Journal of Tropical Medicine and Hygiene 1981, 84, 95–100

Mosquito records from the Rupublic of Niger, with reference to the construction of the new 'Trans-Sahara Highway'

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Introduction

The past decades have seen a steady decline in the distribution and effects of malaria in North Africa: incidence has been reduced to a very low level, although eradication has not yet been achieved. In West Africa south of the Sahara, on the other hand, malaria (primarily as *Plasmodium falciparum*) is still widely endemic; the most important vectors are of the *Anopheles gambiae* complex, *An. arabiensis* and *An. gambiae* s.s.

The Saharan barrier is crossed by few regularly used routes, and its substantive nature to mosquitoes is demonstrated by the occasional invasion of *An. gambiae* s.l. up the easternmost of these – the Nile Valley. Normally the mosquito breeds no further north than the Third Cataract in the Sudan, but sometimes it has moved down the course of the Nile into irrigated Egypt, and exploded into epidemics such as that of 1942 which took 60 000 lives before it was controlled. This Nile-mediated movement is probably effectively, if temporarily, blocked by the expanding Lake Nasser at present (Gillies 1972, unpubl. report to WHO).

The major western route across the Sahara is the line of the new 'Trans-Sahara Highway', the tarring of which will doubtless relegate any other routes into obscurity. Already the volume of traffic using this route is growing, and, as paving proceeds, long-distance haulage between West Africa and the Mediterranean is becoming an increasingly viable proposition. With the advent of containerization and air-conditioned cabs, the risk of alien vectors and strains of malaria being carried either way across the Sahara will rise greatly.

Work in recent years (Ramsdale 1976, 1977, 1978, de Zulueta & Ramsdale 1975, all unpublished reports to WHO, Holstein *et al.* 1970) has led to a much-improved knowledge of the anopheline fauna of the southern Algerian oases. Some of these appear to be suitable for colonization by West African malaria vectors, in particular *An. arabiensis* and *An. gambiae* s.s.

Subregionally on the southern edge of the Sahara, records of both *An. arabiensis* and *An. gambiae* s.s. extend as far north as Bafoulabe (14° 49′N) in Mali, and of *An. gambiae* s.s. to Boutilimit (17° 35′N) in Mauritania to the west (Coz 1973). In the Republic of Tchad to the east, *An. gambiae* s.l. has been found as far as 22°N in the Tibesti Massif (Rioux 1960).

In the Republic of Niger itself, both *An. arabiensis* and *An. gambiae* s.s. have been recorded from Niamey (13° 32′N) and the vicinity of Tanout (15° 00′N), and *An. gambiae* s.s. alone from Ayorou (14° 44′N) in the west (Coz 1973, Coluzzi *et al.* 1979); whilst *An. gambiae* s.l. was found by Hamon *et al.* (1966) as far as 17°N in the region of Agadez. Since penetration northwards is of significance in any assessment of the risk of importation of West African vectors into Algeria, this survey aimed at collecting information on the distribution of mosquitoes in the Sahel-Sahara region of Niger. Culicines were also collected, as records from the area are poor, and they show parallel colonization of ephemeral habitats.

The survey area

The new Trans-Sahara Highway will link Algiers with the existing road networks of southern Niger and Nigeria via the southern oases of Algeria (see Figure 1). The Algerian section (as far as Assamaka, on the border) is nearing completion; in Niger a new route, largely promoted by growing exploitation of mineral deposits in the north, is being constructed from Arlit to Agadez and thence Birni-n-Konni. At present a dry-season route via Tegguida-n-

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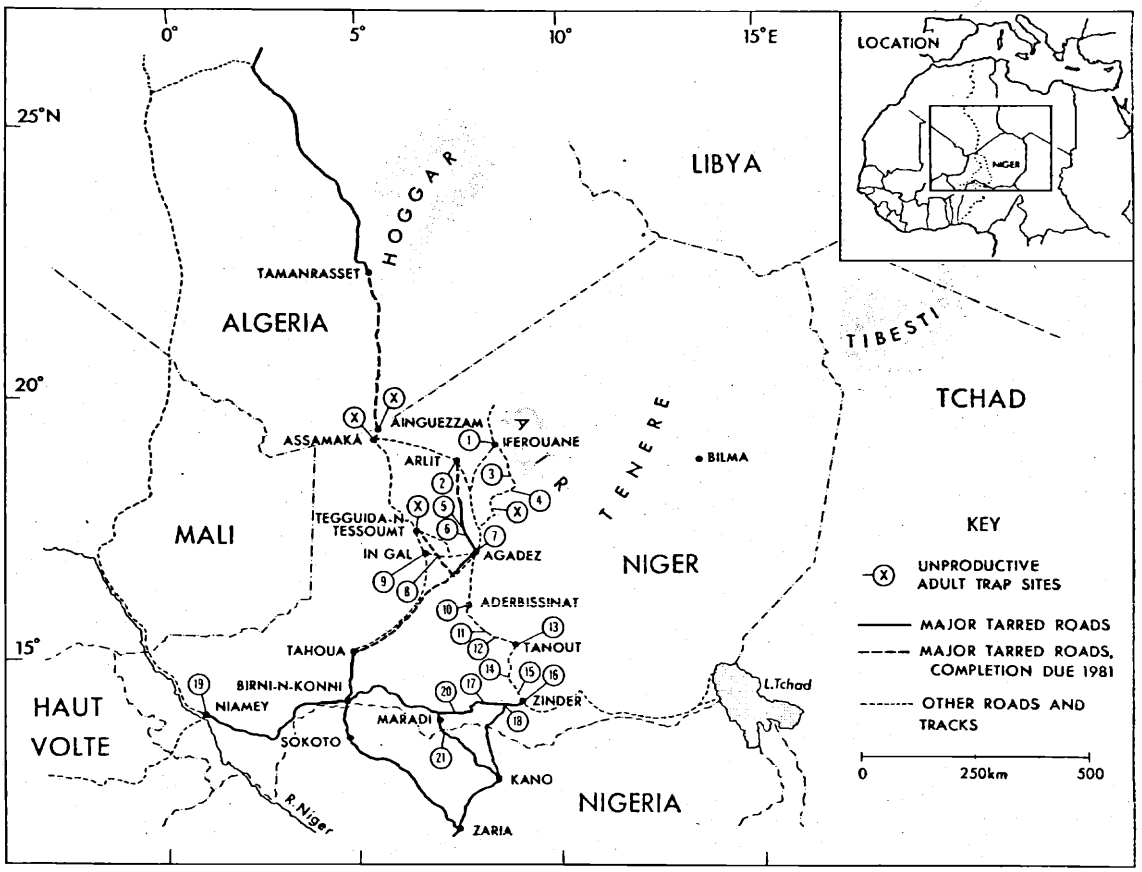

Figure 1. Map of survey area in Niger: collection site locations flagged by numbers (cf. Table 1).

Tessoumt and an all-weather route via Arlit link Assamaka with Agadez, from where the existing unsealed road continues down to meet the paved system at Zinder. By 1981 it should be possible to drive from the Mediterranean to Nigeria on a fully paved highway, except for some 200 km between Assamaka and Arlit; neither this, nor the dry season route through Tegguida-n-Tessoumt, presents much problem to any vehicle.

Because the new tarred road was not yet open and the western track from In Gal to Tahoua was impassable south of Agadez, this survey was made along the route to Zinder. General topological, climatological and vegetational graduations with increasing rainfall to the south are similar on both routes, although local refuge conditions may differ: the presence of the new road itself will modify these details. The survey area therefore ranged from the extremely arid desert, through the Sahel-savanna zone to the relatively fertile Sudan-savanna southern strip of Niger (Figure 2). Diurnal temperature ranges may be considerable, especially in the north where daily maxima of about 42°C and minima of 22°C were typical. Rainfall around Agadez during this survey was sufficient to maintain continuously standing water in the town for at least 6 weeks.

In the north, vegetation is largely confined to dry river-beds with sub-surface water, or oases, and rainfall takes the form of occasional violent, but localized storms. Although average regional rainfall may be fairly constant, local rainfalls vary greatly from year to year because of spatial variability within a given year. This is the domain of the opportunist pastoral nomad. As vegetation becomes more continuous and longer-lived, permanent villages occur with increasing frequency, becoming common south of Tanout as rainfall reliability reaches levels that will support some crops.

Methods

Adult mosquitoes were generally collected at 2-hourly intervals through the night from trap-nets

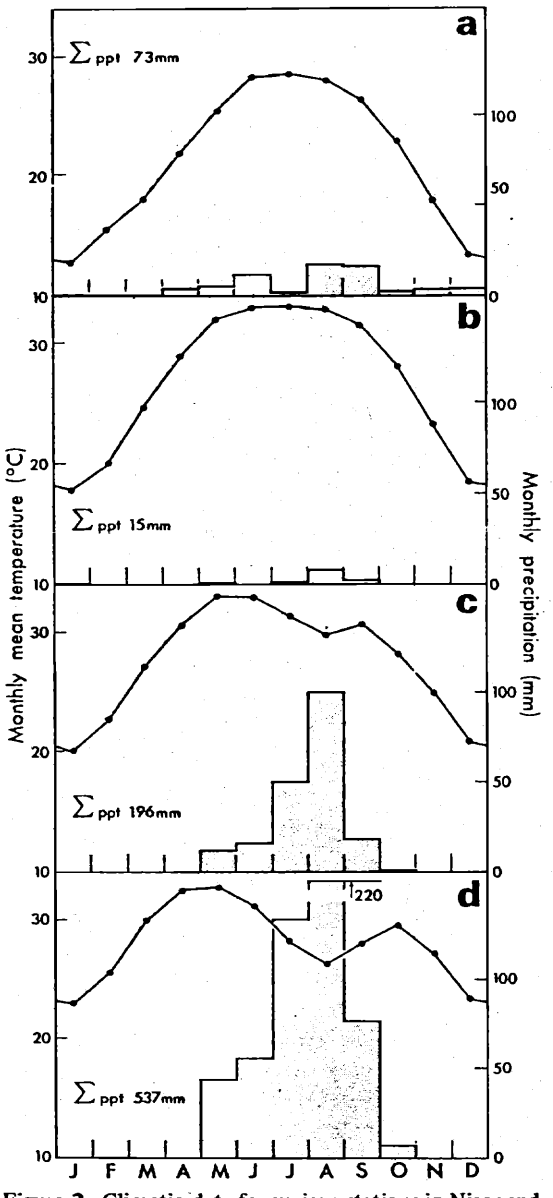

Figure 2. Climatic data for various stations in Niger and southern Algeria (10-year means, 1951–1960; derived from US Department of Commerce 1967). a Tamanrasset, 22° 48′N, 1400 m; b Bilma, 18° 41′N, 359 m; c Agadez, 16° 59′N, 507 m; d Zinder, 13° 48′N, 489 m.

baited with one donkey or two men; some were also collected as they came to bite man or from personal mosquito-nets. Each collection was examined at dawn and pinned for identification, or, in the case of fully-fed specimens of *An. gambiae* s.l., kept until semi-gravid then preserved in fixative and maintained below 20°C for later chromosome analysis (a gas/battery refrigerator was carried).

Larval searches were made at each adult collection site where free water could be found, and at various roadside pools during the day when travelling. These searches are not recorded if negative, the area between Aderbissinat and Agadez being the only consistently negative stretch with several possible sites.

Results

The survey records are summarized in Table 1, and the sites are flagged on the map by number. General distributions are as expected, with desertic forms such as *An. dthali* reaching down to Agadez, and Afrotropical species appearing to the south. *An. hispaniola,* a palaearctic species common in the Hoggar Massif around Tamanrasset (but closely related to and possibly conspecific with *An. cinereus,* a widely distributed Afrotropical species: Gillies and de Meillon 1968), occurs in the northern Aïr in very similar conditions, although the apparent absence of *An. sergentii,* also common in the Hoggar, is notable. The only other anopheline found north of Aderbissinat was *An. arabiensis,* near smallholdings 5 km north of Agadez; this is the most northern record of *An. arabiensis* in Niger.

South of Aderbissinat, the Afrotropical forms *An. pharoensis* and *An. squamosus,* as well as *An. gambiae* s.l., become increasingly common as bioclimatic conditions ameliorate. All positive *Ah. gambiae* s.l. chromosome identifications referred to *An. arabiensis:* in both Agadez and Takoukout, a considerable degree of inversion polymorphism suggests that this species has not here reached the limits of its tolerance range (Lewontin 1974), at least in the restricted 'refuge' conditions of its distribution.

Culicines were generally more numerous than anophelines and occurred at most sampling sites. The presence of *Culex pusillus* at Iferouane in the Aïr Massif seems to be the most southern known of this palaearctic species, not recorded south of the Sahara before, although the related species *C. richeti* has been described from the region of Lake Tchad. The urban species of *C. quinquefasciatus* was found as far north as Agadez, but was not detected in the recently established town of Arlit. In Agadez, *C. perexiguus* adults were discovered resting in a domestic refrigerator (to which access was apparently only possible when the door was opened). Despite the numbers of adults and the presence of long-standing pools of water, no

Table 1. Species detected (by decreasing latitude)

Location (lat. °N)	Anophelines		Culicines	
	adults	larvae	adults	larvae
1. Iferouane (19° 06′)	*An. dthali*	*An. dthali*‡ *An. hispaniola*‡	*Ae. v. arabiensis* *C. laticinctus* *C. pusillus*	
2. Arlit (18° 43′)			*C. antennatus** *C. perexiguus**	
3. Village 50 km NNE of Timia (18° 18′)			*C. decens* *C. duttoni*	
4. Timia (18° 09′)		*An. dthali*‡		
5. By road 65 km N of Agadez (17° 34′)				*Ae. v. arabiensis*‡
6. By road 55 km N of Agadez (17° 29′)		*An. dthali*‡		
7. Agadez (17° 00′)	*An. arabiensis* *An. dthali* *An. gambiae* s.l.	*An. gambiae* s.l.§	*C. decens* *C. duttoni* *C. perexiguus* *C. quinquefasciatus*	*C. decens*‡ *C. quinquefasciatus*§ *C. simpsoni*§ *C. tigripes*§
8. Tamerat (16° 51′)				*Ae. v. arabiensis*† *C. decens*¶
9. In Gal (16° 49′)			*Ae. v. arabiensis* *C. decens* *C. perexiguus* *C. quinquefasciatus*	*C. decens*¶
10. Aderbissinat (15° 34′)	*An. pharoensis*		*Ae. v. arabiensis* *C. quinquefasciatus*	
11. By road 40 km NW of Takoukout (15° 18′)		*An. gambiae* s.l.‡		
12. Takoukout (15° 03′)	*An. arabiensis* *An. gambiae* s.l. *An. pharoensis* *An. squamosus*		*C. perexiguus*	
13. Tanout (14° 58′)	*An. arabiensis* *An. gambiae* s.l. *An. pharoensis*		*Ae. v. arabiensis*	
14. Gezaoua (14° 22′)	*An. gambiae* s.l. *An. pharoensis*	*An. gambiae* s.l.†		
15. By road 30 km N. of Zinder (14° 02′)		*An. gambiae* s.l.†		
16. Zinder (13° 47′)	*An. pharoensis* *An. squamosus*		*Ae. vittatus* *C. perexiguus* *C. poicilipes* *C. quinquefasciatus*	
17. Mai Jirgui (13° 44′)	*An. arabiensis** *An. gambiae* s.l.*		*Ae. fowleri** *M. africana**	

Table 1 (cont.)

Location (lat. °N)	Anophelines		Culicines	
	adults	larvae	adults	larvae
	*An. pharoensis**			
	*An. squamosus**			
18. Takieta (13° 40′)	*An. arabiensis*	*An. gambiae* s.l.†	*Ae. v. arabiensis*	
	An. gambiae s.l.		*C. perexiguus*	
	An. pharoensis		*M. africana*	
19. Niamey (13° 32′)	*An. arabiensis**		*C. quinquefasciatus**	
	An. gambiae s.l.*			
20. Tchadaoua (13° 28′)		*An. gambiae* s.l.†		
21. Jibiya (at frontier) (13° 06′)	*An. gambiae* s.l.*		*Ae. fowleri**	
			*Ae. vittatus**	
			*C. decens**	
			*C. quinquefasciatus**	
			*M. africana**	
			*M. uniformis**	

Adults: * = human bait only (all others had donkey bait available too).

Larvae: † = pools in borrowpits by roadside
‡ = pools in river bed
§ = spring seepages
¶ = wells.

Ae. Aedes, *Ae. v.* Aedes vexans, *An.* Anopheles, *C.* Culex, *M.* Mansonia.

surface water larvae could be found in Arlit, Agadez or In Gal. Larvae of *C. decens,* the only species found well-breeding, occurred in water 30 m below ground level at Tamerat, in a little used well.

Discussion

Roadbuilding techniques in these lands involve raising up a base made of hardcore bulldozed out of large borrowpits, usually near the road and at regular intervals: this is especially true of the paved highway construction. After rains, these hollows turn into small lakes, providing water for animals as vegetation establishes itself over a few years. Almost any of these pools in the south, with cattle footprints around their margins, can be expected to contain *An. gambiae* s.l. larvae. In drier localities, such hollows have become important watering points for herds, and often temporary Tuareg villages appear beside them. The new tarred sections of the road, having a greater frequency of these borrowpits, will doubtless concentrate watering animals along its length as has happened elsewhere, and it may be that they will contribute significantly to the ability of the Afrotropical species to spread after the rains.

In the wetter areas, the distribution of these mosquitoes is effectively continuous, and any range boundary vacillations may be natural, even if aided by artifacts such as these pools; further north, however, it seems to become discontinuous, and the mosquitoes must be transported into temporary breeding sites, or spread out from restricted refugia. For example, unless *An. gambiae* s.l. can survive adverse periods by aestivation (Holstein 1954, Omer & Cloudsley-Thompson 1970), its colonization of northern sites must involve a yearly cycle of extinction and reinvasion. Temporary water collections north and west of Agadez contained only other species' larvae, but it may merely be a matter of time from the start of the wet season before *An. arabiensis* can reach further into the north.

Malaria is reported by locals and doctors to have a definite season from Agadez south (corresponding approximately with the wet season), and also in the Aïr Massif, whilst in Arlit it causes little problem. In the same way that the special conditions of the Tibesti Massif allow *An. gambiae* s.l. to extend its range to almost 22°N (Rioux 1960), the valleys of the Aïr might provide favourable conditions well to the north of these mosquitoes' normal range in Niger; this survey's limited search in the region did not detect them, however. Whether or not dry season

foci exist in these mountains, improved roads will give easier access and facilitate seasonal colonization from the south.

It would be interesting to know how fast Afrotropical species become established at each successively more northern site after the onset of the rains, and a survey at the end of the wet season might find them breeding significantly further north. As livestock aggregations and breeding sites become more patchy, mosquitoes may be transported to some extent whilst resting in the rolled-up matting walls of nomads' tents, but more probably and rapidly in vehicles. During this survey, mosquitoes were often carried in cups for several days whilst waiting for eggs to be laid, in conditions typical of the Sahel. Mosquitoes also sometimes appeared in the back of the truck, carried from the night before.

The condition of the old unpaved road between Zinder and Agadez is not good but the route is easy to follow, and many lorries drive it in the dark, stopping for a few hours in the major villages. Mosquitoes can thus already be carried as far as Agadez without even the need to survive the day in a truck, and this will become far more common with the new sealed road. Furthermore, the various mineral exploitations are creating new settlements in the north, and the increased volumes of traffic will undoubtedly assist pioneer species such as *An. arabiensis* to reach these well-watered potential breeding sites.

Conditions north of Arlit make the journey to the Hoggar especially arduous, and transported mosquitoes seem unable to survive the usual summer daytime temperatures of at least 40°C and the very low humidities, unless preferential conditions are provided. The climate on this stretch is more tolerable in winter, but then it is drier further to the south. However, with shorter journey times, air-conditioned cabs, containerized vehicles and increased movement by night, these preferential conditions are being created, and the dangers of long-distance translocation of vector mosquitoes through the Sahara to the southern oases of Algeria must warrant serious consideration.

Summary

Construction of a new, fully-tarred 'Trans-Sahara Highway' from the coast of Algeria to Nigeria is well advanced. Information on the distribution of anopheline and culicine mosquitoes collected in Niger during a survey in August and September, 1979 is presented and discussed. Particular reference is made to the dangers of West African malaria vectors being transported north along the Highway as traffic increases. The vector species, *Anopheles arabiensis*, was found as far north as Agadez (17°N).

Acknowledgements

This work was carried out as part of the Trans-Sahara Malaria Project, to all the very many supporters of which (including the Francis C. Scott Charitable Trust, the Sir Samuel Scott of Yews Trust, the Wellcome Trust and the Royal Geographical Society) I am most grateful. I am also much indebted to Dr S. Miles for chromosome analyses, to Dr G. B. White for assistance with mosquito identification, and to Dr G. Davidson and Mr C. D. Ramsdale for their help with equipment and in many other ways. Finally especial thanks must go to the other members of the Project, Mr J. W. Dean and Mr S. R. O'Brien.

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