Ohtsuka & T. Suzuki. University of Tokyo Press, Tokyo.

Patrol Report (1970) Dreikikir, Papua New Guinea Government.

Pollard, A. H., Yusuf, F. & Pollard, G. N. (1974) *Demographic Techniques.* Pergamon Press, Sydney.

Potter, R. G. & Kobrin, F. E. (1982) Some effects of spouse separation on fertility. *Demography* **19**, 79–95.

Pritchett, L. H. (1994a) Desired fertility and the impact of population policies. *Popul. Dev. Rev.* **20**, 1–55.

Pritchett, L. H. (1994b) The impact of population policies: Reply. *Popul. Dev. Rev.* **20**, 621–630.

Riley, I. D. & Lehmann, D. (1992) The demography of Papua New Guinea: Migration, fertility, and mortality patterns. In: *Human Biology in Papua New Guinea: The Small Cosmos*, pp. 67–92. Edited by R. D. Attenborough & M. P. Alpers. Oxford University Press, Oxford.

Romaniuk, A. (1980) Increase in natural fertility during the early stages of modernisation: Evidence from an African case study, Zaire. *Popul. Stud.* **34**, 293–310.

Romaniuk, A. (1981) Increase in natural fertility during the early stages of modernisation: Canadian Indians case study. *Demography* **18**, 157–172.

Ross, A. C. (1984) *Migrants from Fifty Villages.* IASER Monograph 21. Institute of Applied Social and Economic Research, Port Moresby.

Umezaki, M. & Ohtsuka, R. (1996) Microdemographic analysis for population structure from a closed to open system: A study in the Kombio, Papua New Guinea. *Man Cul. Oceania* **12**, 19–30.

United Nations (1987) *Fertility Behavior in the Context of Development: Evidence from the World Fertility Survey.* Department of International Economic and Social Affairs, Population Studies, No. 100. United Nations, New York.

Wark, L. & Malcolm, L. A. (1969) Growth and development of the Lumi child in the Sepik District of New Guinea. *Med. J. Aust.* **2**, 129–136.

Werner, D. (1983) Fertility and pacification among the Mekranoti of central Brazil. *Hum. Ecol.* **11**, 227–245.

Wood, J. W. (1990) Fertility in anthropological populations. *Annu. Rev. Anthropol.* **19**, 211–242.

Wood, J. W. (1992) Fertility and reproduction biology in Papua New Guinea. In: *Human Biology in Papua New Guinea: The Small Cosmos*, pp. 93–118. Edited by R. D. Attenborough & M. P. Alpers. Oxford University Press, Oxford.

Wood, J. W. (1994) *Dynamics of Human Reproduction: Biology, Biometry, Demography.* Aldine DeGruyter, New York.

Woods, R. (1979) *Population Analysis in Geography.* Longman, London.

World Bank (1993) *Effective Family Planning Programs.* World Bank, Washington, DC.