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Seasonal variations in indoor resting *Anopheles gambiae* and *Anopheles arabiensis* in Kaduna, Nigeria

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Summary

A longitudinal study in a guinea savanna area in Northern Nigeria showed that indoor resting samples consisted almost entirely of *An. gambiae* in the wet season, characterized by relatively lower temperature and higher relative humidity, whereas *An. arabiensis* predominated in the dry season, characterized by relatively higher temperature and lower relative humidity. A significant change was also observed in the frequency of polymorphic chromosomal inversions in the population of *An. gambiae*. The inverted arrangements 2Rbc, 2Rd and 2La were found more frequent in the dry season samples as compared to the wet season ones.

Key words: *Anopheles gambiae; Anopheles arabiensis;* cytotaxonomy; chromosome inversions; seasonal variation.

Introduction

Of the six sibling species of *An. gambiae* complex, *An. gambiae* and *An. arabiensis* are the most closely associated with man and are major vectors of malaria and filariasis. The distribution of these species overlaps extensively and they occur sympatrically in large areas of tropical Africa.

Investigations in Nigeria (Coluzzi et al., 1979), and along the boundary with Niger, showed that the two species occur in different frequencies along an ecological gradient comprising different vegetational zones and running South to North from the tropical forest with an annual rainfall of over 2000 mm, to the Sahelian savanna with an annual rainfall of less than 500 mm. *An. gambiae* typically occurs in forest and humid savanna areas although its range extends

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into the arid savanna areas. *An. arabiensis* on the other hand is rare or absent in humid savanna areas, at least during the rainy season, but is prevalent in arid savanna areas. *An. arabiensis* may also occur as isolated populations in urban centres that have been developed through deforestation (man-made environment) within the forest zones. The polytene chromosomes of both species show polymorphism for paracentric inversions, the frequencies of which are correlated with climatic and vegetational patterns. In particular, the frequencies of arrangement 2Ra in *An. arabiensis* and arrangements 2Rbc, 2Rd and 2La in *An. gambiae* increase gradually in progressively more arid areas and may reach up to 100%.

The above relationship could also result in different seasonal distributions of the species and of their chromosomal variants in areas of perennial breeding. This hypothesis was tested through a longitudinal study over a period of a year in the Kaduna area in Nigeria. The findings were also expected to be of relevance in the evaluation of new insecticides sprayed indoors against malaria vectors in villages near Kaduna. A preliminary report of the results was presented at the XI Congress of the Italian Society of Parasitology (Di Deco et al., 1981).

Materials and Methods

Study area

The study was carried out in four localities (Nassarawa, Ungwan Maazu, Ungwan Rimi, and Kaballa) in humid guinea savanna area (Keay, 1953) on the outskirts of Kaduna town (Fig. 1). The meteorological data for the years 1974 and 1975 (Fig. 2) show a rainy season extending from April to October with peak rainfall in September. During the wet season, *An. gambiae* s.l. breeds extensively in scattered rainwater collections. However, following the onset of the dry season (December through March), these water collections disappear and breeding continues at a reduced level in drains, garden wells, residual pools in river beds, etc. (Ramsdale and Fontaine, 1970).

Mosquito collection and identification

Only indoor resting collections were made because the immediate purpose of the study was to analyze the composition of the indoor resting populations of *An. gambiae* and *An. arabiensis* in relation to evaluation of the efficacy of residual insecticides. The mosquitos were caught by pyrethrum spray-capture in the afternoon in order to ensure that specimens had reached the correct stage of ovarian development for obtaining readable polytene chromosome preparations. The material was preserved in Carnoy's fluid, and polytene chromosome preparations were obtained from the nurse cells according to the method described by Hunt (1973). The species were identified and the different karyotypes were scored according to the nomenclature of Coluzzi et al. (1979). The agreement between the observed and the expected karyotype frequencies according to the Hardy-Weinberg law was tested by the Wright's F statistics (Brown, 1970).

Results and Discussion

During August (the month before peak rainfall), characterized by over 80% relative humidity at sunrise and mean temperature of less than 25° C, the

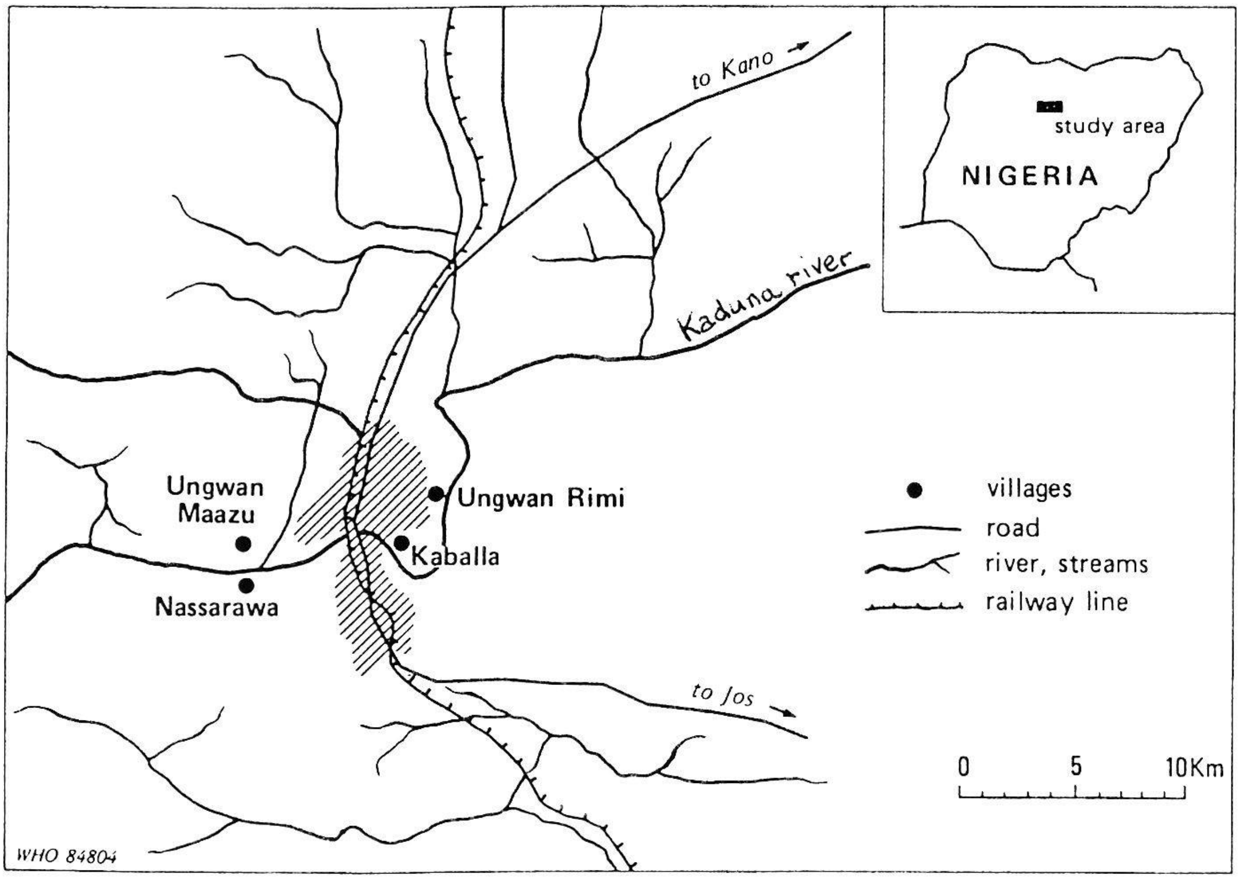

Fig. 1. Sketch map of Kaduna town (shaded) and surrounding area showing study villages.

samples consisted almost entirely of *An. gambiae* (Table 1). However, during the dry season (December through March), the frequency of *An. arabiensis* rose progressively to a maximum of 85% in March, when the relative humidity was less than 50% and the mean temperature was higher than 27° C. In April and May, following the onset of the rainy season, the frequency of *An. arabiensis* decreased rapidly representing less than 3% of the sample in June and less than 0.5% in August.

Earlier studies (Service, 1970; White and Rosen, 1973) had shown that *An. gambiae* was the predominant species in both adult and larval samples. However, these studies were confined to the transitional periods between dry/wet seasons and the wet/dry seasons, respectively.

The results on intraspecific chromosomal polymorphism pertain only to *An. gambiae* because the sample of *An. arabiensis* caught resting indoors during the rainy season was numerically inadequate for statistical comparison with the dry season sample. Full agreement was found between the observed and expected karyotype frequencies according to the Hardy-Weinberg law, as shown by the F values (see Table 2). On the other hand the differences observed in the monthly frequencies of the three inversions on chromosome 2 were found highly significant by homogeneity tests ($p < 0.001$). Arrangements 2Rbc, 2Rd and 2La (which are found at a higher frequency in arid areas) showed a higher

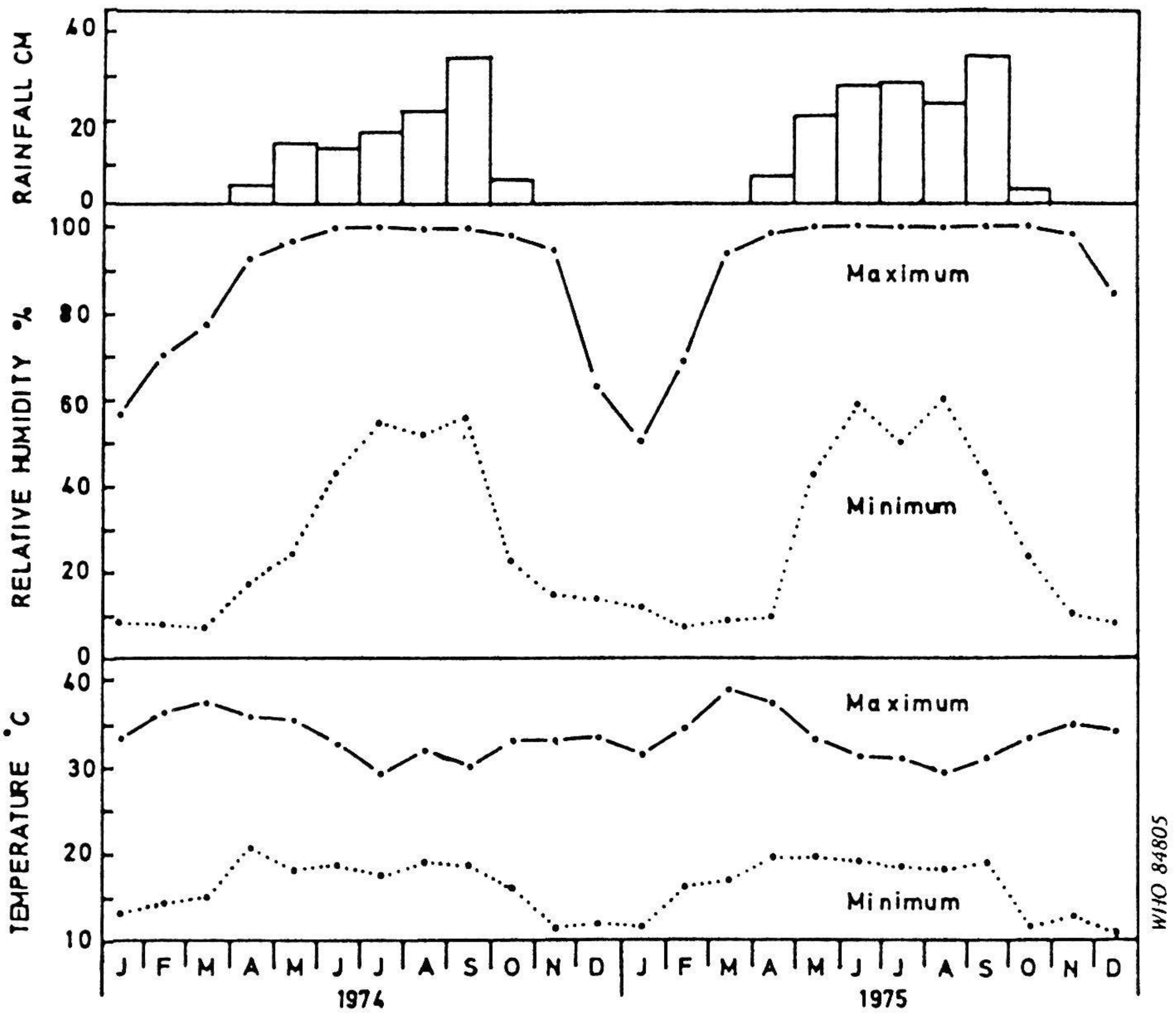

Fig. 2. Meteorological data from Kaduna area, Nigeria, 1974/75 (extracted from Rishikesh et al., 1977).

frequency in the dry season as compared to the wet season. The parallel increase of 2Rbc and 2Rd could be explained by their close association (crossing over values less than 1%) whereas the parallel increase of 2La should be considered largely independent as shown by previous association studies (Di Deco et al., 1980).

The seasonal distribution patterns shown by the two species and the intraspecific chromosomal variants are probably governed by different adaptive values related to changes of climatic conditions in agreement with the patterns of geographical distribution (Coluzzi et al., 1979). *An. gambiae* is predominant indoors during the wet season and up to December. However, for the rest of the dry season and up to May, *An. arabiensis* is the dominant species. Similarly within *An. gambiae*, the carriers of chromosomal arrangements 2Rbc, 2Rd and 2La show an advantage over carriers of other arrangements during the dry months. Most likely, the advantage lies in larval adaptation to restricted, atypi-

Table 1. Monthly percent frequencies of *An. gambiae* and *An. arabiensis* caught indoors in Kaduna area, Nigeria

Month	n	*An. gambiae*	*An. arabiensis*
August 1974	182	100.00	–
December 1974	78	87.18	12.82
February 1975	111*	43.24	56.76
March 1975	182	15.38	84.62
April 1975	153	33.99	66.01
May 1975	149	85.91	14.09
June 1975	75	97.33	2.67
August 1975	315	99.68	0.32

* Includes 11 specimens caught the previous month

Table 2. Monthly percent frequencies of chromosomal arrangements 2Rbc, 2Rd and 2La in *Anopheles gambiae* caught indoors in Kaduna area, Nigeria. When $|F| > 1.96/\sqrt{N}$ the observed karyotype frequencies are significantly ($p < 0.05$) different from the expected frequencies according with the Hardy-Weinberg law

Month	n	$\frac{1.96}{\sqrt{N}}$	2R*bc*	F	2R*d*	F	2L*a*	F
August 1974	182	0.15	24.45	−0.03	21.97	−0.12	82.97	−0.01
December 1974	68	0.24	44.12	−0.01	38.97	0.04	98.53	−0.01
February 1975	48	0.28	55.21	0.03	46.88	0.21	97.92	−0.02
March 1975	28	0.37	39.29	−0.20	35.71	−0.24	100.00	–
April 1975	52	0.27	41.35	0.09	35.58	0.12	93.12	0.03
May 1975	128	0.17	33.20	−0.00	29.69	0.11	94.14	−0.06
June 1975	73	0.23	37.67	−0.02	32.88	0.01	89.04	−0.12
August 1975	314	0.11	30.41	−0.03	26.27	−0.04	87.74	0.07

cal breeding habitats and/or adult adaptation to dryness which could, for instance, find expression in a lower reproductive activity (aestivation) of the species and karyotypes decreasing in frequency during the dry months. However, an alternative hypothesis should also be considered. The seasonal changes could influence the resting behaviour and a karyotype could be exophilic in a given situation and endophilic in another. The lower frequency of *An. arabiensis* and of some karyotypes of *An. gambiae* indoors during the wet season could thus be the result of exophily due to prevalence of outdoor resting places with a suitable microclimate. The seasonal frequencies could even be influenced by the migration of chromosomal types, with different adaptive values, in accordance with seasonal changes.

The evidence of seasonal changes in the *gambiae/arabiensis* ratio and in the chromosomal constitution of *An. gambiae* s.l. populations in Kaduna area, may be relevant in explaining some of the variations in the results obtained in villages sprayed with new insecticides (Rishikesh et al., 1975, 1977). Moreover, the presence of chromosomal polymorphism in both *An. gambiae* and *An. arabiensis* may cause behavioural heterogeneities in each of the vector populations which show in particular partial exophily and non-uniform reduction of longevity under the impact of indoor sprayed insecticides (Molineaux et al., 1976; Coluzzi et al., 1979).

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