Chapter Eight

DEMOGRAPHY

The collection of demographic data in the Garki project was geared to the specific purposes of the project, e.g., to allow the calculation of age-specific indices of malaria, in particular among the newborn and the very young children, to ascertain the mortality rates, to trace the trends of immigration and emigration in the follow-up populations, and to facilitate control of the coverage of the survey and MDA operations generally. In this chapter, these demographic data have been summarized to provide an overview of the structure and movements of the study population. Despite their shortcomings, including limitations in time and space, the observations may be of some value to students of African demography, a field in which data are still relatively scarce. It should be added that the potential of the data bank has not yet been fully explored, in particular with regard to analysis of fertility patterns and certain aspects of migration (see also II, 180).

Methods

Demographic data were collected in the village clusters selected for follow-up by 2 methods: namely, through the periodic demographic-parasitological surveys at lo-week intervals, and through fortnightly visits by specially employed itinerant collectors of data on births, deaths and migration. The latter data were incorporated, as appropriate, into the data from the demographic-parasitological surveys (see p. 32). In addition, some demographic information was extracted for a period of 13 months from the mass-drug administration records in area A2, covering a population of about 12 000 persons. The findings in the

---

[a] The observations presented in this chapter were made by or under the supervision of Mr S. Brøgger, Mr J. Storey and Mr D. Thomas. They have benefited from the advice of Dr A. Benyoussef and Professor M. Prothero.

population receiving MDA are outlined on p. 243, while the rest of the chapter is concerned with the population of the clusters of villages followed up regularly.

Demographic and parasitological (DP) surveys

At the first survey a household roster was established with the name, sex and age of every resident. Age was estimated by questioning the person and his close relatives, and by the field staff's impression; the age recorded was expressed in months for infants, in years for others. At subsequent surveys, each previously registered person was classified as present, absent, moved or dead; new residents were added to the roster and similarly classified. Persons who had moved within the village were traced to their new household (for record linkage). Persons coded "absent" at 4 consecutive surveys were re-coded "moved" with retroactive effect. At a given survey, the registered population includes the present plus the absent. A very high coverage was probably achieved among those persons actually present, except with respect to temporary visitors, especially those not resident in one of the compounds.

Local registrars (pataucis)

From the time of the third survey onwards, three residents of the Garki district were employed as itinerant registrars, known as "pataucis", the Hausa word for a travelling salesman. Each one covered one-third of the follow-up population and visited each village every 2 weeks to record births, deaths and population movements. The village's civil and religious leaders cooperated actively. A preliminary evaluation showed that, in comparison with the pataucis, the DP surveys were missing a significant number of births, but practically no deaths, except the deaths of infants born and dying between 2 successive surveys. Therefore registration of deaths by the pataucis was discontinued, while all births registered by the pataucis were added to the roster of occupants before the following DP survey. Thus from survey 3 onwards the registration of births is more complete, and the age of infants is estimated more accurately. Observations of population movements were much less complete. Efforts to record the whereabouts of persons who were absent at the DP survey had to be abandoned, but reasonably accurate counts were made of temporary visitors to the village at the time of the patauci's visit.

Data-handling

Age was probably estimated with a rather large error, increasing with age itself; the expected "preference" for multiples of 5 and 10 years was observed. For the analysis of results by age, the following age-groups were used: <1, l-4, 5-8, 9-18, 19-28, 29-43, ≥44 (completed years). This (non-standard) grouping avoids the use of "preferred" ages (e.g., 10, 12, 17, 20) as limits of age-groups, in the hope of minimizing misclassification.

Each person was given a "date of birth"-the date recorded by the patauci when available, otherwise the 15th of the recorded month of birth for infants and the 15th of a random month in the recorded year of birth for the others. These "dates of birth" were used for finer analysis of data from infants, and for updating the composition of age-groups at any given survey. The data were stored in a way which allows cross-sectional or cohort analysis as required.

The following demographic events were defined in the longitudinal person data: births, deaths, departures from the village (absences lasting through 1 to 3 surveys, moves lasting through 4 or more surveys), and arrivals into the village (i.e., new registrations, minus births). For births, the probable date of the event was recorded; for the other events, a date of registration was recorded, i.e., in principle, the date of the first survey (in the village) after the event. For the sake of counting infant deaths, the age of death was computed under the assumption that the interval between death and its registration was 37 days (i.e., half the average interval between surveys); for computing convenience and consistency, the same rule was applied to all events (except births) and all age-groups (in most cases, it has of course, no effect).

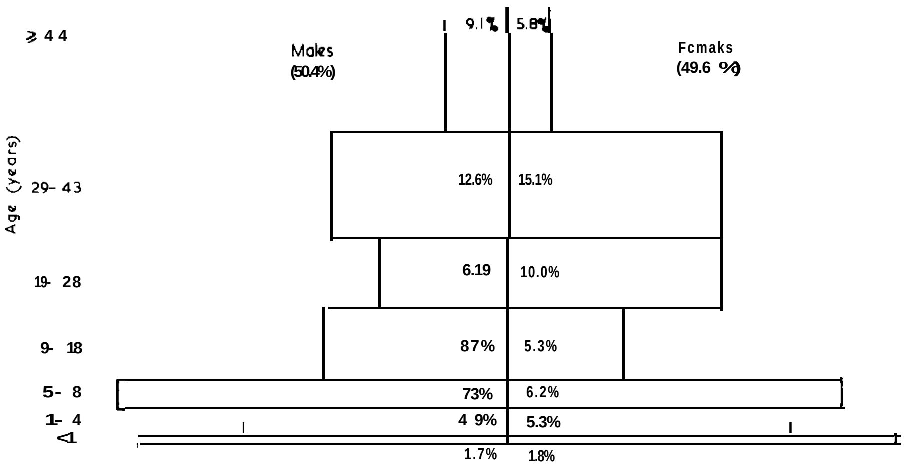
Indices were calculated either by relating the number of events occurring in 1 year to the average registered population (or in the case of the infant mortality rate, to the number of births in the year) or by relating the number of events recorded at a given survey to the registered population at that survey (in relation to absences) or the preceding one (in relation to deaths, moves in and out of the village). The second approach allows the study of seasonal variation, and in certain cases (e.g., infant mortality) may identify more accurately the population at risk.

Results

Distribution of the population by age and sex

The distribution of the registered population by age and sex at survey 7 in February 1972 (Fig. 65) shows that males and females were registered in nearly equal numbers. The age-pyramid is rather irregular, showing

Fig. 65. Distribution of the registered population (N = 7540) by age and sex at survey 7



"excesses" and "deficits" (see p. 244). Variations between village clusters were mostly small, and those between surveys were not statistically significant.

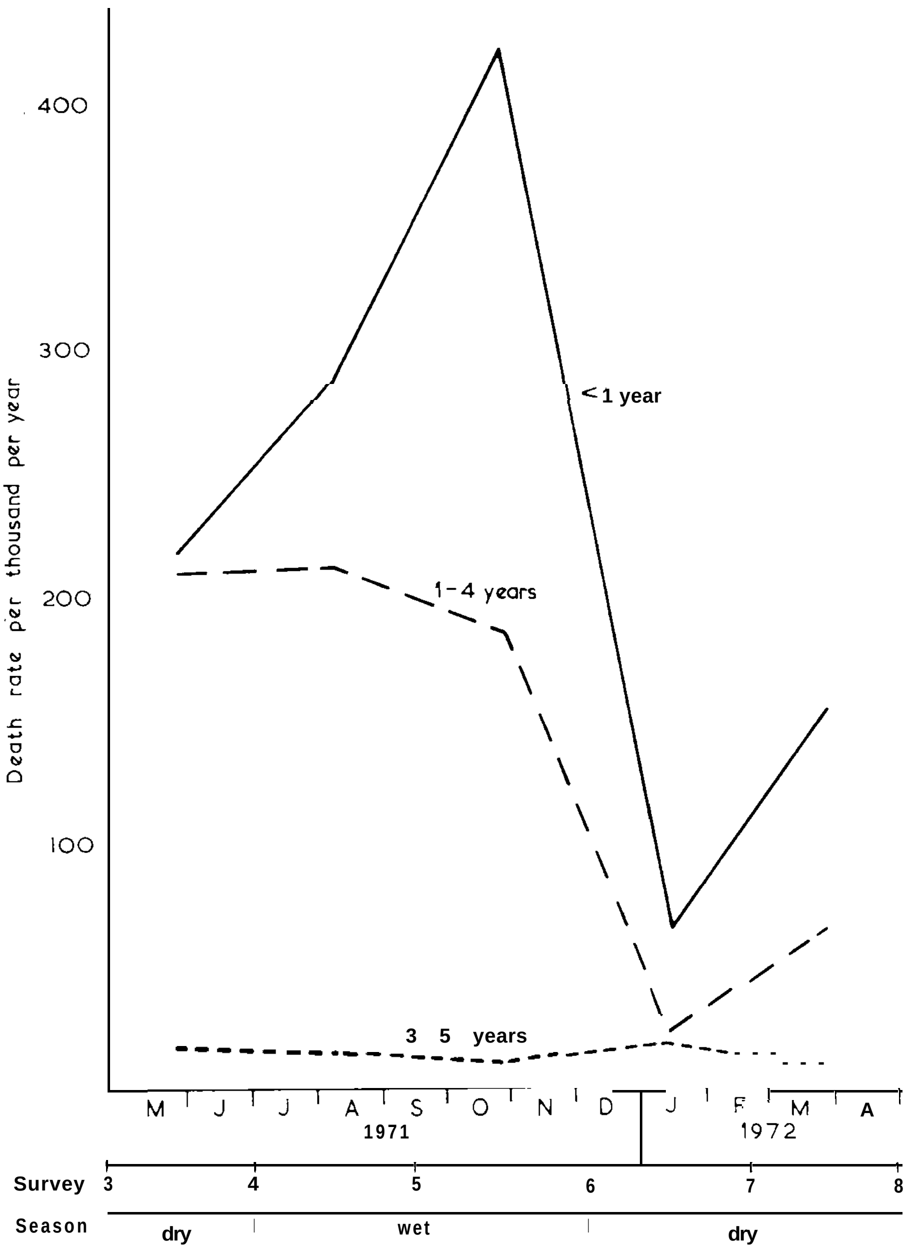
Births

Between surveys 3 and 13 (the last year of the baseline period in 16 villages, plus the first year of the intervention phase in 22 villages) 601 births were registered in 13 050 person years of the population at risk; the estimated crude birth rate (CBR) is, therefore, 46.1 per 1000 per year. There was no significant variation by year, by village or by treatment.

Counting as females of reproductive age those in age-groups 19-28 and 29-43 years plus half those in age-group 9-18 years, their proportion in the registered population was 0.278 and the estimated fertility rate is 46.1/0.278 = 165.8 per 1000 per year. Again, there was no significant variation by year, by village or by treatment in this rate. There was also no significant difference between the Hb AA and Hb AS women (see p. 217).

Birth rates show a marked and relatively regular seasonal variation, with peaks in April-August of 60-70 (annual basis) and lows in October-January of 23-35 (annual basis).

Fig. 6 6 .Seasonal variation in the mortality rate, by age, during the last year of the pre-intervention period



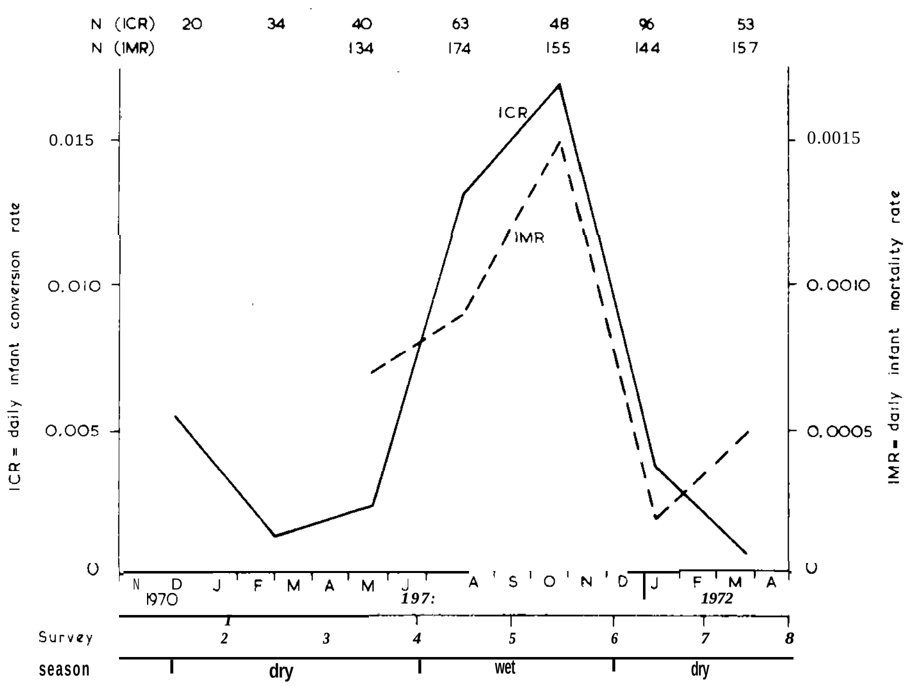
The recorded sex-ratio at birth was 0.92, there being 592 male births and 642 female births between the first and sixteenth parasitological surveys (i.e. over a period of three years) in all the villages surveyed.

Deaths

Crude death rate

The crude death rate (CDR) in the last year of the baseline period was 37.3 per 1000 (215/5757). There was no significant difference between men and women, nor between the village clusters. There was however a marked seasonal variation, with higher mortality in the wet season, caused almost exclusively by variations in mortality in the children below 5 years of age (Fig. 66). In the first year of intervention, the overall CDR decreased to 20.8, a decrease of about 45%; this was observed, rather unexpectedly, in the untreated village clusters as well as in the treated clusters.

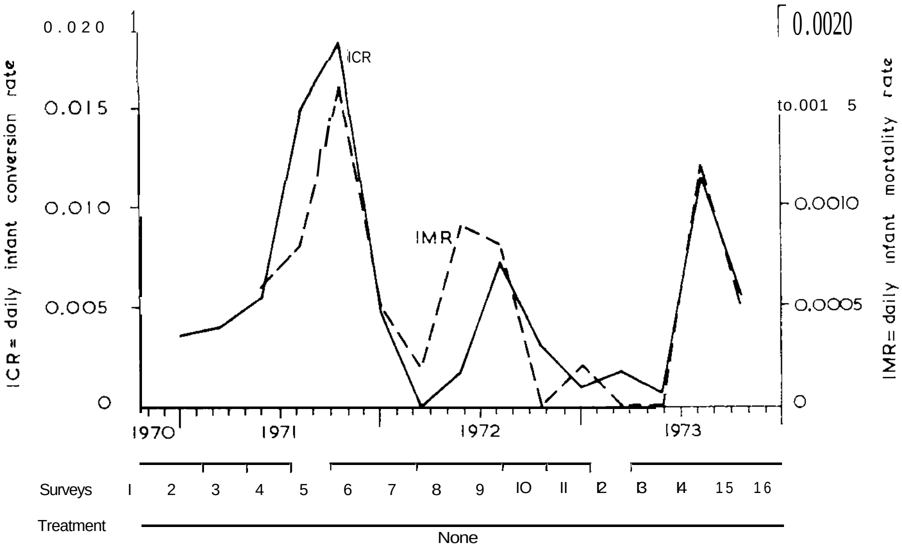
Fig. 67. Daily infant parasitological conversion rate (ICR) for *P. falciparum* and daily infant mortality rate (IMR), by interval (about 10 weeks) between consecutive surveys, during the baseline phase[a]



[a] N(ICR), N(IMR) = number at risk of conversion or death, respectively.

Fig. 68. Daily infant parasitological conversion rate (ICR) for *P. falciparum* and daily infant mortality rate (IMR) by interval (about 10 weeks) between consecutive surveys, in the untreated villages (village clusters No. 1 and 2, area C)[a]

N (ICR)	8	13	13	25	18	13	16	28	35	32	29	34	42	44	25
N (IMR)			54	71	65	58	61	67	70	61	61	57	59	60	49



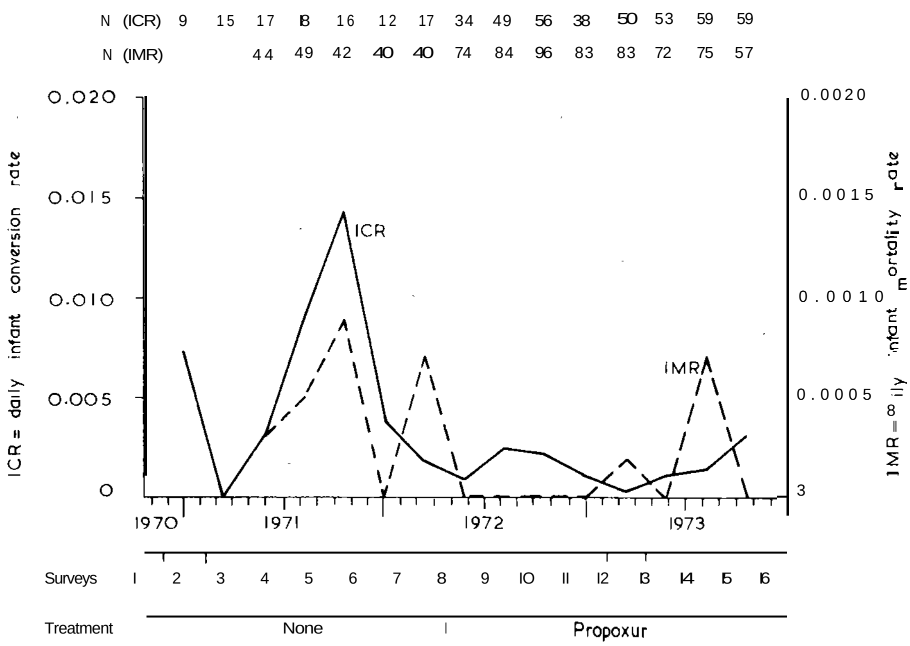
a N(ICR), N(IMR) = number at risk of conversion or death, respectively.

Infant mortality rate (IMR)

The IMR, estimated from the number of infant deaths and the number of births in the same period, was 193.1 per 1000 per year in the last year of the baseline period and 105.3 in the first intervention year, with no significant difference between the treated and the untreated village clusters in either period. A more accurate estimate of the IMR in the last baseline year is 245.7, obtained from the proportion of infants dying in each interval between surveys and adjusted to the annual basis. This method results in estimated IMRs for the first intervention year of 135 (9 deaths/316 infant-periods of $\frac{1}{5}$ year)[a] for the untreated village clusters, and 55 (11 deaths/971 infant-periods of $\frac{1}{5}$ year) for the treated clusters, the difference being in the expected direction and statistically significant. For the subsequent 3 surveys, which covered the intervention phase through the wet season of 1973, the corresponding IMRs (per 1000 per year) were 192 (7 deaths/ 168 infant-periods) and 102 (13 deaths/613 infant-periods) for the untreated and treated village clusters respectively.

a $IMR = 1 - (1 - 9/316)^5$

Fig. 69. Daily infant parasitological conversion rate (ICR) for *P. falciparum* and daily infant mortality rate (IMR), by interval (about 10 weeks) between consecutive surveys, in village clusters No. 3 and 4 (area B) before and during the application of propoxur[a]

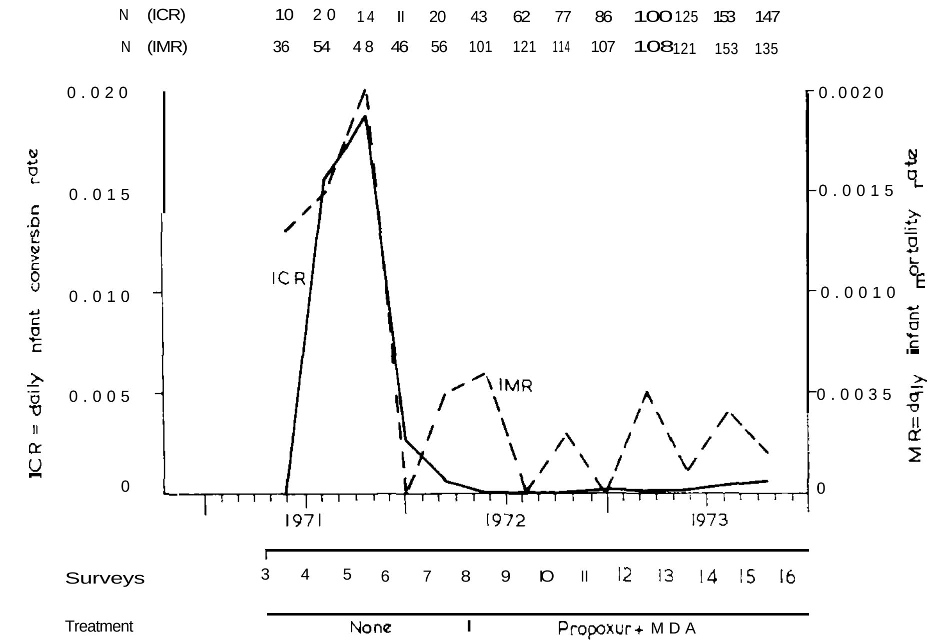


a **N(ICR), N(IMR) = number at risk of conversion or death, respectively.**

The very significant seasonal variation in IMR during the baseline year is shown in Fig. 67, where the IMR is expressed as a daily rate and compared with the estimated daily rate of infant conversion (ICR, see Chapter 5) for P.falciparum. The IMR is equal to about one-tenth of the ICR and shows nearly the same seasonal variation. This comparison between IMR and ICR is continued in Fig. 68,69 and 70, which show their variations over 3 years for treated and untreated village clusters respectively. In the untreated villages (Fig. 69) the daily IMR remains rather consistently equal to about one tenth of the ICR throughout, and the seasonal variations of the two rates are closely correlated. In the treated villages (Fig. 69 and 70) the IMR decreases much less than the ICR, and the seasonal variations of the 2 rates become unrelated after the introduction of malaria control.

Before the introduction of malaria control, the probability of dying within 10 weeks (i.e., before the next survey) was greater (272 per 1000 per year) in infants found positive for ***P. falciparum*** than in those found

Fig. 70. Daily infant parasitological conversion rate (ICR) for *P.falciparum* and daily infant mortality rate (IMR) by interval (about 10 weeks) between consecutive surveys, in village clusters No. 5-8 (areas Al and A2) before and during the application of propoxur and of MDA[a]



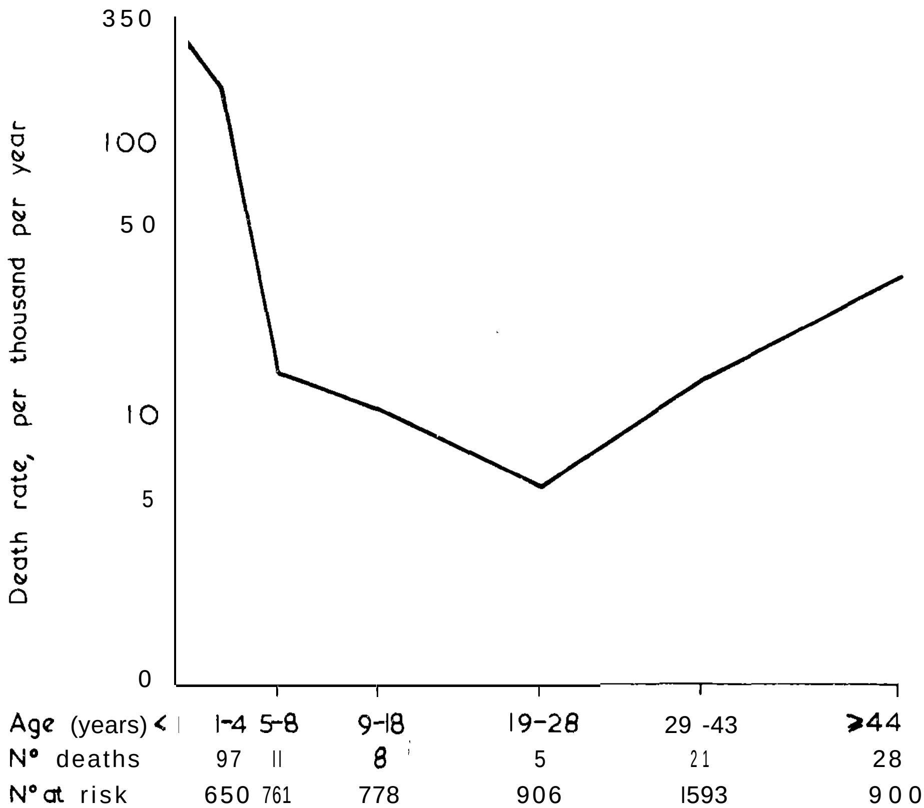
[a] N(ICR), N(IMR) = number at risk of conversion or death, respectively.

negative (202 per 1000 per year); among the positive infants, this probability was greater in those having 25% or more of positive microscopic fields (3 11 per 1000 per year) than in those having a lower density parasitaemia (23 1 per 1000 per year). These differences were, however, not statistically significant (see Table 6 in Ref. *180*).

Age-specific death rates

Among the baseline age-specific death rates (Fig. 71), the mortality in the age-group l-4 years is very high (154 per 1000 per year); at older ages it decreases to 15, 10 and 6 in the age-groups 5-8, 9-18 and 19-28 years respectively, and then increases to 13 and 31 in the age-groups 29-43 and ≥44 years respectively. Mortality in the age-group l-4 years shows a clear and marked seasonal variation (Fig. 66), with much higher mortalities in the late dry season and in the wet season. The older age-groups do not show a clear seasonal variation. For the combined age-groups

Fig. 71. Baseline age-specific death rate in the last year of the pre-intervention period[a]



[a] The infant mortality rate was estimated as explained in the text.

from 5-8 to ≥44 years, the estimated mortality rates for the 5 intervals are: 17.7, 15.1, 11.9, 19.7 and 9.1 per 1000 per year respectively; thus only the infants and the age-group 1-4 years show a clear-cut and marked seasonal variation of the mortality rate, which was similar in the two groups.

As already mentioned, there is an overall decrease in mortality between the last baseline year and the first year of intervention. Excepting the infants, the largest apparent change associated with treatment occurs in the age-group 1-4 years: whereas in village clusters No. 1, No. 2 (untreated) and No. 3 and 4 (insecticide alone), the mortality in this age-group decreased from 159 to 114 and from 111 to 83, i.e., by 25-30%, in village clusters No. 5-8 (insecticide plus mass drug administration) the mortality decreased from 193 to 61, i.e., by nearly 70%.

During the first year of intervention, the seasonal variation in the death rate in age-group l-4 years was nearly reversed in the treated village clusters. The mortality in this age-group in the treated villages (i.e., 40 per 1000 on an annual basis) during the wet season (surveys 9-11) was significantly lower than in the untreated villages (i.e., 189), whereas for the first intervention year as a whole the mortality in the treated villages was 70 as against 113 in the untreated villages, a difference which does not attain statistical significance.

Population movements

Migration in and out of the village

The following definitions are used:

Immigration into the village: new registration of a person as resident, at a given survey, excluding those born after the preceding survey. If infants were missed at the first survey at which they are alive, they were counted as "immigrants" at the following survey and the infant immigration rate is thus overestimated.

Emigration out of the village: first coding of a former resident as moved (after changing certain codes from absent to moved, see p. 232). Absences lasting through 1 to 3 surveys were not counted as migrations.

For the baseline year between surveys 3 and 8, the observed migration rates, by age (excepting infants) and by sex (Figure 72) were found to be relatively high. The average immigration rate was 186 per 1000 per year, the average emigration rate 164 per 1000 per year. The rates varied by age and sex: the females showed higher average immigration and emigration rates than the males and equal rates in both directions! while in the males there was a net immigration (at all ages). The highest rates, in and out, were reached in age-groups 9-18 years for the females, in age-group 19–28 years for the males; there is a strong correlation between the two rates, in and out, within age-groups.

Migration rates in infants are a special case: if we use the same method of estimation as above, we obtain an infant immigration rate of 304 per 1000 per-year (1000 x (58/191)), an infant emigration rate of 126 per 1000 per year (1000 x (24/191)). The excess of infant "immigrants" results mainly from the fact that an infant first registered at the second survey after his or her date of birth is counted as an immigrant (see definition above).

The migration patterns showed a pronounced variation by season and from one year to the next (Fig. 73). The immigration rate is highest in the latter part of the dry season and the emigration rate is highest just after

Fig. 72. Migration rates in and out of the village, by age (excluding infants) and sex, during the last baseline year

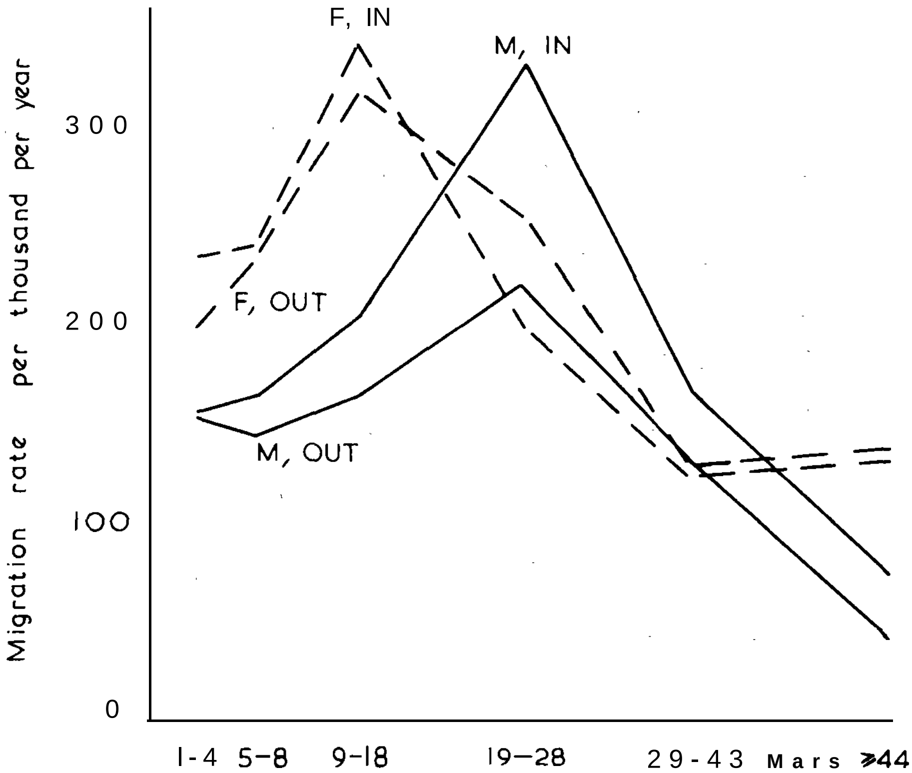
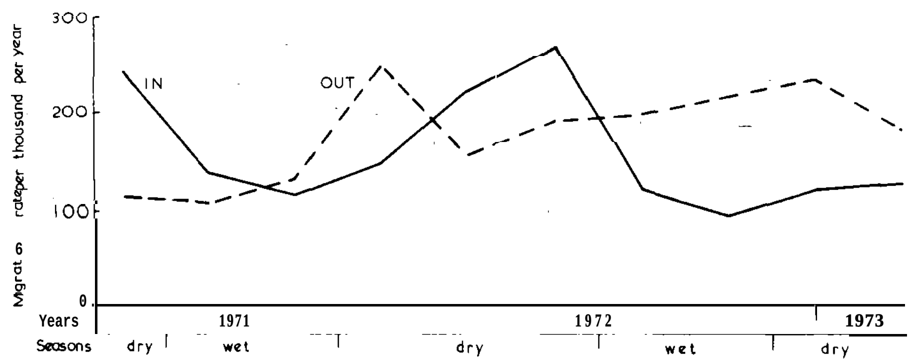


Fig. 73. Migration rates in and out of the village, by interval between consecutive surveys, during the last baseline year and the first intervention year (infants excluded)



the wet season, a pattern repeated in both of the years. In the first intervention year, the net immigration seen in the baseline year changed to a net emigration (158 immigration rate and 224 emigration rate). The seasonal pattern and the change in net migration direction varied little by sex and age. There were some differences in migration patterns from one village to another, repeated in each of the 2 years. The various intervention treatments did not seem to have any influence on the migration.

Absence

As stated above, a person coded "absent" at 1, 2 or 3 consecutive surveys was counted as part of the registered population, but absent. The proportion present out of the registered population ranged from 96.3% (survey 5) to 80.1 % (survey 12). The proportion present was lowest in the first part of the dry season, highest at the end of the dry season and in the wet season; the pattern repeated itself in 3 successive years, superimposed on a slight downward trend. In the dry season, the proportion present was higher among females than among males; in the wet season, there was no difference. The proportion present was lower in the age-group 9-43 years than at younger or older ages, and it was also at 9-43 years that the proportion present was lower in males than in females.

The same pattern of absenteeism was seen in all of the villages and in 3 consecutive years. However, there were some differences in the amplitude, corresponding to the differences in levels of migration, and these differences were repeated from year to year. The intervention treatments, or the occasional collection of larger blood samples for sero-immunological tests, had no apparent effect on the proportion absent.

Demographic analysis of the MDA records

In addition to that collected through the demographic-parasitological surveys, demographic information was extracted from the MDA records in area A2, outside the follow-up villages, in a population of about 12 000 (II). This analysis confirmed the above findings regarding the distribution of the population by age and sex, the seasonal pattern of migration, the higher migration rates in females than in males, and the existence of a net emigration (in the first year of the intervention phase). The birth rate and the infant and crude mortality rates were somewhat lower than in the follow-up villages, but this is readily explicable by the more thorough investigation of the follow-up villages, in particular through the use of itinerant registrars (pataucis). The rates of migration were higher than in the follow-up villages, but in the MDA population a person was classified as "moved" after only 2 consecutive absences, at intervals of 70 days (versus 3 consecutive absences, at the same interval, in the follow-up villages).

Discussion

Methods

The periodic surveys (every 10 weeks), conducted primarily to make a longitudinal parasitological study of persons in complete villages selected as natural epidemiological (transmission) units, also yielded relatively detailed demographic information, although the study population was comparatively small for purposes of demographic study. The deployment of the itinerant local registrars (pataucis) added significantly to the completeness of registration of births and of infant deaths.

The 2 methods used for the estimation of demographic rates-i.e., the one using the number of events in a period over the average (or mid-period) population, and the one using transition frequencies between successive surveys- should, in a stationary situation, yield the same results. In small populations, however, random fluctuations (e.g., of the number of births per year) may be relatively large and this may introduce a large error in the estimation of the IMR by the first method, because this method replaces the real population at risk (the births resulting in infant deaths in a given period) by a substitute (the births in the same period in which the infant deaths are counted) that is assumed to be equal. Therefore, in small populations with relatively large migration movements, the method based on transition frequencies between successive surveys (which relates events to the actual population at risk) is undoubtedly superior.

Age and sex composition

The pyramid of ages (see Fig. 65) differs from what would be expected from a stable population: there was an excess in the age-group 5-8 years, a deficit in the age-groups l-4 and 9-18 years; the ratio of males to females, although equal to 1 .01 for the total population, varied greatly by age (extreme values: 1.63 in age-group 9-18; 0.60 in age-group 19-28; 1.56 in age-group ≥44). The "irregularities" of the pyramid of ages could, in theory, be explained by: (1) past variations in the birth rates and especially in the death rates; (2) differential net migration rates by age and sex; (3) non-random misclassification of persons into age-groups (too many children misclassified from both directions into the 5-8-year age-group, too many females misclassified from both directions into the 19–43-year age-group, i.e., the reproductive age); and (4) differential under-registration.

The age and sex composition varied little between follow-up units, so the same factors were probably operating and approximately to the same degree in the whole area. The characteristics of the pyramid of ages listed above have been found also at different times and places in tropical Africa (see Ref. 9, in particular its Fig. 2.1, 2.6 and 2.7). This is difficult to reconcile with the first 2 “explanations” listed above, and points to the third explanation as the most important. Moreover the observed migration rates by age and sex (see Fig. 72) were no help in explaining the observed age and sex structure.

Birth rate

The high crude birth rate of 46 to 47 per 1000 per year corresponds to expectation. The seasonal variation of the birth rate must be anticipated, with an interval of about 9 months, by a corresponding seasonal variation in the rate of successful conception (i.e. leading to a live birth). The season in which successful conceptions are least numerous is also the period in which the largest numbers of young and middle-aged adult males are absent. The seasonal variation in successful conceptions in the Garki area was similar to that of the risk of acquiring malaria, whereas in the Pare-Taveta area of the United Republic of Tanzania it was the reverse, both in a malarious and in a nonmalarious population (*134*).

Death rates, malaria and malaria control

The small numbers of deaths involved, and their natural fluctuations, impose some caution in drawing conclusions both about baseline values and the possible early effect of malaria control. The crude death rate decreased from 38 per 1000 per year in the last baseline year to 21 per 1000 per year in the first intervention year; as the same proportional decrease occurred in treated and untreated villages, it cannot be attributed to treatment.

During the intervention period (all treatments combined), the IMR became significantly smaller in the treated villages than in the untreated; the death rate in the 1–4-year age-group decreased more in the villages treated with propoxur plus MDA than in the untreated or in those treated with propoxur alone, but the difference either before or under treatment was not significant. The decrease under treatment in both the IMR and the mortality at l-4 years of age was proportionally much smaller than the corresponding decrease in malaria risk.

In the absence of control measures, the mortality rates among infants and children of l-4 years and the malaria risk (infant conversion rate for ***P. falciparum***) have a strongly correlated seasonal variation; under treatment, the correlation is much weaker or disappears.

The observations are compatible with the hypothesis that malaria is a common precipitating cause of death in infants and in the 1–4-year age-group, and that effective malaria control, even in its early stages, removes this immediate cause in most cases. In a large fraction of cases, however, death has been delayed very little; this is possibly because the infants and children who were at high risk of dying from malaria are also at high risk of dying from one or more other precipitating causes, or from a constitutional (e.g., nutritional) underlying cause. The hypothesis that several causes of death are competing for the same "high-risk" children is also supported by the report, from a Gambian village followed for several years, that an exceptionally high mortality in the dry season, due to an epidemic of measles, was followed by an exceptionally low wet season mortality, presumably due to malaria (107).

If chronic malaria affects adversely the general underlying condition of persons, which is likely, death rates may decrease further in the later stages of control; the effect of past malaria experience may be the reason why, in the first year of control, the IMR but not the 1-4-year death rate became significantly smaller in the treated villages than in the untreated.

A relatively weak association between the parasitological status of infants at a point in time and the risk of dying within the next 10 weeks was observed. The finding that such an association is weak is compatible with a high rate of mortality directly caused by malaria: death from malaria in infants is probably related to a rapid increase in parasite density, which would have a high chance of being missed by surveys at intervals of 10 weeks.

It is not known to what extent malaria control affects directly other causes of death. The drugs are probably specific, but the insecticide may reduce other causes of death (e.g., arbovirus infections or fly-transmitted diarrhoeal disease).

The effect of malaria control on mortality has also been studied by Newman (128) from the vital statistics of Sri Lanka and Guyana, by Gramiccia & Hempel (*74*) from the vital statistics of American and Asian countries and by Payne et al. (132) from the results of the Kisumu (Kenya) project, among others. They all conclude that malaria control produces a marked reduction in mortality.

No attempt has been made here to fit together the various demographic estimates from Garki by means of a population model. This may prove interesting and useful, in view of the relative scarcity of demographic information from the African savanna and the importance of demography in health and development planning. The natural rate of growth of the population cannot be precisely estimated, given the small sample size. Taking the CBR and CDR at their face values we get rather unlikely high values for the rate of growth: the difference CBR-CDR was 46.1-37.8 = 8.3 per 1000 per year in the last baseline year, and 47.0-20.8 = 26.2 per 1000 per year in the first intervention year. As argued previously, only a small fraction of this apparent increase in rate of growth is probably attributable to malaria control. In periods of drought, the area probably undergoes net emigration. Computation of the expected demographic consequences of malaria control could only be made with a relatively large error. Even so, it may be worth attempting. with the limited data available.

Population movements

Only 2 types of movement were measured with any precision: migration in and out of the village, and short-term absences from the village. At least 2 other types of population movements are important in the area: short-term visits to the village, and movements of the semi-nomadic Fulani. The reports of the pataucis and the data collected in the MDA population in area A2 indicate that the amount of short-term visits into the village is substantial and highly variable. On the average, temporary visitors accounted for 3–7% of the population present, more in the dry season than in the wet. The movements of semi-nomads are largely due to the seasonal variation in the distribution of pastures.

Even for the movements that were measured, the geographical distribution of the movements is largely unknown. Admittedly the definitions used for “moved” and “absent” were arbitrary. Moreover, whereas actual rates were estimated for migration, for absences only proportions at a given time were estimated, rather than the rates at which persons leave for or return from a period of absence. Motivations of the population movements are incompletely documented, but it is known that many of the dry season migrations and temporary absences are to seek temporary work to the south. It is also known that on marriage (and divorce, which seemed quite common) it is usually the woman who moves. Furthermore, it is customary for a pregnant woman, especially if she is young, to move to her parents’ compound for some months around the time of delivery. The 2 movements which have been measured occur at relatively high rates: 15–20% of the village population are replaced each year; in the dry season, 15–20% of the population are temporarily absent. It is probable that the population is not homogeneous with respect to either type of movement, and that the majority of the population is in fact relatively stable.

Population movements are relevant to the understanding of the epidemiology of malaria and its control. When the parasitology of people coming in (immigrating or returning from absence) and of people going out (emigrating or leaving for a short-term absence) was compared with that of the more stable residents, it was concluded that the parasite reservoir in the more stable part of the population was sufficient to maintain transmission even where MDA was given every 2 weeks in the wet season as in area AI (see Chapter 5). The impact of temporary visitors and of semi-nomads, although not measurable, does not affect the above conclusion.

Summary

Surveys of total village populations (about 7500 persons in 22 villages) conducted at IO-week intervals for the longitudinal study of malaria yielded information on birth, death and migration rates. The surveys were supplemented by the information gathered by local residents used as itinerant registrars, visiting each village every 2 weeks. Two methods of estimation were used, the usual one of relating events to average population and the theoretically more accurate one making use of the transition frequencies observed between consecutive periodic surveys. Possible early demographic effects of malaria control (propoxur with or without MDA for 1½ years) were investigated.

The distribution of the population by age and sex shows some irregularities frequently observed in tropical Africa and probably best explained by non-random misclassification into age-groups. The crude birth rate (CBR) was 46-47 per 1000 per year and unaffected by treatment. The estimated fertility rate was 166 per 1000 per year. The crude death rate (CDR) was 38 per 1000 per year in the baseline period; it was 21 per 1000 per year in the first year of intervention, but the decrease was the same in the treated and untreated villages. The seasonal variation of the CDR was reversed under treatment. The infant mortality rate (IMR), estimated from the proportion of infants dying between consecutive surveys, dropped from 245 per 1000 per year in the baseline pre-treatment year to 55 per 1000 per year in the treated villages (all treatments combined) in the first intervention year. Although in that year the IMR in the untreated villages was 135 per 1000 per year, the difference between treated and untreated is significant.

The baseline death rate in the 1-4-year age-group was high (154 per 1000 per year). In. the wet season this rate became, under treatment, significantly lower in the treated than in the untreated villages, whereas for

the mortality in the entire first year of intervention no significant difference developed; the inversion of the seasonal variation of the CDR was due mostly to the corresponding inversion in the 1-4-year age-group.

In the absence of malaria control, there is a strong correlation between the seasonal distribution of the malaria risk (either infant conversion rate or entomological inoculation rate) and the seasonal distribution of infant deaths. In the first year of control, the malaria risk decreased considerably, but the proportional decrease in the death rates was much smaller and the seasonal distribution of the 2 rates became largely independent. There is an association between the parasitological status of infants and the risk of dying in the next 10 weeks, which although it was in the direction expected, was not statistically significant.

Absence for 4 or more surveys was arbitrarily defined as migration. The yearly migration rates, in and out, are large: 15–20% per year. Migration rates vary by age, sex, place and year; in the second year of observation, there was net emigration. Migration was apparently not affected by the treatments.

Absence from the village for 3 or fewer surveys was arbitrarily defined as absence. Every dry season, the proportion present drops to 80–85%. The proportion absent varies also by age, sex and place; on the average it increased slightly over 3 years of observation but was apparently not affected by the treatments.

Other types of population movements (short-term visits to the village, semi-nomadism) are known to exist, but were not measured with the same precision nor fully analysed.